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SYSTEM

A. Luxenberg

OF

CHEMISTRY,

IN FOUR VOLUMES.

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VOL. IV.

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VOLUME FOURTH.

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SYSTEM

OF

CHEMISTRY.

BOOK IV.

OF VEGETABLES.

VEGETABLES are too well known to require any defi-
nition. They are perhaps the most numerous class of bo-
dies belonging to this globe of ours; the species already
known amounting to no less than 30,000, and very consi-
derable additions are daily making to the number. But it
is not my intention in this place either to enumerate, to
describe, or to classify plants. These tasks belong to the
botanist, and have been successfully accomplished by the
zeal, the singular address, and the indefatigable labour, of
Linnæus and his followers.

It is the business of the chemist to analyse vegetables, to
discover the substances of which they are composed, to ex-
amine the nature of these substances, to investigate the
manner in which they are combined, to detect the processes
by which they are formed, and to ascertain the chemical
changes to which plants, after they have ceased to vegetate,
are subject. Hence a chemical investigation of plants com-
prehends under it four particulars: 1. An account of the
different *substances* found in the vegetable kingdom. 2. An
account of the composition and properties of the different
parts of vegetables; as the leaves, the bark, the seed, &c.
These must be composed of combinations of the various
substances described under the first head. 3. An account

Book IV. of the *vegetation* of plants, as far as it can be illustrated by chemistry.   4. An account of the *changes* which plants undergo after they cease to vegetate.   These different heads shall form the subject of the four following chapters.

CHAP. I.

OF THE INGREDIENTS OF PLANTS.

Chap. I.   THE substances hitherto found in the vegetable kingdom, all of them at least which have been examined with any degree of accuracy, may be reduced under five heads : I. Substances soluble in cold water.   II. Substances insoluble in cold water, but partially soluble in hot water, at least in certain states.   III. Substances which melt when heated (if not already fluid) and which burn like oils.   They are insoluble in water; but most of them are soluble in alcohol. IV. Substances neither soluble in water, alcohol, nor ether, and which have a fibrous or woody texture.   V. Substances which belong to the mineral kingdom, which occur only in small quantity in vegetables and may therefore be looked upon as extraneous or foreign.   The following table exhibits a view of the different vegetable substances hitherto discovered, arranged under their respective heads:

I.   1. Acids.   5. Starch.
   2. Sugar.   6. Indigo.
   3. Sarcocoll.   7. Gluten.
   4. Gum.   8. Pollenin.
   5. Mucus.   9. Fibrin.
   6. Jelly.   III. 1. Fixed oil.
   7. Ulmin.   2. Wax.
   8. Colouring principles.   3. Volatile oil.
   9. Bitter principles.   4. Camphor.
  10. Nicotin.   5. Birdlime.
  11. Extractive.   6. Resins.
  12. Emetin.   7. Guaiacum.
II.   1. Morphia.   8. Balsams.
   2. Asparagin.   9. Gum-resins.
   3. Cerasin.   10. Caoutchouc.
   4. Inulin

IV. 1. Cotton.　　　V. 1. Acids.　　　
　　2. Suber.　　　　　2. Alkalies.
　　3. Medullin.　　　　3. Earths.
　　4. Fungin.　　　　　4. Metals.
　　5. Lignin.

The properties of these different substances form the subject of the following sections:

SECT. I.

OF ACIDS.

THE combustible or vegetable acids found ready formed in plants are the following:

1. Acetic.　　　　8. Sorbic.
2. Oxalic.　　　　9. Benzoic.
3. Tartaric.　　　10. Hydrocyanic.
4. Citric.　　　　11. Kinic.
5. Moroxylic.　　12. Gallic.
6. Boletic.　　　13. Tannin.
7. Malic.

1. Acetic acid is easily detected by its peculiar odour, Acetic. and by the compounds which it forms with the alkalies and earths. It has been found by Vauquelin in the sap of different trees which he examined, and likewise in the acid juice of the *cicer arietinum*, which consists of oxalic acid, malic acid, and a little acetic acid.* Scheele obtained it from the *sambucus nigra.*†

It has been found also in the following plants:

Phœnix dactilifera.‡　　　Rhus typhinus.‖
Gallium verum.§

2. Oxalic acid is easily detected and distinguished by the Oxalic. following properties: It decomposes all calcareous salts, and forms with lime a salt insoluble in water. It readily crystallizes. Its crystals are quadrilateral prisms. It is totally destroyed by heat.

* Jour. de Phys. lii. 362.　　　　† Ann. de Chim. vi. 13.
‡ Fourcroy, as quoted by John, Chemische tabellen der Pflanzenanalysen, p. 53.　　§ Schrader, Ibid.　　‖ John, Ibid.

Book IV.
‿‿‿
Plants containing it.

Oxalic acid was first detected in vegetables by Scheele. It exists in the state of binoxalate of potash in the leaves of the *oxalis acetosella*, *oxalis corniculata*, and different species of *rumex*; and likewise in the *geranium acidum*. In the root of *rhubard* Scheele found it in the state of oxalate of lime; and Deyeux, Dispan, and Vauquelin, have observed it uncombined in the liquid which exudes from the *cicer parietinum*. Scheele detected the presence of oxalate of lime in a variety of roots and barks besides rhubarb. He reduced the substances to be examined to powder or thin slices, digested them for two hours in diluted muriatic acid, and dropped ammonia in excess into the filtered solution. If the oxalate was present, the liquid became gradually milky, and deposited it. The following is his table of the roots and barks from which he obtained this salt : *

I. ROOTS.

Alkana.	Vincetoxicum.	Saponaria.
Apium.	Lapathum.	Scilla.
Bistorta.	Liquiritia.	Sigellum salomonis.
Carlina acaulis.	Mandragora.	Tormentilla.
Curcuma.	Ononis.	Valeriana.
Dictamnus albus.	Iris florentina.	Zedoaria.
Fæniculum.	Iris nostras.	Zengiber.
Gentiana rubra.		

II. BARKS.

Berberis.	Cassia caryophyllata.	Quassia.
Cassia fistularis.	China.	Quercus.
Canella alba.	Culilavan.	Simaruba.
Cinnamomum.	Frangula.	Lignum sanctum.
Cascarilla.	Fraxinus.	Ulmus.

Oxalic acid has been found likewise united to potash, lime, or magnesia, in

> Spinacea oleracea. †
> Lichnis dioica. †
> Atropa belladonna. ‡

Tartaric.

3. Tartaric acid is known by the following properties : When a little potash is cautiously dropped into a solution

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* Crell's Annals, iii. 2. English Trans.

† Braconnot, John, Chemische tabellen der Pflanzenanalysen, p. 52.

‡ Melandre, John, ibid. p. 54.

containing it, common tartar is formed, and precipitates to the bottom. Tartaric acid does not decompose the sulphate, nitrate, or muriate of lime. Tartrate of lime is insoluble in water. Tartaric acid crystallizes. Its crystals are long slender prisms. It is destroyed by heat.

Tartaric acid has been found in the following vegetable substances: Plants containing it.

> Pulp of the tamarind.*
> The juice of grapes.
>> Rhus typhinum.†
>> Vaccinium oxyccos.‡
>> Rheum raponticum.§
>> Morus alba.||
>> Rhus corearia.**
>> Pinus sylvestris. †
>> Pinus abies. †
>> Pinus larix. †
>> Sium sisarum. ††
>> Triticum repens. ||
>> Leontodon taraxicum. ||

4 Citric acid is distinguished by the following properties: Citric. It does not form tartar when potash is added to it. With lime it forms a salt insoluble in water, which is decomposed by sulphuric, nitric, and muriatic acids. It readily crystallizes. It is destroyed by heat.

Citric acid has been found unmixed with other acids in the following vegetable substances: ‡‡ Plants containing it.

> The juice of oranges and lemons.
> The berries of vaccinium oxycoccos, *cranberry.*
>> ————— vitis idæa, *red whortleberry.*
>> Prunus padus, *birdcherry.*
>> Solanum dulcamara, *nightshade.*
>> Rosa canina, *hip.*

It occurs mixed with other acids in many other fruits. Citrate of lime exits also in the onion.

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* Vauquelin, Ann. de Chim. v. 92.   † John, ibid. p. 50.
‡ Bindheim, Crell's Annalen, 1787, p. 537.
§ Bindheim, ibid. 1788, ii. 42. || Hermbstadt.
** Trommsdorf and Gren, John, ibid. 50.
†† Margraaf, John, ibid. p. 54.
‡‡ Scheele, Crell's Journ. ii. 8. Eng. Trans.

Moroxylic.

5. Moroxylic acid has been hitherto found only in the bark of the *morus alba*, or white mulberry. For its characteristic properties I refer to vol. ii. p. 143.

Boletic.

6. Boletic acid has been hitherto found only in the *boletus pseudo igniarius*. For its characters I refer to vol. ii. p. 147.

Malic.

7. Malic acid is known by the following properties: it forms with lime a salt soluble in water, which is decomposed by citric acid. It does not form tartar with potash. It is incrystallizable. Heat destroys it.

Plants containing it.

Malic acid has been found by Scheele * in the fruits of the following plants, which contain no other acid:

> Apples.
> Berberis vulgaris, *barberry*.
> Prunus domestica, *plum*.
> ———— spinosa, *sloe*.
> Sambucus nigra, *elder*.
> Sorbus aucuparia, *roan* or *service*.

Plants containing citric and malic acids.

In the following fruits he found nearly an equal quantity of malic and citric acids: †

> Ribes grossularia, *gooseberry*.
> ———— rubrum, *.currants*
> Vaccinium myrtillus, *bleaberry*.
> Crategus aria, *beam*.
> Prunus cerasus, *cherry*.
> Fragaria vesca, *strawberry*.
> Rubus chamæmorus, *cloudberries, evrochs*.
> ———— idæus, *raspberry*.

Malic acid has also been found in the agave americana, ‡ and in the pulp of tamarinds. § In the first of these it is mixed with tartaric acid; in the second with tartaric and citric acids. Vauquelin has lately detected it in the state of malate of lime, in the following plants:

Sempervivum tectorum.
Sedum album, acre, telephium.
Arum maculatum.
Different species of crassula and mesembrianthemum. ‖

* Scheele, Crell's Jour. ii. 8. Eng. Trans.   † Ibid.
‡ Hoffman of Weimar.   § Vauquelin. Ann. de Chim. v. 92.
‖ Vauquelin, Ann. de Chim. xxxv. 153.

It has been found likewise in the following plants chiefly combined with lime or potash :

Bromelia ananas. *	Rubia tinctorum.
Ruta. graveolens. †	Reseda luteola.
Delphinium elatum.	Staphylea pinnata.
Portulaca oleracea.	Sambucus ebulus.
Eupatorium cannabinum.	Chærophyllum sylvestre.
Nicotiana rustica.	Actæa spicata.
Mirabilis Jalappa.	Brionia alba.
Tropœolum majus.	Syringa vulgaris.
Ricinus communis.	Valeriana officinalis.
Trifolium melilotus.	Spinacea oleracea.

8. Sorbic acid was discovered by Mr. Donovan, in the Sorbic. berries of the *pyrus aucuparia,* where it was accompanied with malic acid. He found it along with the same acid in apples, plums, barberries, and sloes. According to Mr. Donovan's observations, whenever any other acid besides malic is present, no sorbic acid whatever can be detected. Thus raspberries and gooseberries contain no sensible quantity of sorbic acid, citric and malic acids existing in these fruits together. For the characters of sorbic acid, see vol. ii. p. 180.

9. Benzoic acid is distinguished by its aromatic odour, Benzoic. and its volatility on the application of a very moderate heat. It has been found hitherto only in a few vegetable substances, to which the French chemists have confined the term *balsam.* These are, *benzoin, balsam of tolu, storax,* &c. It has been detected likewise in the following plants :

Origanum majorana.‡	Cicer arietinum.**
Salvia sclarea.§	Fungi.††
Epidendron vanilla.‖	

10. The smell and the property of forming Prussian blue Hydrocy-with the oxygenized salts of iron are sufficient to characterize anic.

* Adet, Ann. de Chim. xxv. 32.

† Braconnot, Ann. de Chim. lxv. 277. To him likewise we are indebted, for all the other plants contained in the table.

‡ Göttling, as quoted by John, Tabellen, p. 52. But he thinks that Göttling mistook camphor for benzoic acid.

§ Braconnot, Ann. de Chim. lxv. 285.   ‖ John, Tabellen, p. 53.

** Proust, Ann. de Chim. xxxvi. 273, and xlix. 181.

†† Ibid.

the hydrocyanic acid. Ever since Scheele pointed out the method of procuring this acid in a separate state, the similarity between its smell and the odour of bitter almonds, peach-blossoms, and other vegetable substances, did not fail to be remarked: but it was not till about the year 1802 that Bohn observed a similarity between the taste of hydrocyanic acid and the water distilled from bitter almonds; and that when this water was mixed with potash, it acquired the property of precipitating iron solutions blue. These results were confirmed soon after by Schræder, who succeeded also in obtaining prussian-blue, by the same means, from the distilled waters of *laurocerasus* leaves and peach-blossoms. When lime is added to the concentrated waters of these substances, there is formed a prussiate of lime; for when the liquid is mixed with a salt of iron, prussian-blue precipitates the instant that another acid is added. When these waters are distilled off pure potash, a prussiate of potash remains, and even crystallizes. The water that comes over contains no hydrocyanic acid. When distilled with ammonia, no prussian ley is obtained.*

This discovery was soon after verified by the experiments of Gehlen, Bucholz, and Vauquelin. Bucholz found that hydrocyanic acid was contained in the essential oil of bitter almonds, and that it could be separated by means of fixed alkalies, but not by ammonia.† Vauquelin obtained hydrocyanic acid by distilling water off the kernels of apricots in a water bath. The liquid, when mixed with sulphate of iron, and a little ammonia added, yields a precipitate only partially soluble in sulphuric acid. The residuum is green, but becomes blue when boiled. Hence Vauquelin supposes that the hydrocyanic acid in these bodies is in a peculiar state.‡ Schræder has since obtained hydrocyanic acid from the flowers of the sloe (*prunus spinosa,*) and the leaves of the bay-leaved willow (*salix pentandra.*)§ It cannot be doubted that almost all the bitter-tasted kernels contain this acid.

11. Kinic acid has been hitherto found only in the bark of the *cinchona officinalis*, where it occurs combined with lime. For its characters, see vol. ii. p. 168.

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* Jour. de Phys. lvi. 224.   † Gehlen's Jour. i. 78.
‡ Ann. de Chim. xlv. 206.   § Gehlen's Jour. i. 394.

12. Gallic acid is known by the following properties: with the red oxide of iron it produces a black colour. It is crystallizable. Heat destroys it. It has been found in a great number of plants, chiefly in the bark. The following table, drawn up by Mr. Biggin,* will serve to show the relative proportions of this acid in different plants:

Elm	7	Sallow	8	Plants con-
Oak cut in winter	8	Montain ash	8	taining it.
Horse chesnut	6	Poplar	8	
Beech	7	Hazel	9	
Willow (boughs)	8	Ash	10	
Elder	4	Spanish chesnut	10	
Plum-tree	8	Smooth oak	10	
Willow (trunk)	9	Oak cut in spring	10	
Sycamore	6	Huntingdon or Lei- }	10	
Birch	4	cester willow }		
Cherry-tree	8	Sumach	14	

13. Tannin, like most other vegetable substances, seems to be susceptible of different modifications. The following are the different species of tannin which have been hitherto noticed.

(1). Tannin from nutgalls. This is the common species described in this Work under the name of tannin. It precipitates iron black, and forms a firm insoluble brown precipitate with glue. The bark of oak, and most other astringent trees in this country, are supposed at present to contain this species of tannin.

(2). The tannin which constitutes so large a proportion of catechu forms the second species. Its peculiar nature was first observed by Proust. It was afterwards more particularly examined by Davy. It forms with iron an olive-coloured precipitate.

(3). The tannin of *kino* constitutes a third species. This substance is obtained from different vegetables. It was originally imported, as is supposed, from Africa; but at present the common kino of the shops is, according to Dr. Duncan, an extract from the *coccoloba urifera*, or *sea-side grape*, and is brought chiefly from Jamaica. But the finest kino is the product of different species of *eucalyptus*, par-

* Nicolson's Jour. iii. 394.

Book IV. ticularly the *resinifera* or brown gum tree of Botany Bay.*
It is an astringent substance of a dark-red colour, and very
brittle. It dissolves better in alcohol than water. The
solution in the latter liquid is muddy; in the former trans-
parent, and a fine crimson if sufficiently diluted. It throws
down gelatine of a rose-colour, and forms with salts of iron
a deep-green precipitate, not altered by exposure to the air.
These properties, first observed by Dr. Duncan, and after-
wards by Vauquelin, show that it contains abundance of
tan, but in a particular state.†

Sumach,   (4). The fourth variety of tannin is contained in *sumach*.
This is a powder obtained by drying and grinding the shoots
of the *rhus coriaria* ; a shrub cultivated in the southern parts
of Europe. The tan, which it contains in abundance,
yields a precipitate with gelatine, which subsides very
slowly, and remains in the state of a white magma without
consistence.

Fustic.   (5). The fifth variety, according to Proust, is to be found
in the wood of the *morus tinctoria*, or *old fustic* as the Bri-
tish dyers term it. This wood gives out an extract both to
alcohol and water, which yields a precipitate with gelatine.
A solution of common salt is sufficient to throw it down.‡

Tannin affects particularly the bark of trees; but it exists
also in the sap and in the wood of a considerable number,
and even in the leaves of many. It is very seldom that it
exudes spontaneously; yet this seems to be the case with a
variety of kino from Botany Bay, which I have lately ex-
amined.§

It has been ascertained by Mr. Biggin,‖ that when the
barks of trees are examined at different seasons they vary
in the quantity of tan. The quantity varies also with the
age and size of the trees.** The greatest proportion of tan
is contained in the inner bark.†† The epidermis usually
contains none.

The following table exhibits the proportion of solid matter
extracted by water from different vegetable substances, and
the quantity of tan contained in that solid matter, as ascer-
tained by the experiments of Davy.

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* Nicolson's Jour. vi. 234.   † Ann. de Chim. xlvi. 321.
‡ Proust. Ann. de Chim. xlii. 94.   § Annals of Philosophy, i. 163.
‖ Phil. Tran. 1798, p. 299.   ** Davy, ibid. 1803.
†† Davy, ibid.

One ounce of	Solid Matter. Grains.	Tan. Grains.
White inner bark of old oak	108	72
———————— young oak	111	77
———————— Spanish chesnut	89	63
———————— Leicester willow	117	79
Coloured or middle bark of oak	43	19
———————————— Spanish chesnut	41	14
———————————— Leicester willow	34	16
Entire bark of oak	61	29
———— Spanish chesnut	35	21
———— Leicester willow	71	33
———— elm	—	13
———— common willow	—	11
Sicilian sumach	165	78
Malaga sumach	156	79
Souchong tea	—	48
Green tea	—	41
Bombay catechu	—	261
Bengal catechu	—	231
Nutgalls	180	127

Chap. I.

Table of the quantity of tannin in plants.

SECT. II.

OF SUGAR.

SUGAR, which at present forms so important an article History. in our food, seems to have been known at a very early period to the inhabitants of India and China ; but Europe probably owes its acquaintance with it to the conquests of Alexander the Great. The word *saccharon* occurs in Pliny * and Dioscorides.† They describe it a white brittle solid, which exuded spontaneously from a species of reed. From the description, it does not appear that the sugar known to the ancients was similar to our sugar; but their account is so imperfect that little can be collected from it.‡

* Lib. xii. c. 8.

† De Medica Materia, lib. ii. c. 104, or, in some copies, c. 74.

‡ See Beckmann's Historia Sacchari. Commentationes Soc. Reg. Gottingensis, 1782, vol. v. p. 56.

Book IV. For ages after its introduction into the West, it was used only as a medicine; but its consumption gradually increased; and during the time of the Crusades, the Venetians, who brought it from the East, and distributed it to the northern parts of Europe, carried on a lucrative commerce with sugar. It was not till after the discovery of America, and the extensive cultivation of sugar in the West Indies, that its use in Europe, as an article of food, became general.*

Sugar was formerly manufactured in the southern parts of Europe; but at present almost the whole of our sugar is produced in the East and West Indies. The plant from which it is procured is the *arundo saccharifera* or *sugar cane.* Other plants indeed contain it; but not in such abundance. In North America, however, it is extracted from the *acer saccharinum* or sugar maple, but in too small quantity for exportation. Attempts have been lately made to extract it from the beet.

Manufacture of sugar in Indostan, 1. The method of making sugar practised in Indostan is exceedingly simple, and requires little or no expensive apparatus. The soil chosen is a rich vegetable mould, in such a situation that it can be easily watered from the river. About the end of May, when the soil is reduced to the state of soft mud, either by rain or artificial watering, slips of the cane, containing one or two joints, are planted in rows about four feet from row to row, and eighteen inches asunder in the rows. When they have grown to the height of two or three inches, the earth round them is loosened. In August small trenches are cut through the field to drain off the rain, if the season prove too rainy; and to water the plants, if the season prove too dry. From three to six canes spring from each slip set. When they are about three feet high, the lower leaves of each cane are carefully wrapped round it; and then the whole belonging to each slip are tied to a strong bamboo eight or ten feet high, and stuck into the earth in the middle of them. They are cut in January and February, about nine months after the time of planting. They have now reached the height of eight or ten feet, and the naked cane is from an inch to an inch and

* See Falconer's Sketch of the History of Sugar, Manchester Memoirs, iv. 291; and Mozeley's History of Sugar.

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a quarter in diameter. They have not flowered. When this happens, the juice loses much of its sweetness. The newly cut canes are put through the rollers of a mill, and their juice collected into large iron boilers, where it is boiled down smartly to a proper consistence, the scum being carelessly taken off. The fire is then withdrawn, and the liquid by cooling becomes thick. It is then stirred about with sticks till it begins to take the form of sugar, when it is put in mats made of the leaves of the palmira tree (*borassus flabelliformis*), and the stirring continued till it is cold.* This process yields a *raw* or *powdered* sugar; but it is clammy, and apt to attract moisture from the atmosphere, because the acids in the juice have not been removed. By the addition of quicklime to the juice, in the proportion of about three spoonfuls to every 14 gallons, the sugar loses this property. The impure sugar prepared by this method is called *jagary*. Every three quarts of juice, or every six pounds, yields about one pound of sugar. From an acre of ground about 5000 pounds of sugar, and consequently about 30,000 pounds of juice, are obtained.

2. In the West India islands the raising of sugar is much more expensive, and the produce much less, owing to the high price of labour; or, which is the same thing, to the nature of the labourers, and to the inferiority of the soil. The juice extracted by passing the cane twice between iron rollers is received in a leaden bed, and thence conducted into a *receiver*. Here it cannot be allowed to stand above 20 minutes without beginning to ferment. Therefore, as soon as collected, it is run into a flat copper cauldron, called a *clarifier*, capable of holding 400 gallons or more. Here it is mixed with a quantity of lime. The maximum used is a pint of lime to every hundred gallons; but in general much less will serve. Fire is immediately applied, and the juice heated to the temperature of 140°. The fire is then extinguished. A thick viscid scum forms upon the top, which remains unbroken, and the clear liquid is drawn off from under it by a cock or syphon, and introduced into

* See Dr. Roxburgh's Account of the Hindoo method of cultivating the Sugar Cane, Repertory, ii. 425, Second Series; and Tennant's Indian Recreations, ii. 31.

a large copper boiler.   Here it is boiled briskly; the scum, as it forms, being continually removed by large scummers. When the bulk of the liquid is sufficiently diminished, it is introduced into a second boiler, and the boiling and scumming continued as before; lime-water being sometimes added, if the liquid does not appear clear. From the second copper it passes into a third; and from that to a fourth, where the very same process is continued. This last copper is called the *teache*. When by continued evaporation it has become sufficiently concentrated, which is judged of by its viscidity, it is withdrawn from the fire, and introduced into the *cooler*. This is a wooden vessel about 11 inches deep, seven feet long, and from five to six wide. As it cools it crystallizes or *grains*, forming an irregular mass separated from the uncrystallized syrup or *melasses*. From the cooler it is taken and put into empty hogsheads, having holes in the bottom; through each hole the stalk of a plantain leaf is thrust, long enough to rise above the top of the hogshead. Through these holes the melasses drain into a receiver. In about three weeks the sugar becomes tolerably dry and fair, and the process is finished. The sugar in this state is sent to Britain, under the name of *muscovado* or *raw* sugar.*   A gallon of the raw juice yields at an average about a pound of raw sugar.†

In the French West India islands the process is somewhat different. From the cooler the inspissated juice is poured into conical-shaped pots with the point undermost. As soon as it has become solid, a plug is withdrawn from the point of the cone, and the melasses suffered to drain. When no more will drop, a stratum of clay moistened with water is laid upon the top of the sugar. The water from this, slowly penetrating the sugar, carries down the remains of the melasses. Sugar treated in this way is called *clayed* sugar. The process is said to have been discovered by accident. A hen having her feet dirty had gone over a pot of sugar, and the sugar under her tread was found whiter than elsewhere. By claying, the sugar loses about one-third of its weight; but a considerable portion of the loss

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* Edwards's History of the West Indies, ii. 222.
† Ibid. p. 224.

may be obtained by boiling down the juice that runs off. The process is not considered as so profitable in the British islands as the one which is usually followed.*

3. In North America the farmers procure sugar for their own use by a still simpler process, from the sap of the *acer saccharinum*, or sugar maple tree, which abounds in the woods. It reaches maturity in about 20 years, and is then from two to three feet in diameter. In February, March, and April, the tree is bored with an auger to the depth of about ¾ inch, and in an ascending direction. The hole is then deepened to two inches. A wooden spout is introduced into the hole to direct the flow. The sap flows from four to six weeks. When it ceases on the south side, the north side is bored. This process does not injure the tree; but on the contrary improves it. An ordinary tree yields in good seasons from 20 to 30 gallons of sap; from which are made from five to six pounds of sugar; or every forty pounds of sap yields about a pound of sugar; so that it is not one-sixth so rich as the East-India sugar cane.

The sap ought never to be kept longer than twenty-four hours after it is procured from the tree. It is improved by straining through a cloth. It is put into large flat kettles, mixed usually with quicklime, white of egg, and new milk. A spoonful of slacked lime, the white of one egg, and a pint of new milk, is sufficient for fifteen gallons of sap. A little butter is added to prevent the sap from boiling over. When boiled down sufficiently, it is allowed to *grain*, or form into small crystals, which constitute raw sugar, and then purified in the usual manner.†

4. The raw sugar imported into Europe is still farther purified. It is dissolved in water, mixed with lime, clarified by means of bullock's blood, boiled down to a proper consistency, scumming off the impurities as they rise to the top, and then poured into unglazed conical earthen vessels, where it is allowed to grain. The point of the cone is undermost, and perforated to allow the impurities to separate. The base of the cone is covered with moist clay; the

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* Edwards's History of the West Indies, ii. 232.

† See Dr. Rush's Account of the Sugar Maple Tree, Amer. Trans. iii. 64.

Book V. water of which gradually filters through the sugar, and displaces a quantity of impure liquid. The sugar thus purified is called *loaf sugar*. When redissolved and treated in the same way a second time, it is called *refined* sugar. This process appears to have been first practised by the Venetians.

How refined in Indostan.

5. In the East Indies, where they make very pure sugar, their process is remarkably simple and economical, but tedious. An account of this process, as practised about Aska and Barampour, has been given by Mr. Anderson, surgeon of the Madras establishment. The cane juice is first strained, and then boiled with a little lime to the proper consistency for graining. It is afterwards put into small earthen pots with mouths six inches wide, and allowed to remain at least a month : sometimes six or eight months. A hole is then made in the bottom of the pots, and the liquid syrup suffered to run off from the crystallized sugar. The sugar is put upon a cloth and squeezed, being occasionally moistened with water, the better to remove the remains of the syrup. It is then dissolved in water, and boiled a second time to the proper consistency; milk and some water being added from time to time in order to clarify it, and the scum being removed as it rises. It is poured into small wide-mouthed pots, suffered to crystallize, and a hole bored in the bottom of the pots to allow the remains of the syrup to run off. To whiten the sugar, the tops of the pots are covered with the leaves of the *creeping vine ;* and these are renewed every day for five or six days. When pure *sugar candy* is wanted, the sugar thus obtained is dissolved in water again, and the same process of boiling with milk and scumming is repeated. When poured into pots, thin slices of bamboo are introduced, which prevents it from running into lumps, and induces it to form large crystals.*

Theory of sugar-making.

6. According to Dr. Higgins, who went to the West Indies on purpose to examine the manufacture of sugar, the juice of the sugar cane contains a great number of bodies; but the most important of them (not reckoning sugar and water) are those which he calls *herbaceous matter* and *melasses acid*. Concerning the nature of these substances nothing very precise is known; but the great object of the manufac-

* Phil. Mag. xxi. 272.

turer is to remove them, as they impede the crystallizing of the sugar. The *herbaceous matter* * is partly held in solution by the water, partly by the carbonic acid. When the liquid is heated to 140°, the carbonic acid is disengaged, and the herbaceous matter separates in flakes of an olive-green colour. This produces the scum. Lime facilitates the separation, partly by abstracting the carbonic acid, and partly by forming an insoluble compound with the herbaceous matter. Hence its use in the first part of the process. It is called *temper* by the manufacturers. Too much is injurious in the first part of the process. It redissolves the herbaceous matter, or at least deepens the colour of the syrup.†

The nature of the *melasses acid* is not better known than that of the herbaceous matter; but it combines with the sugar, and forms an uncrystallizable syrup. Lime is necessary in the last part of the process to remove this acid; it combines with it, and the compound runs off with the syrup during the graining of the sugar.‡ This acid is no doubt that which exists in unripe canes, and the quantity of it of course diminishes as the cane improves in quality. I have been informed by my friend Dr. Clarke of Dominica, that the quantity of lime necessary is much less when the canes are rich and ripe than when green or lodged, or when they have been cut some time before they are bruised in the mill : and that he has known the juice of rattoon rich canes boiled down into permanent crystals of sugar without the assistance of any lime. He substituted potash instead of lime; but found that the sugar obtained by this method was liable to deliquesce. Soda made the grain firmer, but smaller than usual. These facts would lead to a suspicion that the *melasses acid* is either the *acetic* or the *citric*. Dr. Clarke's experiments should exclude the oxalic, tartaric, and malic acids.

These observations of Dr. Clarke agree very well with the account of Dutrone, who made a very great number of

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* This is probably a different substance from any that we know at present. It seems to possess many properties in common with *gluten*. Dr. Higgins says that it agrees in its properties with the dregs of refined indigo.

† See Higgins' Observations, Phil. Mag. xxiv. 308.

‡ Ibid.

Book IV. experiments on sugar cane juice, and was very well acquainted with its properties. According to him it chiefly consists of sugar, extractive, and two different kinds of fecula, which are precipitated by lime. He endeavours to prove that unaltered juice contains no acid, and his experiments are sufficient to convince us that the quantity of acid is at least very minute.*

Dutrone's experiments were performed before vegetable chemistry had made nearly the progress which it has now reached. Hence it is difficult, from his description, to recognise the substances which he found in sugar-cane juice. But this loss has been supplied by the experiments of Proust. Living in Spain where the sugar cane is still cultivated, he had an opportunity of examining its juice. He found it to contain gluten or green fecula, gum, extractive, malic acid, sulphate of lime, and two species of sugar ; namely, common sugar, and a species which is incapable of crystallizing, and can only be exhibited in the state of syrup, and which, for that reason, he calls *liquid sugar.* The quantity of acid was very minute, and probably in a warmer climate than Spain its quantity would be still smaller.†

According to Dutrone sugar-canes give about half their weight of juice, the specific gravity of which varies from 1·033 to 1·106. It is at first opaque, but when the feculent matter has precipitated, it becomes transparent, and of a green colour. When allowed to stand for some time it runs into acidity, but if the feculent matter be removed it undergoes the vinous fermentation.

Properties.   7. Sugar procured pure by the preceding methods has a very strong sweet taste, but no smell. Its colour is white; and when crystallized it is somewhat transparent. It has often a considerable degree of hardness; but it is always so brittle that it can be reduced without difficulty to a very fine powder. When two pieces of sugar are rubbed against each other in the dark, a strong phosphorescence is visible.

Sugar is not altered by exposure to the atmosphere, excepting only that in damp air it absorbs a little moisture.

* Historie de la Canne.   Premiere Partie, chap. vi. and vii.
† Ann. de Chim. lvii. 148.

8. It is exceedingly soluble in water. At the tempera-
ture of 48° water, according to Mr. Wenzel, dissolves its
own weight of sugar.* The solvent power of water in- Solubility in water.
creases with its temperature; when nearly at the boiling
point, it is capable of dissolving any quantity of sugar
whatever. Water thus saturated with sugar is known by
the name of *syrup*.

Syrup is thick, ropy, and very adhesive; when spread Syrup.
thin upon paper, it soon dries, and forms a kind of varnish,
which is easily removed by water. Its specific caloric, ac-
cording to the experiments of Dr. Crawford, is 1·086.
When syrup is sufficiently concentrated, the sugar which
it contains may be obtained in crystals. The syrup is
boiled down till it is thick, poured immediately into pans,
and kept in a stove or room, heated so as not to be sup-
ported by animals for any length of time. The crystals Crystals.
concrete upon small sticks placed in the pans for that pur-
pose.† The primitive form of these crystals is a four-sided
prism, whose base is a rhomb, the length of which is to
its breadth as 10 to 7, and whose height is a mean propor-
tion between the length and breadth of the base. The
crystals are usually four or six-sided prisms, terminated by
two-sided, and sometimes by three-sided summits.‡ From
the experiments of Berzelius they are composed of

> Real sugar 100
> Water ...   5·6
> ─────
> 105·6 §

9. The specific gravity of very white sugar, according Specific
to the experiments of Fahrenheit, is 1·6065; ‖ according to gravity.
Hassenfratz, it is 1·4045.**

10. Sugar, as far is known, is not acted upon by oxygen
gas. The effect of the simple combustibles on it has not
been tried; but it does not appear to be great. Azotic gas
nor the metals have no sensible action on it.

11. From the recent experiments of chemists it appears
that sugar is capable of combining with and neutralizing
both acids and alkalines bodies.

* Verwandschaft, p. 308.   † Lewis, Neuman's Chemistry, p. 329.
‡ Gillot, Ann. de Chim. xviii. 317.   § Annals of Philosophy, v. 264.
‖ Phil. Trans. 1724, vol. xxxiii. p. 114.   ** Ann. de Chim. xxviii. 15.

Action of
acids on.

Sulphuric acid and muriatic acid act upon it with considerable energy, charcoal is evolved, and much of the sugar destroyed, the remainder loses the power of crystallizing.*

Nitric acid dissolves it with an effervescence, occasioned by the evolution of nitrous gas, and converts it into malic and oxalic acids. Four hundred and eighty grains of sugar, treated with six ounces of nitric acid, diluted with its own weight of water, and cautiously heated, separating the crystals as they formed, yielded 280 grains of oxalic acid. So that 100 parts of sugar yield by this treatment 58 parts of oxalic acid.† When liquid chlorine is poured upon sugar in powder, it is dissolved, and immediately converted into malic acid; and the chlorine is converted into common muriatic acid.‡

Oxalic, acetic, and tartaric acid, deprive sugar of the property of crystallizing, or at least the crystals are soft and ill defined.§

Of lime.

12. When lime is added to a solution of sugar in water, and the mixture boiled for some time, a combination takes place. The liquid still indeed retains its sweet taste; but it has acquired also a bitter and astringent one. A little alcohol added to the solution produced a precipitate in white flakes, which appeared to be a compound of sugar and lime. Sulphuric acid precipitated the lime in the state of sulphate, and restored the original taste of the sugar. When the compound of sugar and lime was evaporated to dryness, a semitransparent tenacious syrup remained, which had a rough bitter taste, with a certain degree of sweetness.‖

Of stron-
tian.

From the experiments of Mr. William Ramsay, it appears that sugar facilitates and increases the solubility of lime and strontian, and forms a combination with them. But barytes seems to act with more energy, and to occasion a partial decomposition of the sugar. For on endeavouring to dissolve it in syrup it was constantly con-

* Vogel, Ann. de Chim. lxxi. 93.
† Cruickshanks, Rollo on Diabetes, p. 460.
‡ Chenevix, Ann. de Chim. xxviii. 193.
§ Vogel, Ann. de Chim. lxxi. 95.
‖ Cruickshanks, Rollo on Diabetes, p. 460.

verted into a carbonate, and very little in consequence dissolved.*

The fixed alkalies combine with sugar, and form com- Of alkalies. pounds not unlike those which have been just described. Potash destroys the sweet taste of syrup more completely than lime; but when it is neutralized by sulphuric acid, and the sulphate precipitated by alcohol, the sweet taste is completely restored. When alcohol is agitated with the compound of sugar and potash dissolved in water, it refuses to unite with it, but swims on the top in a state of purity.†

When a solution of sugar is digested on oxide of lead, the oxide is gradually dissolved, but after a certain interval of time a light white powder makes its appearance. This powder is a compound of sugar and oxide of lead. It is white, light, tasteless, and insoluble in water. According to Berzelius to whom we are indebted for our knowledge of it,‡ its constituents are as follows :

Sugar .... 41·74 100
Oxide of lead ... 58·26 .... 139·6
_____
100·00

13. Sugar is soluble in alcohol, but not in so large a pro- Of alcohol. portion as in water. According to Wenzel, four parts of boiling alcohol dissolve one of sugar.§ But this proportion is surely too great. Lewis could only dissolve one part of sugar in 12 of boiling rectified spirits, and Margraff in 16 parts. When the solution is set aside for a few days, the sugar separates in elegant crystals. ‖ Sugar unites readily with oils, and renders them miscible with water. A moderate quantity of it prevents, or at least retards, the coagulation of milk; but Scheele discovered that a very large quantity of sugar causes milk to coagulate.**

14. The hydrosulphurets, sulphurets, and phosphurets Of sulphu- of alkalies and alkaline earths, seem to have the property rets, &c. of decomposing sugar, and of bringing it to a state not very different from that of gum. Mr. Cruickshanks introduced

* Ncholson's Jour. xviii. 9.
† Cruickshanks, Rollo on Diabetes, p. 460.
‡ Anuals of Philosophy, v. 263.   § Verwandtschaft, p. 305.
‖ Lewis, Newman's Chemistry, p. 329.   Margraff, Opusc. i. 217.
** Scheele, ii. 32. Dijon Trans.

Book IV. a quantity of syrup into a jar standing over mercury, and then added about an equal quantity of phosphuret of lime. Phosphureted hydrogen gas was immediately extricated. In eight days the syrup was withdrawn : it had lost its sweet taste, and acquired a bitter and astringent one.* From this solution alcohol threw down white flakes, very much resembling those of mucilage separated from water by the same liquid.† A little sugar was dissolved in alcohol, and phosphuret of lime added to it. No apparent action took place. The mixture, after standing in the open air for some days, was evaporated and water added. No gas was disengaged, as the phosphuret had been converted into a phosphate. The liquid being filtered and evaporated, a tenacious substance remained, much resembling gum arabic. Its taste was bitter, with a slight degree of sweetness. It did not seem soluble in alcohol. It burned like gum. ‡

Similar experiments were made by this ingenious chemist with the sulphurets. The sweet taste of the sugar was destroyed; but on account of the solubility of the different products, the nature of the change could not be ascertained.

Action of heat.

15. When heat is applied to sugar it melts, swells, becomes brownish-black, emits air bubbles, and exhales a peculiar smell, known in French by the name of *caromel*. At a red heat it instantly bursts into flames with a kind of explosion. The colour of the flame is white with blue edges.

When sugar is distilled in a retort, there comes over a fluid which, at first, scarcely differs from pure water ; by and by it is mixed with what was formerly called pyromucous acid, and is now known to be a compound of oil and acetic acid ;§ afterwards some empyreumatic oil makes its appearance, and a bulky charcoal remains in the retort. This charcoal very frequently contains lime, because lime is used in refining sugar; but if the sugar, before being submitted to distillation, be dissolved in water, and made

* This is the taste of phosphuret of lime.
† Rollo on Diabetes, p. 452.   ‡ Cruickshanks, ibid.
§ Schrickel, in his dissertation De Salibus Saccharinis, published in 1776, endeavoured to show that pyromucous acid was a mixture of vinegar, oxalic and tartaric acids. Fourcroy and Vauquelin have proved more lately that it is merely acetic acid united to a little oil.

to crystallize by evaporation in a temperature scarcely higher than that of the atmosphere, no lime whatever, nor any thing else, except pure charcoal, will be found in the retort. During the distillation, there comes over a considerable quantity of carbonic acid and carbureted hydrogen gas.[*] Sugar therefore is decomposed by the action of heat; and the following compounds are formed from it: Water, acetic acid, oil, charcoal, carbonic acid, carbureted hydrogen gas. The quantity of oil in a separate state is inconsiderable; by far the most abundant product is pyromucous acid. Sugar indeed is very readily converted into pyromucous acid; for it makes its appearance always whenever syrup is raised to the boiling temperature.

We are indebted to Mr. Cruikshanks for the most precise set of experiments on the decomposition of sugar by heat. Four hundred and eighty grains of pure sugar were introduced into a coated retort, and heated gradually to redness. The products were,

Pyromucous acid with a drop or two of oil. . 270 grains.
Charcoal. 120
Carbureted hydrogen, and carbonic acid gas 90
                                            ———
                                            480

The pyromucous acid required about 75 grains of a solution of potash to saturate it; and when thus neutralized, no ammonia was disengaged. Hence sugar contains no azote, unless we suppose a very minute portion to be present in the pyromucous acid; and even this is not likely. The charcoal burns away without leaving any residue. Hence sugar contains no earth nor fixed alkali. The proportion of the gaseous products was 119 ounce measures of carbureted hydrogen, and 41 ounce measures of carbonic acid gas.[†]

These experiments are sufficient to show us, that sugar is composed entirely of oxygen, carbon, and hydrogen. It is of course a vegetable oxide. Lavoisier endeavoured to determine its constituents experimentally; but at that time pneumatic chemistry had made too little progress to permit him to approach very near the truth. More lately

Constituents.

* Scopoli and Morveau, Encyc. Meth. Chim. i, 269.
† Rollo on Diabetes, p. 452.

Book IV. Gay-Lussac and Thenard have analysed sugar by burning a determinate quantity of it with chlorate of potash, and ascertaining the proportion of carbonic acid gas formed.* Berzelius has repeated this analysis with some modifications, and with his accustomed precision.† The following table exhibits the results of these experiments :

	Gay Lussac and Thenard.		Berzelius.	
Oxygen....	50·63	.. 51·47	.. 49·015	.. 49·083
Carbon....	42·47	.. 41·48	.. 44·200	.. 44·115
Hydrogen..	6·90	.. 7·05	.. 6·785	.. 6·802
	100·00	100·00	100·00	100·00

If we consider the compound of sugar and oxide of lead formed by Berzelius as composed of one atom sugar and one atom oxide of lead, then the weight of an atom of sugar will be 10·03 ; for 139·6 : 100 :: 14 : 10·03. The proportions of constituents which will agree best with this weight and with the preceding analyses are

Five atoms oxygen .... = 5	.. 49.4
Six atoms carbon ...... = 4·5	.. 44·5
Five atoms hydrogen... = 0·625	.. 6·1
Atom of sugar. ...... = 10·125	100·0

If Berzelius' saccharate of lead be a compound of 2 atoms sugar and 1 atom oxide of lead, then the weight of an atom of sugar will be only 5. But as this weight could not be so nearly reconciled to the analyses above stated, I am disposed to consider the saccharate of lead as a compound of 1 atom of sugar and 1 atom of oxide of lead. On that supposition the weight of an atom of sugar must be 10·125.

Species.   16. From the experiments of different chemists, especially of Proust and Goettling, it appears that there are different species of sugar found ready prepared in the vegetable kingdom, distinguished from each other by the figure of their crystals, and other variations in their properties. The species hitherto examined are six in number; namely, common sugar, liquid sugar, sugar of figs, sugar of grapes and of starch, Botany Bay sugar, and manna.

* Recherches Physico-chimiques, ii. 288.
† Annals of Philosophy, v. 262.

Common sugar is the substance which has been described Chap. I.
in the preceding part of this Section. It is obtained from Common.
the sugar cane. As far as is known at present, there is
no difference between the sugar of the maple and common
sugar. The sugar of beet is also the same as common
sugar.

17. Liquid sugar was first pointed out by Proust. He Liquid.
has shown that it exists in a variety of fruits and vegetable
juices. It is distinguished from every other species of sugar
by being incapable of crystallizing. It can only be exhi-
bited in a liquid state. It is transparent and colourless
when pure, and is more soluble in alcohol than common
sugar. By means of that liquid it may be separated from
common sugar when they happen to be mixed. It exists
in the sugar cane juice, and constitutes, according to Proust,
a considerable portion of the molasses. It exists also in
grapes, peaches, apples, and other fruits.* From the ex-
periments of Auarie it appears, that a liquid sugar may
also be obtained from the stalks of the *Zea Mays*, or Indian
corn; but no method tried was capable of inducing it to
crystallize.† From the experiments of Vogel and Bouillon
Lagrange there is reason to suspect that liquid sugar may
be merely common sugar deprived of the power of crystal-
lizing by being combined with an acid.

18. The sugar of figs may be seen in a concrete state Sugar of
upon the outside of that fruit in the state in which it is figs.
usually sold in the shops in this country. If we dissolve it
in boiling alcohol and set the liquid aside, we may easily
obtain it in the state of crystals. These crystals have a form
different from that of common sugar; nor do they appear
to my taste quite so sweet. Hence they must constitute a
distinct species.

19. That grapes contain abundance of sugar has been Sugar of
long known. The Duc de Bullion first extracted it from grapes.
the juice of grapes, and Proust pointed out the difference
between it and common sugar. The juice of grapes, ac-
cording to him, yielded from 30 to 40 per cent. of this
sugar.‡ The sugar of grapes is not so white as common
sugar, but it crystallizes much more readily.§

* Proust, Ann. de Chim. lvii. 131.   † Ann. de Chim. lx. 61.
‡ Jour. de Phys. xxix. 5, and lvi. 113.   § Nicholson's Jour. xiv. 178.

Book IV.　　Proust has published a long dissertation on the properties of this sugar, and the method of extracting it from grapes. It was of great importance on the continent during the last war, on account of the difficulty of obtaining sugar from the West Indies.

Verjuice.　　Verjuice, or the liquid obtained from unripe grapes, contains tartar, sulphate of potash, sulphate of lime, much citric acid, a little malic acid, extractive, and water; but neither gum nor sugar. As the grapes advance to maturity, the citric acid gradually disappears, and gum and sugar appear in its place.

Juice of ripe grapes.　　The juice of ripe grapes contains also gluten and fibrous matter, merely in a state of mixture, and therefore separable by the filter, or still better by boiling and scumming the liquid. The substances held in solution are chiefly sugar, syrup, gluten, gum, and extractive. When this juice is evaporated to dryness, it yields from a third to a fifth of solid matter, according to the species of grape employed, and the season of the year.

Sugar of of grapes.　　To extract the sugar from this juice, Proust saturated the acids which it contains with potash, boiled it down to a half, and left it at rest. By this means several of the salts subsided. Its specific gravity was 1·215. It was then mixed with blood, heated, scummed, filtered, and boiled down to a syrup. It gradually becomes crystallized, and resembles the raw sugar from the West Indies. In this state its specific gravity is about 1·500. This raw sugar, according to Proust, is composed of

Crystallizable sugar . . . . 75·00
Syrup, or uncrystallizable sugar . 24·44
Gum . . . . 0·31
Malate of lime . . . . 0·25
————
100·00

Besides some extractive, the quantity of which cannot well be ascertained. The syrup holds in solution a considerable quantity, probably more than half its weight, of crystallizable sugar; but it is difficult to separate it.

The raw sugar thus obtained is not so sweet as that from the sugar cane, since four parts of the latter will go as far

as five parts of the former. But it may be applied to all the purposes of common raw sugar.

This raw sugar may be refined precisely in the same way as that of the sugar-cane. It is then white, but inferior in consistence to common sugar. It is not so sweet, and has a striking resemblance to the sugar of honey. It does not crystallize, but assumes the form of sphericles. It is not so soluble as the sugar of canes, and is therefore more easily separated from the other substances in the juice of grapes.

Proust informs us that the raw sugar from grapes, when diluted sufficiently with water, ferments and is converted into wine.

Starch may be converted into a sugar possessing exactly the properties of sugar of grapes, by mixing it with about four times its weight of water and about one hundreth part of its weight of sulphuric acid, boiling the mixture for thirty-six hours, supplying water as fast as it evaporates; then saturating the acid with lime, separating the sulphate of lime and concentrating the liquid by sufficient evaporation.

Starch sugar.

This curious fact was accidentally discovered by Kirchhoff, a Russian chemist, as he was employed in a set of experiments to convert starch into gum. He conceived that the starch would be rendered soluble in water by boiling it with very dilute sulphuric acid, and by prolonging the boiling he gradually observed the conversion of the starch into sugar. Vogel ascertained that during the conversion of starch to sugar no gas whatever is extricated. Mr. Moore[*] and M. de Saussure[†] ascertained that the quantity of sulphuric acid was not diminished by the process. Saussure ascertained that 100 parts of starch when converted into sugar become 110·14 parts. Hence he drew as a conclusion that starch sugar is merely a compound of starch and water in the solid state.[‡] According to his analysis the constituents of starch sugar are as follows:

Oxygen .... 55·87
Carbon .... 37·29
Hydrogen .... 6·84
                        ———
                       100·00

[*] Phil. Mag. xl. 134.　　　　[†] Annals of Philosophy, vi. 424.
[‡] Annals of Philosophy, vi. 426.

As we have no data for determining the equivalent number for starch sugar, it is impossible to know of how many atoms of oxygen, carbon, and hydrogen it is composed. Were we to consider it as composed of five atoms of each of its ingredients, its composition and weight would be as follows:

5 Atoms oxygen	= 5	53·33
5 Atoms carbon	= 3·75	40·00
5 Atoms hydrogen	= 0·625	6·67
Atoms of starch sugar	= 9·375	100·00

These proportions do not differ much from the result of the analysis of Saussure. Were we to suppose the above result correct, starch sugar would differ from common sugar by containing one atom of carbon less than it does.

Saussure's analysis of sugar of grapes approaches very nearly to the preceding analysis. He found the composition of sugar of grapes as follows:

Oxygen	56·51
Carbon	36·71
Hydrogen	6·78
	100·00

This species of sugar melts at the temperature of boiling water; when dissolved in water and sufficiently diluted, it undergoes the vinous fermentations without its being necessary to add any yeast. Its crystals are small spheres, exactly similar to the crystals of honey. I believe that these spheres are composed of a congeries of small needles; though it is not always easy to observe this structure.

Botany Bay sugar. 20. About a year ago specimens of a sweet substance were brought from Botany Bay. They were snow-white, in the form of tears, and had obviously dropped in a liquid state from some vegetable. I was informed that these tears were collected in a plain covered with wood; but of what species I could not learn. Some bushels of it might have been collected. These tears had a sweet and agreeable taste. They dissolved in much greater quantity in alcohol than common sugar, and when the alcohol cooled it deposited the sugar abundantly in needle-form crystals. The

form of these crystals approached that of manna; but was
not quite the same. Nor did it make so cooling an impression on the tongue. It was therefore a peculiar species of sugar; though approaching much nearer to manna than any of the preceding species. It is very much to be wished that more complete information could be obtained respecting this species of sugar, and that sufficient quantities of it could be sent over to this country to permit an accurate set of experiments on it to be made. I only had a very few grains of it in my possession.

21. M. Braconnot obtained from the juice of the *agaricus* Mushroom *volvaceus*, by evaporation, a species of sugar, which differs sugar. from every other hitherto known. It crystallizes in four-sided prisms with square bases. It has such a disposition to crystallize, that when a very weak aqueous solution of it is put upon the surface of a vessel it is immediately sprinkled with small acicular crystals. When heated this sugar melts, swells and takes fire, giving out the odour of caromel. There remains a small quantity of charcoal, which is destitute of alkali. Acids do not deprive this substance of the power of crystallizing as they do common sugar. When digested with nitric acid it produces abundance of oxalic acid; but no bitter principle. It is capable of undergoing the vinous fermentation.*

22. Manna was long considered as a substance which fell Manna. from the heavens, till incontestible experiments demonstrated it to be an exudation from trees. It has the form of oblong globules or masses, of a yellowish-white colour, and some degree of transparency. It is the produce of various trees, but is chiefly procured from the *fraxinus ornus*, a species of ash, which grows abundantly in Sicily and Calabria. It partly exudes spontaneously during the summer months, and is partly obtained by incisions. The juice gradually concretes into a solid mass, or it is dried in the sun or in stoves. †

Pure manna is very light, and appears to consist of a congeries of fine capillary crystals. It taste is sweet, and it leaves a nauseous impression on the tongue. It acts as a mild purgative. When dissolved in water it may be ob-

* Ann. de Chim. lxxix. 278.
† See Neuman's Chemistry, p. 325, from which all the accounts of manna to be found in chemical books have been copied.

tained again unaltered by a gentle evaporation. Alcohol dissolves it when assisted by heat; and the solution, when set aside, gradually deposits about $\frac{5}{8}$ths of the manna, in the state of a fine white light spongy crystalline mass, bearing some resemblance to camphor. This deposite has an agreeable sweet taste, and instantly melts upon the tongue like snow in warm water. This may be considered as pure manna. It differs from sugar in the nature of its crystals, and in its more rapid solubility. By evaporating the solution, and setting it aside repeatedly, about $\frac{2}{8}$ths more of the manna is deposited, but not so fine in colour or taste as the first precipitate. By evaporation to dryness, the remaining 8th is obtained in the state of a thick extract, which cannot easily be reduced to dryness. This may be considered as consisting chiefly of the foreign bodies to which manna owes its nauseous taste.* Manna differs from common sugar in several remarkable particulars. It dissolves very readily and abundantly in alcohol, and crystallizes on cooling. When digested in nitric acid it yields both oxalic and saclactic acids, whereas sugar only yields oxalic acid.† It does not ferment like sugar, and of course does not seem capable of furnishing alcohol.‡ In a set of experiments on the juice of the common onion (*alium cœpe*) Fourcroy and Vauquelin found that at a temperature, between 66° and 80°, it gradually underwent the acetous fermentation without emitting any gas; and that by this process a quantity of uncrystallizable sugar which it contained assumed most of the properties of manna. It was not precisely the same, however, with manna, for it did not yield saclactic acid when treated with nitric acid.

The common manna of the shops, according to the experiments of Fourcroy and Vauquelin, consists of four different ingredients. 1. Pure manna, which constitutes at least $\frac{3}{4}$ths of the whole. 2. A little common sugar, which makes it fermentable to a small extent. 3. A yellow matter with a nauseous odour, to which the purgative quality of manna seems owing. 4. A little mucilage convertible into saclactic acid. This last ingredient seems hypothetical. Several substances by fermenting seem to be converted into

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* Neuman, p. 326.   † Proust, Ann. de Chim. lvii. 144.
‡ Du Puytren and Thenard, Ann. de Chim. lix. 51.

manna. The sugar in onion juice has been already mentioned. Fourcroy and Vauquelin found likewise that fermented melon juice contained manna, though none could be detected in it before the fermentation. Manna appears sometimes to be formed and deposited by insects.*

23. The plants containing sugar are very numerous. Margraff first pointed out a method of separating it from them. The plant suspected to contain it is reduced to powder or pulp, and boiled with strong alcohol. The liquid is filtered while hot, and set aside in a close vessel. In a few days the sugar separates from the alcohol and crystallizes. †

The following are the chief plants from which it has been actually extracted by chemists: ‡

The flower of the rhododendron ponticum,
The sap of the acer saccharinum,
——————— betula alba,
——————— asclepias syriaca,
——————— heraclium sphondilium,
——————— cocos nucifera,
——————— juglans alba,
——————— agave Americana, §
——————— fucus saccharinus,
——————— ficus carica,
——————— ceratonia siliqua, ||
The juice of arundo saccharifera,
——————— arundo bambos, **
——————— zea mays,
The roots of pastinaca sativa, ††
——————— sium sisarum, ††
——————— beta vulgaris and cicla, ††
——————— daucus carota, ††
——————— apium petroselinum,
The bulb of the allium cœpe.

It is proper to observe, however, that from the daucus

* See Klaproth, Gehlen's Jour. iv. 328.   † Margraff's Opusc. i. 216.
‡ See Gren's Handbuch, ii. 123.   § Margraff, Opusc. i. 213.
|| Klaproth, Gehlen's Jour. iv. 326.
** Tennant's Indian Recreation, ii. 288.
†† Margraff, Opusc. i. 213.

Book IV. carota, Margraff could obtain only an uncrystallizable syrup. The sugar from the sap of the agave Americana bore a greater resemblance to manna than to sugar.* It is very seldom that sugar exudes spontaneously from vegetables; sometimes, however, it does. Tears of a sweet substance were observed upon the ceratonia siliqua, or locust tree, some time ago in Naples. These tears were examined by Klaproth, and found to be sugar mixed with a little tannin and oxalate of potash.† The inspissated juice of the bamboo (*arundo bambos*) is known in India by the name of *sacar nambu*; a term which is supposed to be the origin of our word *sugar*, and constitutes a species of sugar celebrated as a medicine. How far it agrees with common sugar has not been ascertained.

Small crystals of sugar are found occasionally in the flower of the rhododendron ponticum. I have received some of these crystals from my friend Dr. Charles Mackenzie, but too small in quantity to admit of a rigid examination. They have no regular shape; but in other respects seem to agree with common sugar in their properties. The same sugar has been noticed by Fourcroy, Vauquelin, and Bosc.‡

The list of the saccharine plants would be greatly extended were we to add all sweet-tasted fruits, such as grapes, &c. which obviously contain sugar, and some of the mushroom tribe, from which Humboldt affirms he extracted it.§

24. Sugar has now become an essential part of the food of Europeans. It contains perhaps a greater proportion of nourishment than any other vegetable substance in the same bulk. It has the advantage of most other articles of food, in not being liable to be injured by time nor by the weather. If we believe Dr. Rush, the plentiful use of it is one of the best preventatives of the diseases occasioned by worms. It has been long supposed to have a tendency to injure the teeth; but this prejudice is now given up. It

Exudes spontaneously.

Uses.

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* Margraff, i. 241.   † Gehlen's Jour. iv. 327.
‡ Ann. de Chim. lxiii. 102.
§ The reader will find a much fuller list than I have given in John's Tabellen, p. 11. I have not ventured to make use of his materials, because I have no means of determining the particular species of sugar which each vegetable contains.

has the property of preserving other vegetable substances from putrefaction; and accordingly is often employed for that purpose, constituting the base of conserves, &c.

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SECT. III.

OF SARCOCOLL.

THIS substance has hitherto been confounded with the gum resins, though its properties are very different. It is supposed to be the produce of the *penæa mucronata;* a shrub which is said by botanical writers to be indigenous in the north-eastern parts of Africa.* Nothing precise is known concerning the way in which it exudes.

Sarcocoll comes to this country from Persia, Turkey, and India, and is usually sold in the state of oblong glo-bules, from the size of a pea to that of a particle of sand. Its colour is usually yellow; and it has the semitransparency and much of the appearance of gum arabic. But some of the grains are reddish-brown. Its smell is peculiar, and not unlike that of anise seed. When carefully examined, four different substances may be detected: The first, and by far the most abundant, is pure sarcocoll: The second consists of small woody fibres, and a soft yellowish-white substance, not unlike the covering of the seeds of some of the cruciform plants: The third is a reddish-brown sub-stance apparently earthy: And the fourth is only detected when the sarcocoll is dissolved in water or alcohol. It then appears in soft transparent tremulous masses like jelly.

The pure sarcocoll amounts to 0·8 of the whole. When the sarcocoll is dissolved in alcohol or water, and obtained again by evaporation, it loses its smell. It then assumes the form of semitransparent brittle-brown cakes very like gum. Its specific gravity is 1·2684.†

This substance has a sweet taste, but leaves an impression of bitterness. In the mouth it dissolves like gum.

It is almost equally soluble in water and alcohol; the

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* Dioscorides informs us that sarcocoll exudes from a tree which grows in Persia, and nothing farther respecting it is known at present.

† Brisson.

Book IV. solution is yellow. The watery solution has the appearance of mucilage, and may be used for the same purposes.

Cannot be made to crystallize. When heated softens, but does not melt. It emits a slight smell of caromel. When strongly heated, it blackens, and assumes the consistence of tar, emitting a white heavy smoke having an acrid odour. In a strong fire it scarcely leaves any residuum.

To determine the properties of sarcocoll more in detail, I dissolved 50 grains of it in five ounce measures of water. The solution had a light brown colour, and tasted very like a decoction of liquorice. It did not feel in the least glutinous, and could not be used like gum to paste pieces of paper together, or to stiffen linen.

The effects of reagents on it are as follows:

Infusion of nutgalls ...... A slight precipitate.

Tincture of nutgalls...... { A copious light-yellow precipitate. Liquor becomes colourless.

Gallic acid .... No change.

Hydrocyanate of potash .. No change.

Nitric acid .... { A white precipitate and some effervescence.

Sulphuric acid .... Becomes dark coloured.

Potash .... Becomes green.

Carbonate of ammonia.... Becomes green.

Lime water .... Becomes green.

Strontian water.......... Becomes green.

Silicated potash .... { Becomes green. No precipitate.

Oxalate of ammonia ...... Becomes slightly opal.

Sulphate of alumina ...... No change.

Muriate of magnesia ...... No change.

Sulphate of iron .... { Colour becomes darker and more opaque. A precipitate falls after an interval of some hours.

Nitrate of lead .... No change.

Acetate of lead .... Becomes milky.

Subacetate of lead .... A copious white precipitate.

Corrosive sublimate ...... No change.

Nitrate of silver .... No change.

5

Sulphate of zinc .... No change.

Sulphate of copper .... No change.

Muriate of gold .... A slight precipitate.

The most remarkable property pointed out by this table is that of being precipitated by tannin. This distinguishes sarcocoll from gum and mucilage.

Liquorice seems to approach in its nature to sarcocoll. This substance is obtained from the root of the *glycirhiza glabra*; a plant cultivated in the south of Europe, and even in Britain. The roots are long, slender, and fibrous, of a yellow-colour, and when fresh very juicy. The juice of these roots is expressed and inspissated by boiling. The substance thus obtained is *liquorice* or *black* sugar. It comes to this country from Spain in cylindrical rolls covered with bay leaves. It is afterwards purified by a subsequent process, and sold in small cylinders about the size of a goose quill, under the name of *refined liquorice*. It is of a fine black colour and glossy. It is brittle, and its fracture is glassy.

Liquorice.

Besides the sweet matter of liquorice, there is present in it about a third part of mucilaginous matter,[*] and even some charcoal. When dissolved in nitric acid, a quantity of tannin is formed, owing probably to this charcoal; for neither the saccharine or gummy substances yield this substance to nitric acid.[†] When treated with sulphuric acid, it leaves a quantity of charcoal, amounting to $\frac{1}{4}$th of its weight. During the treatment of this substance with sulphuric acid, no tannin was evolved in Mr. Hatchett's experiments.[‡] We are indebted to Robiquet for an interesting analysis of liquorice.[§] The saccharine matter which it contains approaches very closely to sarcocoll. It has a brown colour, does not crystallize, is sparingly soluble in cold, but very soluble in hot water. It dissolves readily in alcohol and does not appear susceptible of fermentation.

* Neuman, p. 425.   + Hatchett, ibid.
‡ Third Series of Experiments on Artificial Tannin, Phil. Trans. 1806.
§ Ann. de Chim. lxxii. 143.

SECT. IV.

OF GUM.

THERE is a thick transparent tasteless fluid which some-times exudes from certain species of trees. It is very adhesive, and gradually hardens without losing its transparency; but easily softens again when moistened with water. This exudation is known by the name of *gum*. The gum most commonly used is that which exudes from different species of the *mimosa*, particularly the *nilotica*.* It is known by the name of *gum arabic*. Gum likewise exudes abundantly from the *prunus avium*, or common black cherry tree of this country.

Properties. Gum is usually obtained in small pieces like tears, moderately hard, and somewhat brittle while cold, so that it can be reduced by pounding to a fine powder. When pure it is colourless, but it has commonly a yellowish tinge, and it is not destitute of lustre. It has no smell. Its taste is insipid. Its specific gravity varies from 1·3161 to 1·4317.

1. Gum undergoes no change from being exposed to the atmosphere; but the light of the sun makes it assume a white colour. Water dissolves it in large quantities. The Mucilage. solution, which is known by the name of *mucilage*,† is thick and adhesive: it is often used as a paste, and to give stiffness and lustre to linen. When spread out thin it soon dries, and has the appearance of a varnish; but it readily

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* Schousbae, Phil. Mag. v. 241.

† Hermbstadt uses this word in a different sense. He makes a distinction between gum and mucilage. The solution of gum in water is transparent and glutinous, and can be drawn out into threads; whereas that of mucilage is opaque, does not feel glutinous, but slippery, and cannot be drawn into threads. Gum may be separated from mucilage by the following process:

Let the gum, which is supposed to be mixed with mucilage, previously reduced to a dry mass, be dissolved in as small a quantity of water as possible, and into the solution drop at intervals diluted sulphuric acid. The mucilage coagulates, while the gum remains dissolved. When no more coagulation takes place, let the mixture remain at rest for some time, and the mucilage will precipitate to the bottom, and assume the consistence of jelly. Decant off the liquid part, and evaporate the mucilage to dryness by a gentle heat till it acquires the consistence of horn. Med. and Phys. Jour. iii. 370.

attracts moisture, and becomes glutinous. Water washes it away entirely. When mucilage is evaporated the gum is obtained unaltered. This mucilaginous solution may be kept for years without undergoing putrefaction. Scarcely any vegetable substance is less liable to decomposition. At last, however, the odour of acetic acid becomes perceptible in it.

When gum is exposed to heat it softens and swells, but it does not melt; it emits air bubbles, blackens, and at last, when nearly reduced to charcoal, it emits a low blue flame. This flame appears sooner if a flaming substance be held just above the gum. After the gum is consumed, there remains a small quantity of white ashes, composed chiefly of the carbonates of lime and potash.

2. It does not appear that gum is acted upon by oxygen gas. A solution of gum in water, when exposed to the air, soon becomes mouldy on the surface, but undergoes no farther change for a long time. The action of the simple combustibles on gum has scarcely been examined. Azotic gas seems to have no action whatever.

Gum does not act upon metals; but it has the property Action of of combining with several of the metallic oxides, and form- metallic salts. ing compounds; at least some of the metallic salts occasion precipitates when dropped into solutions of gum. The most curious effect is that produced by the permuriate of iron. When this salt, concentrated, is dropped into a very strong mucilage, the whole becomes a brown semitransparent jelly, which is not readily dissolved by water. When dried, the jelly becomes lighter coloured, and assumes nearly the appearance of gum. Its taste is that of gum mixed with iron.

The following table exhibits the effects of different metallic salts on the solution of gum in water, as far as my experiments go. The mucilage I used was composed of eight parts of water to one part of gum. It was transparent and quite fluid, though a little thready.

Book IV.

SALINE SOLUTIONS.	EFFECTS.
1. Muriate of gold	No change.
2. Nitrate of silver	No precipitate nor change.
3. Corrosive sublimate	No change.
4. Supersulph. of mercury	No change.
5. Nitrate of mercury	A white coagulum: it disappears by agitation, but returns when the solution is much diluted.
6. Prussiate of mercury	Becomes slightly opal, but no precipitate.
7. Nitrate of copper	No change.
8. Sulphate of copper	No change.
9. Muriate of copper	No change; yet the muriate is precipitated by water.
10. Cuprate of ammonia	No change.
11. Sulphate of iron	No change.
12. Permuriate of iron	Little change except the mucilage be more concentrated.
13. Pernitrate of iron	No change.
14. Muriate of tin	No change.
15. Permuriate of tin	No change.*
16. Smoking liquor of Libavius	No change.
17. Nitrate of lead	No change.
18. Subacetate of lead	A copious coagulum.
19. Acetate of lead	No change.
20. Sulphate of zinc	No change.
21. Nitrate of zinc	No change.
22. Muriate of arsenic	No change.
23. Oxide of arsenic	No change.
24. Tartar emetic	Becomes yellow, but no precipitate.

* When the permuriate is approaching the gelatinous state, a flaky precipitate appears; but the same precipitate is occasioned by pure water.

SALINE SOLUTIONS.	EFFECTS.
25. Nitrate of bismuth	No precipitate; yet the salt is precipitated by pure water.

These phenomena indicate an affinity between gum and the peroxides of mercury and iron. Copper, antimony, and bismuth, seem also to be acted on by it; for it prevents water from precipitating them in the state of subsalts.

My experiments on the action of the alkalies and earths on mucilage of the strength indicated above, are contained in the following table: Action of alkalies and earths.

SOLUTIONS.	EFFECTS.
Potash	No precipitate.
Ammonia	No precipitate.
Lime water	No precipitate.
Barytes water	No precipitate.
Strontian water	No precipitate.
Alum	No precipitate.
Sulphate of magnesia	No precipitate.
Silicated potash	A white flaky precipitate, though very much diluted. The liquid remains transparent.
Aluminated potash	No precipitate.

From this table it appears that silica alone forms with gum an insoluble precipitate. It is by far the most delicate test of gum which I have yet met with.

Liquid potash first converts gum into a substance not unlike curd, and then dissolves it. The solution is of a light amber colour, and transparent. When long kept, the gum again falls in the state of curd. Alcohol throws down the gum in white flakes still soluble in water; but it retains the potash obstinately, and is much more friable than before. Lime water and ammonia likewise dissolve gum, and it may be afterwards separated little altered.

Charcoal powder, when mixed with a solution of gum in water, gives a black colour, which cannot be removed by filtration, unless a very great proportion of the powder be Of charcoal.

Book IV. added. In that case the water passes clear; but the whole of the gum is retained by the charcoal. Mr. Lowitz found, that not less than 30 lbs. of charcoal powder must be mixed with water containing an ounce of gum dissolved in it before the water is entirely deprived of the gum.*

Of acids.   The vegetable acids dissolve gum without alteration; the strong acids decompose it.

When thrown into-sulphuric acid it blackens, and soon is resolved into other substances. The charcoal formed, according to Hatchett's experiments, amounts to 0·29, and some traces of artificial tannin may also be detected.† Water and acetic acid are said likewise to be formed.‡

When gum is dissolved in strong muriatic acid, a brown solution is obtained, which becomes perfectly transparent when diluted with water, while at the same time some charry matter falls. If the solution be now saturated with ammonia, evaporated to dryness, and the residue digested in alcohol, the alcohol assumes a deep brown colour, and dissolves the whole except a very little sal-ammoniac. The gum now bears some resemblance to sugar in its properties; at least when heated it melts, and gives out a very strong smell of caromel.

Chlorine converts gum into citric acid, according to the experiments of Vauquelin. He passed a current of chlorine gas through a diluted solution of gum in water. In a few days almost the whole of the gum was acidified; and he detected citric acid by the formation of supercitrate of lime, soluble in water, and decomposable by oxalic acid.§ If nitric acid be slightly heated upon gum till it has dissolved it, and till a little nitrous gas is exhaled, the solution on cooling deposits saclactic acid. Malic acid is formed at the same time; and if the heat be continued, the gum is at last changed into oxalic acid. Thus no less than three acids are developed by the action of nitric acid on gum.‖ We are indebted to Mr. Cruikshanks for the most precise ex-

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* Crell's Annals, ii. 167. Eng. Trans.
† Third Series of Experiments on Artificial Tannin, Phil. Trans. 1806.
‡ Fourcroy, vii. 197. Engl. Trans.
§ Ann. de Chim. vi. 178. These properties alone were not sufficient to prove the presence of citric acid, since malic acid possessed them both.
‖ Fourcroy, vii. 148.

periments on the quantity of oxalic acid obtainable from gum by nitric acid. By digesting 480 grains of it with six ounces of nitric acid, he obtained 210 grains of oxalic acid and six grains of oxalate of lime.* No artificial tannin is formed during this process.† According to the experiments of Fourcroy and Vauquelin, the quantity of saclactic acid yielded by gum, when treated with nitric acid, varies from 0·14 to 0·26.‡

Of Alcohol.

Gum is insoluble in alcohol. When alcohol is poured into mucilage, the gum immediately precipitates; because the affinity between water and alcohol is greater than that between water and gum. The gum in this case is in the state of soft opaque white flakes. Neither is gum soluble in ether. It is not soluble in oils; but when triturated with a little oil it renders the oil miscible with water.

The action of the hydrosulphurets, sulphurets, phosphurets, and of most of the salts on gum, has not been examined with any attention.

Combines with sugar.

Gum and sugar readily unite together by dissolving both in water. By gentle evaporation a perfectly transparent solid substance is obtained, which does not crystallize. When treated with alcohol it becomes white, opaque, and soft. The greater part of the sugar is dissolved, and the gum remains united to a small portion. It has a sweetish taste, and very much resembles in appearance the substance of which the nests of wasps are formed.

Destructive distillation.

3. When gum is distilled in a retort, the products are water impregnated with a considerable quantity of pyromucous acid or *acetic acid* combined with oil, a little empyreumatic oil, carbonic acid gas, and carbureted hydrogen gas. When the pyromucous acid obtained by this process is saturated with lime, a quantity of ammonia is disengaged, with which that acid had been combined. The charcoal which remained in the retort leaves behind it, after incineration, a little lime and phosphate of lime. Mr. Cruickshanks, to whom we are indebted for these facts, gradually heated 480 grains of gum arabic to redness in a coated glass retort. The products were,

* Rollo on Diabetes, p. 452.
† Hatchett, Additional Experiments on Artificial Tannin, Phil. Trans. 1805.
‡ Fourcroy, vii. 199. Engl. Trans.

Pyromucous acid mixed with some oil .... 210 gr.
Charcoal 96
Lime and a little phosphate of lime 10
Carbureted hydrogen and carbonic acid gas 164
                                            ———
                                            480

The pyromucous acid liquid contained less than what was obtained from an equal weight of sugar in the proportion of 118 to 150. The gases consisted of 93 ounce measures of carbonic acid and 180 of carbureted hydrogen, composed of 5 parts charcoal to 1 of hydrogen. When the pyromucous acid was saturated with lime, ammonia was disengaged.*

From the experiments of Vauquelin, it appears that gum also contains traces of iron. A hundred parts of gum arabic left after incineration three parts of white ashes. These were composed chiefly of carbonate of lime; but contained also some phosphate of lime and iron, without any traces of an alkali or of sulphur. He conjectures, that in the gum the lime is usually combined with acetic acid, and perhaps sometimes with malic acid.†

Composition. It is only of late that any notions approaching to precision respecting the composition of gum have been acquired. Gay-Lussac and Thenard analysed it, by burning it along with chlorate of potash, and found it composed of

Oxygen .. .. 50·84
Carbon .... 42·23
Hydrogen .. 6·93
            ———
            100·00 ‡

Berzelius analysed it by a process of the same kind but somewhat modified. He found its constituents as follows:

Oxygen .... 51·306
Carbon .... 41·906
Hydrogen .. 6·788
            ———
            100·000 §

* Rollo on Diabetes, p. 452.   † Ann. de Chim. liv. 312.
‡ Recherches Physico-chimiques, ii. 290.
§ Annals of Philosophy, v. 270.

To determine the equivalent number for the weight of an atom of gum, Berzelius mixed caustic ammonia with a boiling solution of gum, and then mixed the liquid with a solution of subnitrate of lead, likewise boiling hot. A precipitate fell, which when washed and dried was a compound of gum and oxide of lead. Its constituents according to the analysis of Berzelius were,

Gum .... 61·75 100
Oxide of lead .... 38·25 .... 62·105
——————
100·00 *

If we suppose this compound to consist of an atom of gum united to an atom of oxide of lead, the weight of an atom of gum will be 22·542. But if the gummate contain 2 atoms of gum united to 1 atom of oxide of lead, (which may be the case,) then an atom of gum will weigh 11·271. I am rather disposed to adopt this last number for the weight of an atom of gum ; because it seems to approach very nearly to sugar in its properties, and seems capable of being converted into sugar with great facility in the processes of vegetation. On that account it seems likely that the composition of gum and sugar do not differ very much from each other. But if the weight of an atom of gum be 11·250, (which differs materially from the preceding number) its composition as indicated by the preceding analysis must be as follows :

Six atoms oxygen .... = 6   .... 53·33
Six atoms carbon .... = 4·5   .... 40·00
Six atoms hydrogen .. = 0·75 .... 6·67
                        ——————   ——————
                        11·25   100·00

Sugar then it would seem differs from gum merely in containing an atom of water less. Hence an atom of sugar + an atom of water constitute an atom of gum.

4. The species of gum at present known are considerable in number; and it is likely that a more rigid examination of the vegetable kingdom will discover a greater number. The most remarkable are *gum arabic, gum senegal, gum kuteera.*

* Annals of Philosophy, v. 270.

Book IV.
Gum arabic.
Gum senegal.

Gum arabic exudes from the *mimosa nilotica,* and other species of mimosa. It is the species described in the preceding part of this section.

5. Gum senegal, brought from the island of that name in the coast of Africa, commonly supplies the place of gum arabic in the shops, and is the sort chiefly employed by the calico-printers. It is generally in larger masses than the arabic, and its colour is darker,[*] but in other respects its properties are the same, excepting that it does not go so far in thickening water as gum arabic.

Gum kuteera.

6. Gum kuteera is the produce of the sterculia urens,[†] a tree which grows in Indostan; and having a considerable resemblance to gum tragacanth, great quantities were imported into this country, but did not answer as a substitute. The only account of this gum with which I am acquainted was given by Mr. Cowie, in one of the volumes of the Society of Arts.[‡] It is in loose wrinkled drops or pieces, without smell or taste, and mostly transparent. In water it slowly forms a pulp or jelly like gum tragacanth; but if pounded well in a mortar, and then boiled in water for fifteen minutes with constant agitation, it is completely dissolved. A tea spoonful of its powder gives to water the consistence of capillaire. In India it enters into the composition of some varnishes; it is used in calico-printing, and is one of the ingredients of a famous medicine for horses among them.[§]

Plants containing it.

7. It has been remarked by Mr. Barrow, and probably also by others, that all the plants which yield gum have an astringent bark.[‖] Almost all the trees known to yield gum have been enumerated in the preceding part of this section.

Uses.

8. Gum is a nutritive food, though seldom employed for that purpose, except when in the state of mucilage, and though from M. Magendie's experiments it does not seem capable of supporting life by itself. It is used frequently as a paste, and to give stiffness or lustre to linen. The calico-printers use it in great quantities to give their colours such a degree of consistency as prevents them from running upon

* Lewis, Neuman's Chem. p. 282.
+ Roxburgh, Nicholson's Journal, xxvii. 70.
‡ See Nicholson's Jour. vii. 301.   § Cowie, Nicholson's Jour. vii. 301.
‖ Travels in South Africa.

the cloth. It forms an ingredient in ink for a similar reason. Chap. I.
In medicine it forms the base of many mixtures.

SECT. V.

OF MUCUS.

The substances to which I give the name of *mucus* have
been hitherto considered as varieties of gum. But the ex-
periments on them by Dr. Bostock have shown that their
properties differ so much from those of gum, as to entitle
them to a separate place as peculiar vegetable principles.
They are extremely numerous, existing in the roots, leaves,
and seeds of a great variety of plants. They seldom or
never separate spontaneously, but may be obtained artifi-
cially in a state of tolerable purity. Only a few species have
been hitherto examined, so that we are uncertain how far
their properties agree, and only include them all under one
head from analogy.

Linseed yields one of the purest. Dr. Bostock obtained Linseed
it by infusing the seeds in ten times their weight of water. mucus.
A fluid is obtained of the consistence of the white of an egg,
which has the adhesive qualities of mucilage of gum arabic.
Its taste and appearance resemble those of that liquid.
When mixed with alcohol the mucus is precipitated in white
flocks, but the liquid does not become opaque and milky
like mucilage of gum arabic when mixed with alcohol.
Acetate of lead throws down a copious dense precipitate.
Super-acetate of lead, and permuriate of tin render the
liquid opaque, and also throw down a precipitate. The
nitrate of mercury occasions a very slight precipitate, while
muriate of gold, persulphate of iron, and silicated potash,
produce no sensible effect whatever. No change is pro-
duced by the infusion of nutgalls.*

From quince seeds, and the root of the hyacinth, Dr. Other va-
Bostock obtained solutions of mucus which exhibited the rieties.
above properties with some shades of difference. This
quince seed mucus was coagulated by acids, and by most

* Bostock, Nicholson's Jour. xviii. 31.

metallic salts, and the mucus from the hyacinth was preci-pitated by infusion of nutgalls.   These differences were pro-bably owing to foreign bodies; such as starch, gluten, &c. with which the mucus happened to be mixed in these cases, and from which we know no method of separating it com-pletely.

Mucus is contained in the roots and leaves of a vast num-ber of plants.   Almost all the bulbous roots and fleshy leaves yield it.   For example, the roots of the *hyacinthus nonscriptus* and the *althea officinalis;* the leaves of the *althea,* of the *malva sylvestris,* of many of the *fuci,* and of the greater number of the lichens; the seeds of flax, quinces, fenugrec, &c.

The bulbs of the hyacinth contain so much mucus, that when dried they may be employed as a substitute for gum arabic.   This was first made known to the public by Mr. Thomas Willis.*   He afterwards found that the roots of the vernal squill, the white lily, comfrey, and salop, might be employed also for similar purposes.†   A mucus may be extracted from most of the stringy lichens, which likewise answers all the purposes of a solution of gum.   This was first ascertained by Georgi, who published a dissertation on the subject in the Memoirs of the Petersburgh Academy for 1779. ‡   His experiments were repeated and varied by Amoreux, who published the result of his trials in 1787. §

Hoffman also found abundance of gum in many lichens. ‖ Lord Dundonald first thought of applying this discovery to practical purposes.   During the last war, when the price of gum was high, lichens, at his Lordship's suggestion, were very much employed as a substitute by the calico-printers in this country.

The mucilaginous quality of the fuci is apparently still greater than that of the lichens, though the mucilage ob-tained from them does not answer so well.

* Phil. Mag. xv. 1803.   † Nicholson's Jour. ix. 233.

‡ The lichens which he tried were the *farinaceus, glaucus, physodes,* and *pulmonarius.*

§ The academy of Lyons had proposed a prize dissertation on the li-chens in 1786.   Three memoirs were approved of, and published by them in 1787, written respectively by Willemet, Amoreux, and Hoffman. The lichens examined by Amoreux, and found to yield a gum, were the *pulmonarius, prunastri, islandicus, fraxineus, canius, caperatus.*   See his Memoir, p. 95.   ‖ See his Memoir, p, 23, and *passim.*

SECT. VI.

OF JELLY.

IF we press out the juice of ripe blackberries, currants, How ob-
and many other fruits, and allow it to remain for some time tained.
in a state of rest, it partly coagulates into a tremulous soft
substance, well known by the name of *jelly*. If we pour off
the uncoagulated part, and wash the coagulum with a small
quantity of water, we obtain *jelly* approaching to a state of
purity.

In this state it is nearly colourless, unless tinged by the Properties.
peculiar colouring matter of the fruit; it has a pleasant
taste and a tremulous consistency. It is scarcely soluble in
cold water, but very soluble in hot water; and when the
solution cools, it again coagulates into the form of a jelly.*
When long boiled, it loses the property of gelatinizing by
cooling, and becomes analogous to mucilage.† This is the
reason that in making currant jelly, or any other jelly, when
the quantity of sugar added is not sufficient to absorb all
the watery parts of the fruit, and consequently it is neces-
sary to concentrate the liquid by long boiling, the mixture
often loses the property of coagulating, and the jelly of
course is spoiled.‡

Jelly combines readily with alkalies; nitric acid converts
it into oxalic acid, without separating any azotic gas. § When
dried it becomes transparent. ‖ When distilled it affords a
great deal of pyromucous acid, a small quantity of oil, and
scarcely any ammonia.**

Jelly exists in all acid fruits, as oranges, lemons, goose-
berries, &c. If the juices of these fruits be allowed to gela-
tinize, and then poured upon a searce, the acid gradually
filters through, and leaves the other; which may be washed
with a little cold water, and allowed to dry. Its bulk gra-
dually diminishes, and it concretes into a hard transparent
brittle mass, which possesses most of the properties of gum.
Perhaps, then, jelly is merely gum combined with vegetable
acid.

* Vauquelin, Ann. de Chim. vi. 282.   † Ibid. v. 100.
‡ Ibid. v. 10.   § Ibid. vi. 282.   ‖ Ibid. v. 100.
** Ibid. vi. 286.

SECT. VII.

OF ULMIN.

History.   THIS substance was first noticed in 1804, by Klaproth, who found it in a spontaneous exudation from the *elm*.*   It was noticed in 1810 by Berzelius in his experiments on the bark of the pine, and on Jesuits bark.†   On the tenth of December, 1812, a set of experiments on the exudation from the elm, which had been examined by Klaproth, was read to the Royal Society.   These experiments were made by Mr. Smithson, well known for his precision.‡   Two or three days before the tenth of December, I had printed in the first number of the *Annals of Philosophy*, a set of experiments on an exudation from the common elm which had been collected at Plymouth by Mr. Coulson.§   The result of my experiments corresponded very nearly with those of Mr. Smithson; and showed that the extraordinary properties of ulmin, announced by Klaproth, did not belong to it.   I afterwards examined varieties of ulmin from the oak, the hornbeam, and the horse-chesnut; and was so fortunate as to receive a specimen from Dr. Leach in a state of purity.‖

From the observations of Berzelius it appears that ulmin forms a constituent of the bark of almost all tress.   If the bark be first digested in alcohol, and afterwards in cold water, we may obtain the ulmin nearly pure, by digesting the bark thus treated in hot-water, holding some carbonate of potash in solution.**   The properties of ulmin are as follows.

Properties.   1. Its colour is dark brown or almost black.   It has scarcely any taste or smell.

2. It dissolves slowly, and only in small quantity, in water and in alcohol.   The solution is pale brown and tasteless.   Hardly any metalline salt precipitates the aqueous solution of ulmin, except pernitrate of mercury and acetate of lead, both of which cause brown flocks to fall

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* Gehlen's Jour. iv. 329.   † Afhandlingar, iii. 347.
‡ Phil. Trans. 1813, p. 64.   § Annals of Philosophy, i. 23.
‖ Annals of Philosophy, ii. 11, 395, 396.
** Ibid. ii. 314.

down. The alcohol solution is precipitated dark brown by sulphate of iron and sulphate of copper.

3. When a weak solution of carbonate of potash is poured upon ulmin a dark brown solution is immediately effected. The ulmin as it exudes from the elm is almost always combined with a quantity of carbonate of potash. Hence the reason that it dissolves so readily in water.

This solution (supposing the carbonate of potash to amount to $\frac{1}{5}$th of the weight of the ulmin) has a dark brown colour, it is not in the least mucilaginous or ropy, and cannot, like the solution of gum in water, be employed to paste pieces of paper together. It is not precipitated by gelatine, tincture of nut-galls, or hydrocyanate of potash. Sulphate of iron occasions a copious precipitate, which in some cases is brown, and in some cases green. Nitric acid occasions a reddish-brown precipitate by saturating the potash which held the ulmin in solution. Alcohol occasions no precipitate. But all the acids precipitate the ulmin. When thus obtained it is buff-coloured, and after being dried is not sensibly soluble either in water or alcohol.

4. Ulmin when heated swells and catches fire; but does not melt. The smell which is given out has not the least resemblance to that of caromel.

Ulmin seems hitherto to have been confounded with *extractive* by chemists. In many cases it has passed for tannin.

SECT. VIII.

OF COLOURING MATTERS.

THE colouring principles of vegetables are so numerous and so various in their properties that they will hereafter fill a very extensive department of vegetable chemistry. But hitherto so few of them have been obtained in a separate state and subjected to a chemical examination, that it would be in vain to attempt a particular description of each. I shall therefore merely notice the following, which have been honoured with a more particular investigation of their properties.

                              I. POLYCHROITE.

This substance constitutes the colouring matter of *crocus sativus* or *safron*, and is the substance which Hermbstaedt announced as pure extractive. Its properties were investigated in 1811, by Bouillon Lagrange and Vogel,* who gave it the name of polychroite on account of the different colours which it is capable of assuming.

How ob-
tained.
To obtain polychroite, form an infusion of safron in water, evaporate the infusion to the consistency of honey, digest the residue in alcohol of the specific gravity 0·800, filter the solution and evaporate to dryness. The dry mass is polychroite in a state of purity. It possesses the following properties.

Properties.
Its colour is intensely yellow. When exposed to the air it absorbs moisture and becomes a viscid liquid. It is very soluble in water and in alcohol. But insoluble, or scarcely soluble in sulphuric ether.

When the aqueous solution is exposed to the rays of the sun it becomes colourless, and the yellow colour cannot be again restored. Hence it appears that the polychroite is destroyed, or at least its nature altered by the action of the solar ray.

When sulphuric acid is dropped into the aqueous solution of polychroite the liquid assumes a deep indigo-blue colour, which gradually becomes lilac. The same change is produced by sulphuric acid on the alcoholic solution.

Nitric acid causes these liquids to assume a green colour. The addition of a little water causes these colours to disappear, and when the proportion of acid is increased, other shades make their appearance.

Chlorine destroys the colour of these liquids altogether.

Sulphate of iron throws down a dark brown precipitate, lime-water a yellow precipitate, barytes water a red precipitate. Subacetate of lead throws down a safron coloured precipitate. Acetate of lead produces no effect; but nitrate of mercury throws down a red powder.

Polychroite is insoluble in oils.

When this colouring matter is distilled, there comes

* Ann. de Chim. lxxx, 188.

over an acid water, and an oil of a lemon-yellow colour, which is succeeded by an oil of a darker colour, and almost brown. At the same time carbonic acid and carbureted hydrogen gases are disengaged. When the charcoal that remains is calcined with potash a portion of hydrocyanic acid is formed.

II. HEMATIN.

This substance constitutes the colouring matter of the *hæmatoxylon campechianum* or *logwood* so universally known as a dye stuff. Its properties were investigated by Chevreul in 1812, who first recognised it as a peculiar substance, and gave it the name prefixed to this article.*

Hematin may be obtained by the following process. How obtained. Digest for several hours logwood in powder in water of the temperature 125°. Filter the liquid, evaporate it to dryness, and digest the residue for a whole day in alcohol of the specific gravity 0·837. Filter the alcohol, concentrate it by evaporation, then add a little water, evaporate a little farther, and leave it to itself. Crystals of hematin are deposited in abundance. These, when washed with alcohol and dried, may be considered as hematin in a state of purity.

Hematin thus prepared is in small brilliant crystals, of Properties. a reddish-white colour, and a slightly astringent, bitter, and acrid taste.

Boiling water dissolves it with facility, and acquires an orange-red colour; which becomes yellow when the liquid cools; but heat again restores the original colour. When this liquid is evaporated the hematin crystallizes. The addition of an acid renders it first yellow and then red. Sulphurous acid however gradually destroys the colouring matter altogether if it be left long enough in contact with it. Potash, soda, and ammonia, give it a purplish-red colour, and when a great excess of these alkalies is added the colour becomes violet-blue; then reddish-brown, and at last yellowish-brown. The hematin is then decomposed as its colour cannot be again restored by the addition of acids. Barytes, strontian, and lime-water produce the same effects: only they gradually precipitate hematin from its solution.

* Ann de Chim. lxxxi. 128.

Book IV.   When a current of sulphureted hydrogen gas is passed through an aqueous solution of hematin it assumes a yellow colour, which disappears in the course of a few days. The oxides of lead, tin, iron, copper, nickel, zinc, antimony, and bismuth, unite with hematin, and give it a blue colour with a shade of violet. The peroxide of tin acts upon it as the mineral acids do. Gelatine throws it down in reddish flocks.

Other species.   Besides these colouring matters there are several others, such as *madder*, *saflower*, *litmus*, that would deserve a particular description. But as these substances have not yet been analysed, and their colouring ingredient obtained in a separate state, I think it better to defer the account of them to the ensusing chapter. Indigo, which has been sufficiently examined to ascertain its peculiar properties seems entitled from its great importance to rank as a peculiar vegetable principle.

SECT. IX.

OF BITTER PRINCIPLES.

Plants containing bitter principle.   MANY vegetable substances have an intensely bitter taste, and on that account are employed in medicine; by brewers, &c. This is the case with the wood of the *quassia amara* and *excelsa*, the common *quassia* of the shops; with the roots of the *gentiana lutea*, common *gentian*; the leaves of the *humulus lupilus* or *hop*; the bark and wood of the *spartium scoparium* or common broom; the flowers and leaves of the *anthemis nobilis* or *chamomile*; and many other substances. These bodies owe their bitter taste to the presence of peculiar vegetable substances differing from every other, which may be distinguished by the name of *bitter principles*.

Of late years several of these peculiar substances have been examined and characterized; and doubtless there are others with which we are not yet acquainted. I shall give an account in this section of the different bitter tasted vegetable substances that appear to possess distinct qualities.

and to differ from each other by well characterized pro-
perties.

I. *Quassin*, or *Bitter Principle of Quassia*.

I. When water is digested over *quassia* for some time, it Experi-
acquires an intensely bitter taste and a yellow colour, but ments on
the infusion
no smell. When water thus impregnated is evaporated to of quassia.
dryness in a low heat, it leaves a brownish yellow sub-
stance, which retains a certain degree of transparency. It
continues ductile for some time, but at last becomes brittle.
This substance I shall consider as quassia in a state of pu-
rity. If it contain any foreign body, it must be in a very
minute proportion. This substance I find to possess the
following properties :

1. Its taste is intensely bitter. Colour brownish-yellow.

2. When heated, softens, and swells, and blackens; then
burns away without flaming much, and leaves a small quan-
tity of ashes.

3. Very soluble in water and alcohol.

4. Does not alter the colour of infusion of litmus.

5. Lime-water, barytes-water, and strontian-water, oc-
casion no precipitate. Neither is any precipitate thrown
down by silicated potash, aluminated potash, or sulphate
of magnesia.

6. The alkalies occasion no change in the diluted solu-
tion of the bitter principle.

7. Oxalate of ammonia occasions no precipitate.

8. Nitrate of silver renders the solution muddy, and a
very soft flaky yellow precipitate falls slowly to the bottom.

9. Neither corrosive sublimate nor nitrate of mercury
occasion any precipitate.

10. Nitrate of copper, and the ammoniacal solution of
copper, produce no change; but muriate of copper gives
the white precipitate, which falls when this liquid salt is
dropped into water.

11. Sulphate and permuriate of iron occasion no change.

12. Muriate of tin renders the solution muddy, but oc-
casions no precipitate, unless the solution be concentrated ;
in that case a copious precipitate falls.

13. Acetate of lead occasions a very copious white preci-
pitate ; but the nitrate of lead produces no change.

14. Muriate of zinc occasions no change.

15. Nitrate of bismuth produces no change, though when the salt is dropped into pure water a copious white precipitate appears.

16. Tartar emetic produces no change; but when the muriate of antimony is used, the white precipitate appears, which always falls when this salt is dropped into pure water.

17. Muriate and arseniate of cobalt occasion no change.

18. Arseniate of potash produces no effect.

19. Tincture of nutgalls, infusion of nutgalls, gallic acid, occasion no effect.

These properties are sufficient to convince us that the bitter principle is a substance differing considerably from all the other vegetable principles. The little effect of the different reagents is remarkable. Nitrate of silver and acetate of lead are the only two bodies which throw it down. This precipitation cannot be ascribed to the presence of muriatic acid; for if muriatic acid were present, nitrate of lead would also be thrown down. Besides, the flakes produced by nitrate of silver are too light, and indeed have no resemblance whatever to muriate of silver. The precipitate by acetate of lead is very copious. This salt is therefore the best substance for detecting the presence of the bitter principle, when we are certain that no other substance is present which throws down lead.

Exists in other plants.
Vauquelin has lately examined the bitter principle in the fruit of the colocynth (*cucumis colocynthis*), and in the root of the briony (*brionia alba*), two vegetable bodies which have been employed in medicine, and possess strong lethargic powers. The bitter principle in these substances, as far as his experiments went, possesses exactly the properties of the bitter principle of quassia.* It is probable also that hops, gentian, and broom, contain the same bitter principle.

When alcohol is digested for some months upon wheat flour, and then distilled, it leaves a yellowish brown substance behind it, which possesses (as far as I have examined it) all the properties of the bitter principle of quassia.

* Vauquelin, Essais Analytiques des Racines d'Ellebore d'Hiver et de Brione. Ann. de Mus. d'Hist. Nat. No. xliii. 91.

I

II. *Picrotoxin, or bitter Principle of Cocculus Indicus.*

This is the substance to which the cocculus indicus, the fruit of the *menispermum cocculus* owes its deletereous qualities. Its nature and properties were investigated by Boullay in 1811.* He bestowed upon it the name of picrotoxin, from its bitter taste and its poisonous nature.†

Picrotoxin may be obtained by the following process: How obtained. Boil the berries in a sufficient quantity of water. Filter the decoction, and add to it acetate of lead as long as any precipitate falls. Filter the liquid a second time, and evaporate it with caution to the consistence of an extract. Dissolve this extract in alcohol of the specific gravity 0·817. Evaporate this liquid to dryness. These alternate solutions and evaporations in water and alcohol must be repeated till the dry residue is completely soluble both in water and alcohol. It is now picrotoxin united with a yellow colouring matter. Agitate it with a small quantity of water. That liquid dissolves the colouring matter, which is very soluble and occasions the separation of a great number of small crystals which constitute picrotoxin nearly pure. Wash them with a little water and then with alcohol. Picrotoxin thus prepared possesses the following properties.

Its colour is white. Its crystals have the figure of four- Properties. sided prisms. It is intensely bitter.

It is soluble in 25 times its weight of water and no reagent is capable of precipitating it from this solution. Alcohol of the specific gravity 0·810 dissolves one third of its weight of it. Sulphuric ether of the specific gravity 0·7 dissolves two fifths of its weight of it. It is insoluble in oils.

Concentrated sulphuric acid dissolves it; but when that acid is diluted with water it has no action on it. Nitric acid dissolves it and converts it into oxalic acid. It dissolves readily in acetic acid, and is precipitated from the solution by carbonate of potash. Neither muriatic acid, sulphurous acid, nor chlorine dissolve it.

A solution of potash or soda in ten times its weight of water dissolves it. When triturated with potash it emits

* Ann. de Chim. lxxx. 209.
† From πικρος, *bitter,* and τοξικον, *poison.*

Book IV. no smell of ammonia. It burns without melting. When swallowed it intoxicates and acts as a poison.

III. *Scillitin,* or *Bitter Principle of Squills.*

This is the peculiar substance to which the bulb of the *scilla maritima,* or squill, owes its medicinal qualities. Its properties were investigated by Vogel in 1812, who pointed out its peculiar nature, and gave it the name by which it is distinguished.* It may be obtained by the following process. The juice of the bulbs being expressed was boiled for a few minutes, and a quantity of citrate of lime which appeared was separated. It was then evaporated to dryness, and the dry residue digested in alcohol as long as that liquid took up any thing. The alcoholic solution was evaporated to dryness, and the residue (which consisted of scillitin and tannin) was redissolved in water. Acetate of lead was dropped in to throw down the tannin. The liquid was filtered, and the excess of lead which had been added was separated by means of a current of sulphureted hydrogen gas. The liquid being again filtered, was evaporated to dryness to drive off the acetic acid from the acetate. The dry mass was scillitin, mixed with a little sugar, from which it was not in Vogel's power to separate it.

How ob-
tained.

Properties. Scillitin thus obtained is white and transparent, and breaks with a resinous fracture. It was easily reduced to powder. It absorbs water rapidly from the atmosphere, and becomes at first a viscid mass, and at last quite fluid. Its taste is intensely bitter, leaving a slight impression of sweet from the sugar with which it is mixed. It dissolves readily in water, and gives it a mucilagenous consistency like gum. It dissolves likewise very readily in cold alcohol of 0·817, and still more readily in that liquid while hot. When heated, it swells prodigiously, and gives out a distinct odour of caromel. When treated with nitric acid no saclactic acid is formed.

IV. *Caffein,* or *Bitter Principle of Coffee.*

This species is distinguished from the preceding by the property which it has of striking a green colour with iron, and of precipitating that metal from concentrated solutions.

* Ann. de Chim. lxxxiii. 147.

Mr. Chenevix separated a portion of it from coffee by the following process: he digested unburnt coffee in water, and filtered the liquid. It was then treated with muriate of tin. The precipitate was edulcorated, mixed with water, and treated with sulphureted hydrogen gas. The tin was thus precipitated, and the substance with which it had been combined was dissolved by the water. The liquid was then evaporated to dryness. The substance thus obtained pos-sessed the following properties:

1. Semitransparent like horn, and of a yellow colour.

2. When exposed to the air, it does not attract moisture.

3. Soluble in water and in alcohol. The solution in water is semitransparent, and has a pleasant bitter taste. When the alkaline solutions are dropped into it, the colour becomes garnet-red.

4. It is not precipitated from water by the alkaline car-bonates. Sulphuric acid renders the solution brown, but produces no further change. Neither muriatic acid, nor phosphoric acid, nor the vegetable acids, produce any change on this solution.

5. The muriates of gold, platinum, and copper, occasion no change.

6. With solutions of iron it forms a fine green-coloured liquid; and when concentrated, iron throws down a green-coloured precipitate. Indeed it is almost as delicate a test of iron as tan and gallic acid.

7. Muriate of tin throws down a copious yellow precipi-tate. This precipitate, and that by iron, are soluble in all acids, but they lose their colour.

8. Neither lime nor strontian water occasion any precipi-tate in the aqueous solutions of this substance; but barytes water occasions a brown precipitate.

9. Gelatine occasions no precipitate.*

From the experiments of Boillon la Grange, it appears that a substance similar to this species of bitter principle exists in the flowers of the *arnica montana*.† There is reason for believing that the bitter principle which charac-terizes the following plants belongs also to this species; *absinthium vulgare* (worm-wood), *juniperus sabinus* (sabine),

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* Phil. Mag. 1802, May, p. 350. † Ann. de Chim. lv. 35

ruta graveolens (rue), *anthemis nobilis* (chamomile), *achillea millefolium* (milfoil).

V.   *Daphnin,* or *Bitter Principle of Daphne Alpina.*

Preparation.

This species was obtained by Vauquelin from the bark of daphne alpina.   The bark was digested in alcohol, and the liquid was concentrated till the resin separated.   The residual liquid, being diluted with water and filtered, was mixed with acetate of lead.   A copious yellow precipitate falls.   This precipitate being separated by the filter, is diluted with water, and is treated with sulphureted hydrogen gas to get rid of the lead.   Being filtered and sufficiently concentrated, the daphnin separated in small transparent crystals.   It is hard, has a greyish colour, and a very bitter taste.   When heated, it evaporates rapidly in sharp vapours.   It is sparingly soluble in cold water, much more soluble in boiling water, and separates in crystals as the solution cools.   Its solution is not precipitated by acetate of lead.   When heated in a retort, it melts, blackens, and emits an acid.[*]

Properties.

VI.   *Artificial Bitter Principle.*

History.

This species has been formed by the action of nitric acid on various vegetable and animal substances.   It was first obtained by Haussman while examining indigo, but he mistook its nature.   Welther afterwards formed it by digesting silk in nitric acid, ascertained its properties, and gave it the name of *yellow bitter principle;* [†] he is therefore to be considered as the real discoverer.   Bartholdi afterwards procured it by treating the *white* willow with nitric acid.[‡]   Mr. Hatchett obtained it during his experiments on artificial tannin, by treating indigo with nitric acid; [§] and about the same time Fourcroy and Vauquelin procured it by the same means, and examined its properties in detail.[||]   M. Chevreul is of opinion that it is a compound of nitric acid and a peculiar vegetable substance, probably of an oily nature.[**]   It possesses the following properties :

[*] Ann. de Chim. lxxxiv. 174.   [†] Ibid. xxix. 301.
[‡] Ibid. xxxii. 187.   [§] Phil. Trans. 1805.
[||] Phil. Mag. xxiii. 255.   [**] Ann. de Chim. lxxii. 113.

Its colour is a deep yellow, its taste intensely bitter. It
is soluble both in water and alcohol, and has the property
of dyeing silk, woollen cloth, and cotton, of a durable
yellow colour. It crystallizes in elongated plates, and pos-
sesses many of the characters of an acid, combining readily
with alkaline substances, and forming crystallizable salts.
When potash is dropped into a concentrated solution of it,
small yellow prismatic crystals are gradually deposited,
consisting of bitter principle combined with potash. These
crystals were examined by Welther, but it was Fourcroy
and Vauquelin that ascertained their composition. They
have a bitter taste, are not altered by exposure to the air,
are less soluble than pure bitter principle. When thrown
upon hot charcoal they burn like gunpowder, and detonate
very loudly when struck upon an anvil, emitting a purple
light.* Ammonia dropped into the solution of bitter prin-
ciple deepens its colour, and occasions a copious deposition
of fine yellow spicular crystals. These are a combination
of bitter principle and ammonia.† It combines likewise
with the alkaline earths and with metallic oxides, as has
been shown by the experiments of Chevreul.

VII. *Artificial Tannin.*

This itself may be considered as approaching the bitter
principle in many of its properties. Its taste is always in-
tensely bitter, and the colour of the precipitates which it
throws down from the metals is similar to what takes place
when artificial bitter principle is present. It is indeed possi-
ble that the bitter taste may be owing not to the tannin, but
to a portion of artificial bitter principle which may be always
formed along with the tannin; but this has not been ascer-
tained. It is well known that the bitter taste very easily over-
powers and conceals all other tastes.

SECT. X.

OF NICOTIN.

THIS substance exists in the leaves of the *nicotiana lati-
folia,* or *tobacco,* and gives that plant its peculiar properties.

* Welther, Fourcroy, and Vauquelin.
† Hatchett, Phil. Trans. 1805.

It was obtained in 1809 by M. Vauquelin, to whom we are indebted for all the facts respecting it yet known.* It may be obtained from the juice of tobacco leaves by the follow-process.

Prepára-tion.   Evaporate the juice to one-fourth of its volume, and allow it to cool.   A quantity of malate of lime will be deposited under the form of a gritty powder.   Separate this matter, and continue to concentrate the liquid as long as any saline matter can be obtained from it.   When it is so much in-spissated that nothing farther can fall, digest it in alcohol, which will take up the uncombined malic and acetic acids that it contains, the nicotin and a portion of sal ammoniac. Distil the alcohol off in a retort, and concentrate the resi-dual matter nearly to dryness, taking care not to injure it by the application of too much heat.   Dissolve it a second time in more concentrated alcohol, in order to separate a portion of animal matter which had been dissolved in the first alcohol solution in consequence of the water present. Distil off this second portion of alcohol.   Dissolve the residue in water, saturate the acetic and malic acids with potash; and distil the water off to dryness.   This water, though colourless, contains in solution a quantity of nicotin. By dissolving the residual matter in water, and distilling a second time, an additional quantity of nicotin may be ob-tained.   And by repeating this process, a sufficient number of times, the whole of the nicotin may be obtained in solu-tion in water.   By a very cautious evaporation, the water may be driven off, and the nicotin obtained in a state of purity.

Properties.   This substance is colourless.   It has an acrid taste, and the peculiar smell which distinguishes tobacco.   It occa-sions violent sneezing.

It is soluble in water and in alcohol.   Both solutions are colourless, and distinguished by the peculiar taste and smell of nicotin.

It is precipitated from its solutions by tincture of nutgalls. It is volatile, and possesses poisonous qualities.   And ac-cording to Vauquelin approaches the volatile oils in its pro-perties.

* Ann. de Chim. lxxi. 139.

SECT. XI.

OF EXTRACTIVE.

The word *extract* was at first applied to all those sub- History. stances which were extracted from plants by means of water, and which remained behind in the state of a dry mass when the water was evaporated; consequently it included gum, jelly, and several other bodies. But of late it has been confined by many to a substance which is supposed to exist in many plants, and which may be obtained tolerably pure from the bark of the cinchona officinalis according to the experiments of Schrader. But as the word *extract* occurs even in modern authors in its original sense, I shall rather denote this substance by the phrase *extractive principle*, to prevent ambiguity.

The difficulty of obtaining the extractive principle in a Uncertain- separate state, and the facility with which it alters its nature, ty. have hitherto prevented chemists from examining it with that attention to which it is entitled. It was first particularly attended to by Rouelle; but it is to Fourcroy and Vauquelin that we are chiefly indebted for ascertaining its characters. The dissertation of Vauquelin in the Journal de Pharmacie, is by far the best account of extractive matter which has hitherto appeared. Many valuable facts and curious observations were published by Schrader in his dissertations on *extractive*.* But unfortunately the term has not been always taken by chemists in the same acceptation. Parmentier has for example published a dissertation on the *extracts* of vegetables taken in the loose and general sense of the word, which contains much information.† There cannot I think be any doubt that under the term *extractive*, chemists have hitherto confounded together a variety of different vegetable principles. Some of these, as *ulmin*, *polychroit*, *&c.* I have distinguished by peculiar names, and perhaps it would be wisest to lay aside the term *extractive* altogether. But in the present state of obscurity in which this department of vegetable chemistry continues, I am unwilling to withhold the facts collected in this section, which

* Gehlen's Jour. Second Series, viii. 548, and Schweigger's Jour. ix. 139.
† Ann. de Chim. xliii. 19.

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though imperfect and probably partly inaccurate, will yet be useful to those who apply themselves to the investigation of this subject.

The extractive principle possesses the following properties :

Properties.   1. Soluble in water, and the solution is always coloured. When the water is slowly evaporated, the extractive matter is obtained in a solid state and transparent ; but when the evaporation is rapid the matter is opaque.

2. The taste of extractive is always strong ; but it is very different according to the plant from which it is obtained.

3. Insoluble in absolute alchohol and in ether ; but soluble in alcohol when it contains water.

4. By repeated solutions and evaporations, the extractive matter acquires a deeper colour, and becomes insoluble in water. This change is considered as the consequence of the absorption of the oxygen of the atmosphere, for which the extractive principle has a strong affinity. But if the solution be left to itself, exposed to the atmosphere, the extract is totally destroyed in consequence of a kind of putrefaction which speedily commences.

5. When chlorine is poured into a solution containing extractive, a very copious dark-yellow precipitate is thrown down, and the liquid retains but a light lemon-colour. These flakes are considered as oxygenized *extractive*. It is now insoluble in water ; but hot alcohol dissolves it.

6. The extractive principle unites with alumina, and forms with it an insoluble compound. Accordingly, if sulphate or muriate of alumina be mixed with a solution of extractive, a flaky insoluble precipitate appears, at least when the liquid is boiled ; but if an excess of acid be present, the precipitate does not always appear.

7. It is precipitated from water by concentrated sulphuric acid, muriatic acid, and probably by several other acids. When the experiment is made with sulphuric acid, the fumes of vinegar generally become sensible.

8. Alkalies readily unite with extractive, and form compounds which are insoluble in water.

9. The greater number of metallic oxides form insoluble compounds with extractive. Hence many of them, when thrown into its solution, are capable of separating it from water. Hence also the metallic salts mostly precipitate ex-

tractive.   Muriate of tin possesses this property in an emi-
nent degree.   It throws down a brown powder perfectly
insoluble, composed of the oxide of tin and vegetable matter.

10. If wool, cotton, or thread, be impregnated with alum,
and then plunged into a solution of extractive, they are
dyed of a fawn-brown colour, and the liquid loses much of
its extractive matter. This colour is permanent. The same
effect is produced if muriate of tin be employed instead of
alum. This effect is still more complete if the cloth be
soaked in chlorine, and then dipped into the infusion of
extractive. Hence we see that the extractive matter re-
quires no other mordant than oxygen to fix it on cloth.

11. When distilled, extractive yields an acid liquid im-
pregnated with ammonia.*

It cannot be doubted that there are many different species
of extractive matter; though the difficulty of obtaining each
separately has prevented chemists from ascertaining its
nature with precision. Extracts are usually obtained by Properties
treating the vegetable substance from which they are to be of extracts.
procured with water, and then evaporating the watery solu-
tion slowly to dryness. All extracts obtained by this method
have an acid taste, and redden the infusion of litmus.
They all yield a precipitate while liquid if they are mixed
with ammonia. This precipitate is a compound of lime and
insoluble extractive. Lime always causes them to exhale
the odour of ammonia. It has been ascertained that the
extractive principle is more abundant in plants that have
grown to maturity than in young plants.

As the *extracts* of vegetables prepared by apothecaries
for medical purposes, besides the extractive principle, always
contain other bodies, frequently to the number of eight or
more, and as the greater number of them are still but im-
perfectly examined, I shall satisfy myself at present with
pointing out some of those vegetable substances which have
been ascertained to contain extractive principle, and stating
the constituents of such as have been analysed.

1. Extractive principle is not an uncommon ingredient Extractive
in the sap of trees. Indeed Deyeux and Vauquelin found of sap,
it in almost all those which they examined. It is usually
thrown down when the sap is mixed with chlorine.

* See Vauquelin.

Book IV. and it precipitates in brown flakes while the sap is evaporating on a sand bath.

Of bark,   2. It forms a constituent of the bark of all trees hitherto examined. This was evidently the case with all the barks which Davy subjected to experiment; namely, those of oak, Leicester willow, Spanish chesnut, elm, common willow, and undoubtedly all barks which have an astringent taste; for tan and extractive seem scarcely ever to be found separate.

Of catechu,   3. The infusion of catechu contains an extractive principle, united chiefly to tan. It may be obtained in a state of purity by washing the catechu in powder repeatedly with water till the fluids obtained cease to precipitate gelatine. What remains is extractive. It is of a pale reddish-brown colour and a slightly astringent taste, leaving in the mouth a sensation of sweetness. It has no smell. Its solution in water is at first yellow-brown; but it acquires a tint of red when left exposed to the air. The solution in alcohol is of a dirty brown. It does not affect vegetable blues. Alkalies brighten its colour; but neither these bodies nor the alkaline earths precipitate it from water. Nitrate of alumina and muriate of tin render the solution slightly turbid. Nitrate of lead throws down a dense light-brown precipitate. It renders persulphate of iron green, and throws down a green precipitate, becoming black by exposure to the air. Linen, when boiled in the solution, extracts almost the whole of the extractive, and acquires a light red-brown colour. When this extractive is exposed to heat, it softens, and its colour becomes darker, but it does not melt. When distilled, it yields carbonic acid and carbureted hydrogen gas, weak acetic acid, and a little unaltered extractive. A porous charcoal remains.*

Of senna,   4. The infusion of senna contains a matter of a very peculiar nature, but which may be considered as a species of *extractive.* The senna of commerce consists of the dried leaves of the *cassia senna,* a shrub-like annual cultivated in Egypt. Water, at the ordinary temperature of the atmosphere dissolves nearly one-half of the substance of these leaves. The infusion obtained has a brown-colour, a bitter taste, and a peculiar aromatic odour. It contains a con-

* Davy on Astringent Vegetables, p. 25.

siderable proportion of carbonate of lime, sulphate of potash, and carbonate of magnesia, besides a little silica ; but the most curious of its constituents is the extractive. When common air is made to pass for some hours through the infusion, a yellow-coloured precipitate appears: the same substance is thrown down immediately by muriatic acid and chlorine. It appears also when a current of chlorine gas is made to traverse the infusion. This substance is the extractive altered by its combination with oxygen. It has a slight bitter taste. It is no longer soluble in water. Alcohol dissolves it, but lets it fall when diluted. The alkalies dissolve it, and form a deep-brown solution. On burning coals it emits a thick smoke, exhales an aromatic odour, and leaves a spongy charcoal. These properties indicate a very decided approach to the resinous state.*

5. The infusion of Peruvian bark likewise yields an extractive matter of a peculiar nature, which assumes a fine red-colour when united to oxygen; and, like the extractive of senna, acquires nearly the properties of a resin. It was obtained by Fourcroy from the quinquina of St. Domingo. Water, boiled on it till it refused to dissolve any thing more, was slowly evaporated, and the extract obtained was dissolved in alcohol. The alcohol, by evaporation, deposited the peculiar extractive. Its colour was brown, its taste bitter, insoluble in cold, but very soluble in hot water. It was soluble in alcohol. When dry it was black, brittle, and broke with a polished fracture. Lime-water precipitated it in the state of a red powder: chlorine threw it down in the state of a fine red powder, neither soluble in water nor alcohol, but capable of uniting with alkalies. A stronger dose of chlorine rendered it yellow.†

6. Steinacher has shown that distilled vinegar contains a quantity of extractive.‡

The resemblance between extractive bodies and the colouring matter of plants is sufficiently striking. It is more than probable, that when this last set of bodies have been examined with more precision by chemists, they will be found to belong to the same class.

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* Bouillon La Grange, Ann. de Chim. xxiv. 4.
† Fourcroy, Ann. de Chim. viii. 120.   ‡ Jour. de Phys. lxv. 327.

SECT. XII.

OF EMETIN.

THIS remarkable substance was extracted from ipecacu-
anha by MM. Magendie and Pelletier, and called by them
emetin, because it constitutes the substance in that root,
which occasions vomiting.

How ob-
tained.

They obtained it by the following method : Ipecacuanha
was digested first in sulphuric ether, then in alcohol. The
alcoholic solution was evaporated to dryness, re-dissolved
in water and acetate of lead dropped into the solution. A
copious precipitate fell, which being edulcorated and dif-
fused through water was exposed to a current of sulphureted
hydrogen gas. The lead was precipitated in the state of
sulphuret, and the emetin dissolved in water. The liquid
being filtered and evaporated to dryness, the residue con-
sisted of emetin in a state of purity. Thus obtained it pos-
sessed the following properties :

History.

It is in the form of transparent scales which have a brown-
ish red colour. It has no smell. Its taste is bitter and a little
acrid; but not in the least nauseous. It is not altered by
a degree of heat inferior to that of boiling water. When
exposed to a stronger heat it does not melt; but swells,
blackens, and is decomposed, furnishing water, carbonic
acid, a little oil and acetic acid. A very spongy and light
coal remains. No ammonia can be discovered in these
products, indicating that azote does not enter into the com-
position of emetin.

Emetin when exposed to the air undergoes no change,
unless the air be very damp, in which case it becomes
moist. It dissolves very readily in water; but cannot be
made to crystallize. It is soluble in alcohol; but insoluble
in sulphuric ether.

Diluted sulphuric acid produces no effect on it; but con-
centrated sulphuric acid chars and destroys it. Nitric acid,
when applied either cold or hot, dissolves it and forms a
fine red-coloured solution, which gradually passes into
yellow while nitrous gas exhales, and crystals of oxalic
acid are formed, but no yellow bitter principle. Muriatic
and phosphoric acid dissolve it without alteration, and let
it fall again when they are saturated with an alkali, acetic

acid is one of the best solvents of it. Gallic acid on the contrary throws it down from its solution in the state of a dirty white precipitate. It is precipitated equally by infusion of nutgalls, and a slight precipitate is produced by the infusion of cinchona.

The alkalies dissolve the compound of emetin and gallic acid. When iodine is poured into the tincture of emetin a red precipitate falls which is a compound of emetin and iodine.

Acetate of lead throws down emetin from its solution in abundance. Protonitrate of mercury gradually throws down a slight precipitate. Corrosive sublimate occasions rather a greater one. Tartar emetic has no action on it whatever.

Neither vegetable nor animal substances as far as they have been tried have any action on emetin.

Half a grain of emetin when swallowed occasions violent vomiting followed by sleep, and the animal awakes in a state of health. Twelve or even six grains of emetin produce vomiting and sleep, followed by death. A violent inflammation of the lungs and intestinal canal appears to be the proximate cause of the death which in this case ensues.*

SECT. XIII.

OF MORPHIA.

In the year 1803, M. Derosne published an analysis of *opium* in which he announced the existence of a peculiar crystallizable substance to which that drug owes its narcotic properties.† In 1805 M. Sertürner, apothecary at Eimbeck, in Hanover, published an analysis of the same substance;‡ but the results were so different as to destroy the confidence of chemists in both. But in the year 1817, Sertürner, who had not lost sight of the subject but had

History.

* Ann. de Chim. et Phys. iv. 172. † Ann. de Chim. xlv. 257.
‡ Trommsdorf's Journal, xiv. 47.

Book IV. been investigating it with care ever since his first paper, published a new set of experiments,* in which he shows the method of separating a peculiar substance from opium, to which he has given the name of *morphia.* It is to this substance that opium owes its peculiar properties; and the narcotic principle of Derosne, according to Sertürner, is a compound of morphia and a peculiar acid which opium contains. But M. Robiquet has shown that this opinion is not well founded.† The experiments of Sertürner have been repeated and verified both in France and Great Britain, so that the existence and properties of morphia may be considered as well ascertained.

According to Sertürner, morphia occurs in opium combined with a peculiar acid, which he calls *meconic* acid.‡ His formula for procuring it is as follows:

Prepara-
tion.

Rub eight ounces of pulverized opium with two or three ounces of concentrated acetic acid and a little water to the consistence of a soft pap. Dilute this pap with two or three pounds of water, and strain it through a cloth. The residue may be washed with a little water and strained a second time. The liquid thus obtained is but little coloured and contains acetate and meconate of morphia, a little morphia combined with extractive and neutral free extractive. Pour caustic ammonia into it and the morphia is precipitated in abundance. Evaporate the liquid to one fourth or one fifth of its bulk, when an additional quantity of morphia will precipitate. The morphia thus obtained is not quite free from extractive. M. Sertürner reduced it to a fine powder and digested it with a very small quantity of alcohol. The alcohol acquired a dark colour, and the morphia remained nearly colourless and in a state of considerable purity. Thus obtained it possesses the following properties:

Properties.

It is colourless. It dissolves only in small quantity in boiling water; but it is very soluble in alcohol and ether. This solution has a very bitter taste and the morphia may

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* Gilbert's Annalen, lv. 57.   † Ann. de Chim. et Phys. v. 275.

‡ He has not given a sufficient description of this acid to enable us to appreciate its nature and properties. Its name is obviously derived from μηκω, the Greek word for *poppy.*

be obtained from it in crystals. The figure of these crys- tals is a short four-sided pyramid whose base is either a square or a rectangle. Sometimes two of these pyramids are applied base to base, constituting an octahedron. The solution of morphia gives a brown colour to turmeric paper, and restores the blue colour to litmus paper reddened by vinegar, and these effects are not owing to the presence of ammonia. Hence it is obvious that morphia acts the part of an alkali.

It combines readily with the different acids, neutralizes them, and forms a new kind of salts which claim particular attention.

Subcarbonate of Morphia is formed when morphia is placed in contact with carbonic acid gas, or when it is precipitated from its solutions by an alkaline subcarbonate. It is more soluble in water than morphia, and seems capable of crystallizing, but M. Sertürner did not determine the figure of its crystals. The *carbonate* of morphia crystallizes in short prisms.

Acetate of morphia crystallizes in soft prisms and is very soluble in water.

Sulphate of morphia crystallizes in the form of the twigs and branches of trees, and is likewise very soluble.

Muriate of morphia assumes a plumose appearance. It is much less soluble in water than the other salts of morphia, and when the solution is too far evaporated it speedily concretes on cooling into a shining silver white plumose saline mass.

Nitrate of morphia crystallizes in prisms which are grouped together and appear to issue from a central point.

Meconiate of morphia was not examined. But *submeconiate* of morphia crystallizes in oblique prisms. This is the substance which constitutes the narcotic principle, which Derosne extracted from opium. It is but sparingly soluble in water.

Tartrate of morphia crystallizes in prisms and has a close resemblance to the preceding salts.

From the experiments of Sertürner, it would appear that morphia possesses the characters of a new combustible alkali, and that it ought to be placed in the tables of affinity below ammonia, as that substance possesses the property of separating it from all its combinations.

Morphia melts in a gentle heat, and in that state has very much the appearance of melted sulphur. On cooling it again crystallizes. It burns easily, and when heated in close vessels leaves a solid, resinous, black mass having a peculiar smell. It combines with sulphur by the assistance of heat; but the combination is speedily destroyed and sulphureted hydrogen evolved.

No remarkable change was produced upon morphia by the action of galvanism. Sertürner made no experiments to determine its composition; but he considers it as a compound of oxygen, carbon, and hydrogen.

It acts with great energy on the animal economy. Half a grain of it dissolved in spirits being swallowed by a young man of 17 years of age, produced a flushing in the face, and an augmentation of the muscular energy. Another half grain being swallowed half an hour after occasioned a dull pain in the head, giddiness, stupor, and nausea. A third half grain being swallowed aggravated the symptoms so much that Sertürner became alarmed and made his patient swallow a quantity of vinegar. But the symptoms were rather aggravated and continued all night; but were removed next morning by the use of magnesia.

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SECT. XIV.

OF ASPARAGIN.

I give this name to a substance discovered in the juice of asparagus by Vauquelin and Robiquet.* It was procured by the following process.

Preparation.

The juice of asparagus is expressed in the usual way, filtered, evaporated to the consistence of a syrup, and then set aside. Various crystals gradually make their appearance, and among others crystals of asparagin, easily separated from the rest on account of their colour and figure. This substance possesses the following properties:

Properties.

1. The crystals are white and transparent, and have the figure of rhomboidal prisms. The greater angle of the

* Ann. de Chim. lv. 167. Nicholson's Jour. xv. 242.

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rhomboidal base, as ascertained by Haüy, is 130°. The edges of this base, and the two angles at the extremity of its greater diagonal, are truncated.

2. It is hard and brittle. Its taste is cool and slightly nauseous, so as to occasion a secretion of saliva.

3. It dissolves readily in hot water; but in cold water, only sparingly. Alcohol does not dissolve it.

4. The aqueous solution does not affect vegetable blues. Neither infusion of nutgalls, acetate of lead, oxalate of ammonia, muriate of barytes, nor the hydrosulphuret of potash, occasion any change in it.

5. When triturated with potash no ammonia is disengaged. The potash appears to render it more soluble in water.

6. When heated it swells, and emits penetrating vapours, affecting the eyes and nose like the smoke of wood. It leaves a large portion of insipid charcoal, which, when incinerated, leaves scarcely a trace of residue.

7. Nitric acid dissolves it with the evolution of nitrous gas. The solution has a yellow colour and a bitter taste, like that of animal substances in the same acid. Lime disengages from it a considerable quantity of ammonia.

Such are the properties of this substance ascertained by Vauquelin and Robiquet. They distinguish it sufficiently from all other vegetable substances known.

SECT. XV.

OF CERASIN.

I ADOPT this name from Dr. John, to denote a particular vegetable principle which has been long known; but which hitherto has been confounded with gum. It may be distinguished by the following characters.

1. It is a solid substance possessing the appearance of gum and distinguished by a similar taste. It is usually harder than gum and not so easily reduced to powder; though this is not always the case, especially when it is mixed with gum which it frequently is.

2. When put into water it imbibes that liquid, swells up

Book IV. very considerably, and becomes semitransparent and gelatinous, but is not in the least soluble. It dissolves in boiling water, but again precipitates when the liquid cools, and remains in the state of a jelly. This gelatinous mass may be used, like gum, to paste together pieces of paper.

3. Cerasin is insoluble in alcohol and ether.

4. Cold water acidulated with nitric, sulphuric, or muriatic acid dissolves a small portion of it, and when heat is applied, the whole of the cerasin dissolves in these liquids. When alkali is dropped into the nitric acid solution, a portion only of the cerasin is precipitated. If the liquid be evaporated, the remainder is obtained converted into a peculiar bitter tasted substance.

Tragacanth.

Gum tragacanth may be considered as pure cerasin. It has been longest known and is in the most general use. Perhaps on that account it might have been as well to have given to cerasin the name of tragacanth.

Tragacanth is the produce of the *astragalus tragacantha*, a thorny shrub which grows in Candia and other islands of the Levant. The gum is said to exude about the end of June from the stem and larger branches, and soon dries in the sun. It is in the state of whitish vermiform pieces, not nearly so transparent as gum arabic. From the two preceding species it differs extremely in many of its properties. When put into water it slowly imbibes a large quantity of the liquid, swells into a large volume, and forms a soft, but not fluid, mucilage. If the quantity of water be more than the gum can imbibe, the mucilage forms an irregular mass, which does not unite with the rest of the liquid. By agitation, indeed, an apparent solution is effected, and the whole assumes a wheyish appearance; but on standing, the mucilage again subsides, as at first, and the water becomes transparent.* When a solution of gum arabic is poured into this solution, the mucilaginous gum tragacanth separates much sooner than usual, and forms no union with the gum arabic.† When treated with nitric acid, it yields abundance of saclactic acid, malic acid, and oxalic acid; but not the slightest trace of artificial tannin.‡ Sulphuric acid developes some traces of artificial tannin. The quan-

* Lewis, Neuman's Chem. p. 282.   † Lewis, ibid.
‡ Hatchett, Phil. Trans. 1805.

tity of charcoal which it yielded, when digested in sulphuric acid, was 0·22, or considerably less than gum arabic yielded in the same circumstances. * When Mr. Cruickshanks distilled 480 grains of it in a glass retort, he obtained the following products :

Pyromucous acid .... 245 gr.
Charcoal 93
Lime with some phosphate............. 12
Carbonic acid and carbureted hydrogen gas 130
                                      ———
                                      480

When the pyromucous acid was saturated with lime, a considerably greater proportion of ammonia was disengaged than from the pyromucous acid of gum arabic.   The gases were 78 ounce measures of carbonic acid, and 91 of carbureted hydrogen.†   This gum yielded to Vauquelin 0·03 of ashes.   They dissolved in muriatic acid with effervescence, while the odour of sulphureted hydrogen was perceptible.   They consisted chiefly of carbonate of lime, with a little iron and phosphate of lime, and contained likewise some potash.‡

These experiments show us, that gum tragacanth contains more azote and lime, and perhaps more oxygen and less carbon, than gum arabic.

Dr. Bostock by digesting tragacanth in water till it became gelatinous, and then triturating it with pure water in a mortar, formed a homogeneous mucilage, consisting of 100 parts of water and 1 part of tragacanth.   Subacetate of lead formed a copious precipitate with this mucilage. Acetate of lead produced a light precipitate, which increased by standing, though on mucilage of gum arabic it produced no effect.   The permuriate of tin likewise throws down a firm coagulum, though it does not alter mucilage of gum arabic.   Persulphate of iron produced no effect.   Nitrate of mercury threw down a slight precipitate of a reddish tinge.   Silicated potash produced no effect. §

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* Hatchett, Third Series of Experiments on Artificial Tannin, Phil. Trans. 1806.
† Cruickshanks, Rollo on Diabetes, p. 452.   ‡ Ann. de Chim. liv. 512.
§ Nicholson's Jour. lviii. 30.

Book IV.   I suppose the gum bassora of Vauquelin to be a variety of tragacanth.

Cerasin constitutes a portion of the gummy matter that exudes from the prunus cerasus, prunus avium, prunus domestica, xanthorea hastilis. It was on that account, I presume, that Dr. John distinguished it by the name of *cerasin*. It may be worth while to state here the result of my experiments on cherry tree gum.

Cherry-tree gum.   The prunus avium, the common cherry and plum trees, and the almond and apricot likewise, yield a gum which exudes in great abundance from natural or artificial openings in the stem.   It is of a reddish-brown colour, in large masses, at first much softer than gum arabic, but by keeping it becomes much harder than any other species of gum which I have seen except tragacanth.   When put into water it gradually swells, and is converted into a semitransparent reddish-brown jelly.   A portion dissolves in the water, but a considerable portion remains in the gelatinous state, and does not dissolve even though boiled for some hours in a very large portion of water.   In this respect cherry-tree gum differs from every other species which I have tried. The portion dissolved in water possesses the common appearance of mucilage of gum arabic, excepting that its colour is darker, and that it is much weaker, and of course less adhesive and thready.   The gum is not precipitated by alcohol, nor is any effect produced by silicated potash. Acetate of lead produces no immediate effect ; but on standing the whole becomes opaque, and a precipitate at last subsides.   Fuming liquid of libavius causes the liquid to gelatinize immediately. The acetate of lead, and the nitrate of mercury, produce no effect.   No precipitate was produced by any of the other metallic salts tried.   Dr. Bostock found, that when treated with nitric acid it yielded a portion of saclactic acid.

Congo gum.   The gentlemen constituting the late unfortunate expedition to the Congo, while travelling along the banks of that river, picked up a large piece of gum, which bore a very close resemblance to the cherry-tree gum of this country.   Its colour was equally dark and its hardness as great.   On examination, I found that it consisted entirely of cerasin darkened by a colouring matter, which was partly soluble in water and possessed the characters of extractive. But

the cerasin still continued dark coloured even after all the
extractive which water was capable of taking up was re-
moved.

Some time ago, I received from Dr. Clarke of Dominica, Dominica
specimens of gum very different in appearance from any gum.
that I had previously seen. It was in large masses like sta-
lactites, four or five inches long, and above an inch thick,
and composed of a number of irregularly cylindrical masses,
some of them hollow, cemented together, or running into
each other. I have learned nothing respecting the plant
from which this gum exudes. It is rather brittle, light
yellowish-brown, and translucent. I found it a compound
of about 3 parts cerasin and 1 part gum.

SECT. XVI.

OF INULIN.

I GIVE this name to a new vegetable principle, dis-
covered by Rose in the roots of the *inula helenium (ele-
campane.)*

When the roots of this vegetable are boiled in water,
the decoction, after standing some hours, deposits the *inulin*
in the form of a white powder like starch. Its properties
are as follows:

1. It is insoluble in cold water. By trituration the inulin Properties.
is uniformly diffused, and gives the liquid a milky appear-
ance; but it soon falls down in the state of a white powder,
leaving the liquid quite transparent.

2. It dissolves readily in hot water. One part of inulin Action of
in four parts of boiling water formed a solution which water,
passed readily through the filter, though its consistence
was somewhat mucilaginous, and it was not quite transpa-
rent. After some hours the greater part of the inulin pre-
cipitates from the water in the form of a white powder. An
equally concentrated solution of gum arabic is much thicker,
and more adhesive.

3. When the aqueous solution of inulin is mixed with Alcohol,
an equal bulk of alcohol, no change takes place for some
time, but the inulin soon separates, and falls to the bottom

Book IV. in the state of a bulky white powder. A solution of gum
arabic, when treated in this manner, remains milk white
for days without any precipitate falling.

Heat,   4. When thrown upon burning coals it melts as readily
as sugar, and emits a thick white smoke, not unpleasantly
pungent, and similar in odour to that of burning sugar.
The residue, which is but small, sinks into the coal. Starch
emits a similar smoke, but leaves a more bulky residue.
When heated in an iron spoon inulin melts, and emits a
thick smoke, with the same odour; and as soon as the
spoon becomes red-hot, burns with a vivid flame, and leaves
a very small coaly residue.

        5. When distilled it yields a brown acid liquid, having
the smell of the pyromucous acid, but not a trace of oil.

Nitric acid.   6. When treated with nitric acid it yields malic and
oxalic acids, or acetic acid if too much nitric acid be em-
ployed; but no saclactic acid is formed, as happens with
the gums, neither is any of the waxy matter separated
which is formed when starch is digested with the same acid.

        Such are the properties of inulin, as far as they have
been investigated by Rose.* When the root of elecampane
is distilled, it yields a portion of a white solid matter,
which seems to be intermediate between camphor and vola-
tile oil in its nature.† No other vegetable substance has
been observed to yield a similar product. How far it is
connected with inulin remains to be determined.

        Inulin has been found, by Dr. John, in the roots of
several other plants. Besides the inula helenium in which
it had been already detected by Rose, he found it in the
roots of the anthemis pyrethrum, in nutgalls, in angelica
archangelica. He suspects its presence, likewise, in the
hyacinthus nonscriptus, and in several other plants.‡

<center>———————</center>

<center>SECT. XVII.</center>

<center>OF STARCH.</center>

Analysis of   IF a quantity of wheat flour be formed into a paste, and
wheat flour. then held under a very small stream of water, kneading

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* Gehlen's Jour. iii. 217.   † Neuman's Chem. p. 420.
‡ John's Tabellen der Pflanzen Analysen, p. 17.

continually till the water runs off from it colourless, the flour by this process is divided into two distinct constituents. A tough substance of a dirty white colour, called *gluten*, remains in the hand; the water is at first milky, but soon deposits a white powder, which is known by the name of *starch*. A sweet-tasted mucilaginous substance remains dissolved in the water.

The starch obtained by this process is not altogether free Method of from gluten; hence its colour is not very white, and it has making starch. not that fine crystallized appearance which distinguishes the starch of commerce. Manufacturers employ a more economical and more efficacious process. Good wheat is allowed to steep in cold water till it becomes soft, and yields a milky juice when squeezed. It is then taken out of the water; put into coarse linen sacks, which are subjected to pressure in a vat filled with water; a milky juice containing abundance of starch exudes, and mixes with the water of the vat. This process is repeated as long as the wheat yields any milky juice. The sack and its contents are then removed. The starch soon falls to the bottom of the vat; and the water which covers it gradually ferments, in consequence of the substances which it holds in solution. Alcohol and vinegar are formed in it, partly, no doubt, at the expence of the starch. The vinegar, thus evolved, dissolves all the impurities, and leaves nothing behind but starch. It is then poured off, and the starch edulcorated with water. It is afterwards dried by a moderate heat. During the drying it usually splits into small columnar masses, which have a considerable degree of regularity. The water which has stood over the starch was analysed by Vauquelin. It contains a considerable portion of alcohol and of acetic acid. The acid holds in solution gluten somewhat altered, phosphate of lime, and ammonia.*

Starch was well known to the ancients. Pliny informs us, that the method of obtaining it was first invented by the inhabitants of the island of Chio.†

1. Starch has a fine white colour, and is usually con- Properties.

* Ann. de Chim. xxxviii. 248. See La Fabrique de l'Amidon, by Du Hamel de Monceau. See also Gmelin's Handbuch der Technischen Chemie, ii. 737. The reader will find a description of the process followed by our manufacturers in making starch in Phil. Mag. xxix. 166.

† Lib. xviii. cap. 7.

creted in longish masses; it has scarcely any smell, and very little taste. When kept dry, it continues for a long time uninjured though exposed to the air.

Action of water,
2. Starch does not dissolve in cold water, but very soon falls to powder, and forms with it a kind of emulsion. It combines with boiling water, and forms with it a kind of jelly, which may be diffused through boiling water; but when the mixture is allowed to stand a sufficient time, the starch slowly precipitates to the bottom. This subsidence takes place even when 90 parts of water are employed to dissolve one of starch; but in that case, at least a month elapses before the starch begins to precipitate. This solution (if it be entitled to the name) is glutinous in proportion to the quantity of starch. If the quantity be considerable, linen dipped into it, and suddenly dried, acquires (as is well known) a great degree of stiffness. When the solution is evaporated to dryness, a brittle opaque substance is obtained, differing in appearance from common starch, but exhibiting nearly the same properties with reagents. Hence the apparent difference is probably owing to a portion of water remaining united to the boiled starch. When the solution of starch is left exposed to damp air, it soon loses its consistency, acquires an acid taste, and its surface is covered with mould.

Alcohol,
3. Starch is so far from dissolving in alcohol, even when assisted by heat, that it does not even fall to powder. Neither does starch dissolve in ether.

4. The action of oxygen gas and of the simple combustibles and azote upon starch has not been examined, but it is probable that it is not remarkable.

Metallic solutions.
5. The metals seem to have but little action on starch; neither does it combine with the metallic oxides; at least none of the metallic salts which I have tried, have the property of forming a precipitate when dropped into a solution of starch in water. The following were the metallic salts which I tried. The decoction used was made by boiling together one part of starch and 90 parts of water.

Nitro-muriate of gold, of platinum.
Nitrate of silver, of mercury, of lead.
Muriate of tin; acetate of lead.
Sulphate, muriate, and nitrate of copper.

Sulphate, muriate, and nitrate of iron.

Sulphate, muriate, and nitrate of zinc.

Ammoniated nickel and cobalt.

Dr. Bostock found that sub-acetate of lead throws down a copious precipitate from the solution of starch in water. He obtained likewise a precipitate when permuriate of tin was used.* Hence it is obvious that his starch infusion must have contained a much greater proportion of starch than mine, which formed no precipitate with muriate of tin.

6. When lime-water is mixed with the same decoction of starch, no change is produced, neither is any perceptible alteration occasioned by strontian water; but barytes water throws down a copious white flaky precipitate. This precipitate is redissolved by muriatic acid; but appears again on standing, unless a considerable excess of acid be employed. Yet muriate of barytes occasions no change in the decoction of starch. Silicated potash occasions no precipitate in this decoction. *Earths.*

7. When starch is triturated with the hot infusion of nutgalls, a complete solution is effected. The solution is transparent, and rather lighter coloured than the infusion of nutgalls. When this solution cools it becomes opaque, and a copious curdy precipitate falls. A heat of 120° redissolves this precipitate, and renders the solution transparent, but the precipitate is again deposited when the solution cools. This property I consider as characteristic of starch. The infusion of nutgalls throws it down from every solution, but the precipitate is redissolved by heating the liquid to 120°. *Infusion of nutgalls.*

This precipitate is a compound of tannin and starch, and the constituents are capable of uniting in various proportions; but it is least soluble when deposited from the solution of 24 grains of starch in a half-ounce measure of the infusion of nutgalls, made by boiling together two parts of water and one of nutgalls. In that case it is composed of about three parts starch and two tannin. The whole of it does not precipitate; about $\frac{1}{4}$th remains in solution, seemingly containing an excess of tannin. This compound of starch and tannin is of a light-brownish colour, semi- *Tannate of starch.*

* Nicholson's Jour. xviii. 33.

transparent, and brittle, and has a good deal of resemblance to common sarcocoll. Its taste is astringent. It feels glutinous between the teeth like gum. In cold water it dissolves very imperfectly, but very copiously and readily in hot water. Alcohol, when digested on it, acquires a brown colour, but is incapable of separating the whole of the tannin from the starch. When this compound is heated it froths, swells, and melts, and then burns with a clear flame, leaving behind it a small portion of white ashes.

Action of potash.

8. When potash is triturated with starch, and a little water added, the whole assumes, on standing, the appearance of a semitransparent jelly. On adding water, an opal-coloured solution is obtained, from which the starch is readily thrown down by an acid. When muriatic acid is employed a peculiar aromatic odour is exhaled. When the infusion of galls is dropped into the solution of starch in potash, a yellowish-white precipitate appears, but is immediately redissolved, and the liquid remains opaque, and of a dark brown colour. On adding muriatic acid a copious precipitate appears, similar to the compound of starch and tannin; but nitric acid occasions no precipitate, neither does ammonia.

The decoction of starch is neither altered by potash, carbonate of potash, nor ammonia.

Of acids.

9. When starch is thrown into any of the mineral acids, at first no apparent change is visible: But if an attempt is made to reduce the larger pieces while in acids to powder, they resist it, and feel exceedingly tough and adhesive. Sulphuric acid dissolves it slowly, and at the same time a smell of sulphurous acid is emitted; and such a quantity of charcoal is evolved, that the vessel containing the mixture may be inverted without spilling any of it. Indeed if the quantity of starch be sufficient, the mixture becomes perfectly solid. Diluted sulphuric acid does not act sensibly on starch while cold; but when heated it dissolves it completely, apparently without decomposition, as the starch may be again thrown down by means of alcohol. Sulphurous acid has no effect upon starch.

Diluted nitric acid reduces starch to powder, and then slowly dissolves it without the assistance of heat. The acid assumes a green colour, and a small portion of white matter

swims on the surface, on which the acid does not act. Alcohol throws down the starch from this solution.* Concentrated nitric acid dissolves starch pretty rapidly, assuming a green colour, and emitting nitrous gas. The solution is never complete, nor do any crystals of oxalic acid appear unless heat be applied. In this respect starch differs from sugar, which yields oxalic acid with nitric acid, even at the temperature of the atmosphere. When heat is applied to the solution of starch in nitric acid, both oxalic and malic acid are formed, but the undissolved substance still remains. When separated by filtration, and afterwards edulcorated, this substance has the appearance of a thick oil, not unlike tallow; but it dissolves readily in alcohol. When distilled it yields acetic acid, and an oil having the smell and the consistence of tallow.†

Strong muriatic acid dissolves starch slowly and without effervescence. When the starch does not exceed $\frac{1}{20}$th of the acid, the solution is colourless and transparent; but if we continue to add starch, a brown colour soon appears, and the acid loses a portion of its liquidity. Its peculiar smell is destroyed, and replaced by the odour which may be perceived in corn mills.

Acetic acid does not dissolve starch. I have not tried the action of any of the other acids.

10. Alcohol separates starch in part from its decoction. Of Alcohol. A solution of potash in alcohol occasions a copious white precipitate, which is redissolved on adding a sufficient quantity of water. A solution of sulphuret of potash in alcohol occasions a flaky precipitate in the decoction of starch. This precipitate has sometimes an orange colour.

11. When starch is thrown upon a hot iron, it melts, Of heat. blackens, froths, swells, and burns with a bright flame like sugar, emitting at the same time a great deal of smoke; but it does not explode, nor has it the caromel smell which distinguishes burning sugar. When distilled it yields water impregnated with an acid, supposed to be the pyromucous, a little empyreumatic oil, and a great deal of carbonic acid

* Vauquelin has applied this property of nitric acid to detect starch in vegetables. He digested the substance under examination in diluted nitric acid for two days, and then poured into the solution alcohol. The starch precipitated. See Ann. de Chim. lv. 28.

† Scheele, Crell's Annals, ii. 14. English Trans.

and carbureted hydrogen gas. The charcoal which remains is easily dissipated when set on fire in the open air; a proof that it contains very little earth. When starch is torrified in a flat vessel till it assumes a grey colour it becomes partly soluble in water, and if the torrefaction be continued till the starch becomes brown it is wholly soluble in cold water. The solution is glutinous, and may be applied to most of the purposes of gum. But tannin still continues to precipitate it; a proof that it has not been converted into gum; but merely undergone an alteration which renders it soluble.

Constituents of starch.

12. Three sets of experiments have been made in order to determine the constituents of starch. Gay-Lussac and Thenard burnt a quantity of wheat starch made up into a paste with chlorate of potash, and ascertained the substances formed. According to their experiments 100 parts of wheat starch are composed of

$$
\begin{array}{ll}
\text{Hydrogen} \dots\dots & 6\cdot77 \\
\text{Carbon} \dots\dots\dots & 43\cdot55 \\
\text{Oxygen} \dots\dots\dots & 49\cdot68 \\
\hline
& 100\cdot00 \;*
\end{array}
$$

M. Theodore de Saussure analysed wheat starch by burning it in oxygen gas, ascertaining the proportion of oxygen gas consumed, and the quantity of carbonic acid gas formed. According to him 100 parts of starch are composed of

$$
\begin{array}{ll}
\text{Azote} \dots\dots\dots & 0\cdot40 \\
\text{Hydrogen} \dots\dots & 5\cdot90 \\
\text{Carbon} \dots\dots\dots & 45\cdot39 \\
\text{Oxygen} \dots\dots\dots & 48\cdot31 \\
\hline
& 100\cdot00 \;\dagger
\end{array}
$$

Professor Berzelius analysed a quantity of potatoe starch by burning it along with chlorate of potash, and using various precautions to ensure an accurate result. According to his experiments 100 parts of potatoe starch are composed of

* Recherches Physico-chimiques, ii. 291.
† Annals of Philosophy, vi. 427.

5

Hydrogen ...... 7·066
Carbon .... 43·481
Oxygen .... 49·455
_____
100·000 *

To be able from these experiments to determine the constitution of starch, it is requisite to know the equivalent number, denoting the weight of it which enters into combinations. Berzelius united it with oxide of lead by digesting an excess of subnitrate of lead in a boiling solution of starch in water. The precipitate was washed repeatedly in boiling water, in order to remove any excess of subnitrate of lead that might be contained in it. The amylate of lead thus formed was composed of

Starch .... 72 .... 100 36
Oxide of lead .. 28 .... 38·89 14

If this compound consisted of 1 atom of starch, united with 1 atom of oxide of lead, the weight of an atom of starch will be 36. But it is more probable from the process employed to form it that it is a binamylate of lead, or a compound of 2 atoms starch and 1 atom protoxide of lead. On this supposition an atom of starch must weigh 18. The nearest number to this formed of the requisite proportion of atoms to correspond with the preceding analyses is 17·75. If we consider this as the weight of an atom of starch it constituents will be

10 atoms hydrogen .... = 1·25 .... 7·04
10 atoms carbon ...... = 7·50 .... 42·25
9 atoms oxygen ...... = 9·00 .... 50·71
_____   _____
17·75   100·00

13. Starch is contained in a great variety of vegetable substances; most commonly in their seeds or bulbous roots, but sometimes also in other parts. Mr. Parmentier, whose experiments have greatly contributed towards an accurate knowledge of starch, has given us the following list of the plants from the roots of which it may be extracted: Plants containing it.

* Annals of Philosophy, v. 273.

Arctium lappa.
Atropa belladonna.
Polygonum bistorta.
Bryonia alba.
Colchicum autumnale.
Spiræa filipendula.
Ranunculus bulbosus.
Scrophularia nodosa.
Sambucus ebulus.
———— —— nigra.
Orchis morio.

Imperatoria ostrutheum.
Hyoscyamus niger.
Rumex obtusifolius.
———— acutus.
———— aquaticus.
Arum maculatum.
Orchis mascula.
Iris pseudacorus.
—— fœtidissima,
Orobus tuberosus.
Bunium bulbocastanum.

It is found also in the following seeds :

Oats.
Rice.
Maze.

Millet.
Chesnut.
Horse-chesnut.

Peas.
Beans.
Acorn.

Indeed the greater number, if not the whole, of the vegetable seeds employed by man as an article of food, consists chiefly of starch. But that substance is always combined with some other which serves to disguise its properties; such as sugar, oil, extractive, &c. It is only by processes similar to those described in the beginning of this Section that it is extracted from these substances in a state of tolerable purity. The following substances, which may be considered as varieties of starch, deserve particular attention.

1. *Potatoe Starch.*

Potatoe
starch.

When the potatoe is grated down to a pulp, and placed on a fine searce, if water be poured on it, a great deal of starch passes through the meshes of the searce, and may be collected in proper vessels. When washed with water and dried, it assumes a fine white colour, and possesses all the essential properties of starch. Indeed it goes much further; a smaller quantity being sufficient to form a thick paste with water than is required of wheat starch. It has a very perceptible crystallized appearance, and is much heavier apparently than common starch. It is not likely therefore that it could be employed with the same advantage as a hair powder.

2. *Sago.*

Sago.

This substance is extracted from the pith of several spe-

cies of palm in the Moluccas, Philippines, and other East Indian islands. The palm is cut into pieces of five or six feet in length : the woody part is cut off one side, exposing the pith lying, as it were, in the hollow of a canoe. Cold water is poured in, and the pith well stirred ; by which means the starch is separated from the fibrous part, and passes through with the water when the whole is thrown on a searce. The sago, thus separated, is allowed to settle ; the water is poured off ; and when it is half dry it is granulated, by being forced through a kind of funnel. It is said to acquire its grey colour while dried in an artificial heat. This substance is employed as an article of food, and its nourishing properties are well known.*

3. *Salop.*

This substance comes from Persia ; but is said also to be manufactured in Europe. It is supposed to be the prepared roots of different species of *orchis*, as the *morio, mascula, bifolia, pyramidalis.* According to Moult, the bulbous roots of these plants are deprived of their cuticle, baked in an oven for 10 or 12 minutes, which gives them the semitransparency, and then fully dried in a moderate heat.† Like sago, salop is used only as a nourishing article of food. It is said by Dr. Percival to have the property of concealing the taste of salt water.‡

4. *Cassava* or *Tapioca,*

As it is called, is prepared from the roots of the *jatropha manihat*, an American plant. They are peeled and subjected to pressure in a kind of bag made of rushes. The juice that is forced out is a deadly poison, and is employed by the Indians to poison their arrows ; but it deposits gradually a white starch, which when properly washed is innocent. What remains in the bag consists chiefly of the same starch. It is dried in smoke, and afterwards passed through a kind of sieve. Of this substance the cassava bread is made.

5. *Sowans.*

This very nutritious article of food is made in this coun-

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* Forest's Voyage, p. 39.   † Phil. Trans. lix. 2.
‡ Phil. Mag. xviii. 161.

try from the husk of oats, by a process not unlike that by which common starch is made. The husk of the oat (called *seeds*) is separated from oat-meal by the sieve. It still retains a considerable portion of farinaceous matter. It is mixed with water, and allowed to remain for some days till the water has become sour. The whole is then thrown upon a sieve. The milky water passes through; but all the husk remains behind. The water thus obtained is loaded with starchy matter, which soon subsides to the bottom. The sour liquor is decanted off, and about an equal quantity of fresh water added. This mixture when boiled forms a very nourishing article of food; and the portion of the sour water which still adheres to the starch gives the whole a pleasant acidity.

It is curious enough that the starch-maker's water, notwithstanding the great quantity of acid which it contains, likewise the still sourer water of sowans, are swallowed greedily by hogs. They fatten upon it.

SECT. XVIII.

OF INDIGO.

THIS valuable pigment, one of the capital manufactures of America, is obtained from the leaves of different species of plants; the *indigofera argentea* or *wild indigo*, which is said to yield the finest pigment, but in smallest quantity; the *indigofera disperma* or *Guatimala indigo*; and the *indigofera tinctoria* or *French indigo*, which yields the greatest quantity of indigo, and is therefore preferred by the planter, though its quality be inferior to the indigo obtained from the other species.* For the first accurate account of the

Manufac-
ture.

mode of preparing indigo from these plants, we are indebted to Labat.† Since his time some improvements have been introduced into the manufacture; but the mode of

* Edward's History of the West Indies, ii. 275; and Berthollet, Elemens de la Teinture, ii. 37.

† See his account detailed by Dr. Lewis in Neumann's Chemistry, p. 435.

rearing the plants still continues the same. In the West Indies the seeds are sown in March, in trenches about a foot asunder, and the plant comes into blossom, and is fit for cutting down in May; but in South America about six months elapse before it can be cut. In the West Indies four cuttings are often obtained in the same plant in the course of a year; but in America never more than two, and often only one. The produce continually diminishes after the first cutting; so that it is necessary to renew the plants from seed every year.

The plants are cut down with sickles, and laid in strata in the *steeper*, till it is about three parts full. This is a large cistern of mason work or wood about 16 feet square. Here they are pressed down with planks, and loaded to prevent them from swimming, and covered with water to the height of four or five inches. Here they ferment; and the utmost attention is required to the process. If they be allowed to remain too long, the pigment is spoiled; and if the water be drawn off too soon, much of the indigo is lost. This fermentation, according to Le Blond, goes on best at the temperature of 80°. The water soon becomes opaque, and assumes a green colour; a smell resembling that of volatile alkali is exhaled, and bubbles of carbonic acid are emitted.* When the fermentation has continued long enough, the liquor is let out into a second cistern, placed lower than the first. This cistern is called the *battery*, and is commonly about 12 feet square and four and a half deep. Here it is agitated for 15 or 20 minutes by means of levers moved by machinery, till the flocculi, beginning to separate, give it a curdled appearance. A quantity of lime water is now poured in, and the blue flocculi are allowed to subside. The lime water is supposed to prevent putrefaction, which otherwise might endanger the pigment; and according to Le Blond, it absorbs carbonic acid, which existed in the liquid, and prevented the indigo from separating. The water is drawn off, and the pigment put to be drained in small linen bags; after which it is put into little square boxes, and alowed to dry in the shade.†

Europe was long supplied with indigo from the West

* Jour. de Phys. xxxviii. 141.
† Edward's History of the West Indies, ii. 278.

Indies and America; but of late the manufacture has been
introduced into Indostan, and carried on with such spirit
and success as promises fair to secure to that country in
future the supply of the European market. *

The leaves of the *indigofera* yield a green infusion to hot
water, and a green powder may be precipitated from it;
but unless a fermentation has taken place, neither the co-
lour nor properties of it have any resemblance to indigo.
Le Blond affirms that the contact of air is necessary to the
fermentation of indigo; but his proofs are insufficient.
The separation of carbonic acid is a sufficient proof that
chemical decompositions are going on during the fermen-
tation; but of what nature we are ignorant.

The *indigofera* is not the only genus of plants from which
indigo may be obtained. Dr. Roxburgh first drew the
attention of manufacturers to the *nerium tinctorum*, a tree
very common in Indostan, from the leaves of which it may
be extracted in abundance. His process is shorter. The
leaves are kept in a copper full of water, supported at the
temperature of 160°, till they assume a yellowish hue, and
the liquid acquires a deep green colour. The liquid is then
drawn off, agitated in the usual manner, and the indigo
thrown down by lime-water.†

Indigo may be obtained also from the *isatis tinctoria*, or
woad; a plant commonly enough cultivated in Britain, and
even found wild in England.‡ When arrived at maturity,
this plant is cut down, washed, dried hastily in the sun,
ground in a mill, placed in heaps, and allowed to ferment
for a fortnight. It is then well mixed, and made up into
balls, which are piled upon each other, and exposed to the
wind and sun. In this state they become hot, and exhale
a putrid ammoniacal smell. The fermentation is promoted,
if necessary, by sprinkling the balls with water. When it
has continued for a sufficient time, the woad is allowed to
fall to a coarse powder; in which state it is sold as a dye-
stuff. By treating woad nearly in the same manner with
the *indigofera*, indigo has been obtained from it by differ-

* See Tenant's Indian Recreations, ii. 142.
† Bancroft on Permanent Colours, p. 423.
‡ Some think that this is the plant with which the ancient Britons
stained their bodies, to make them appear terrible to their enemies.

ent chemists. Justi * was one of the first of these. Borth published a paper on the subject in 1754,† Kulencamp ‡ in 1755, and Edel § a third in 1756. And several experiments on the subject have been published in Germany.||

Chevreul obtained, by digesting *woad* in alcohol, and evaporating the solution, *white* crystalline grains, which gradually became blue when exposed to the atmosphere, and assumed the usual appearance of indigo. These white grains he considers as indigo destitute of oxygen. Their crystallized state is remarkable.**

The method of preparing indigo, and of applying it to the purposes of dyeing, seems to have been very early known in India; but in Europe, though it had been occasionally used as a paint,†† its importance as a dye-stuff was not understood before the middle of the 16th century. It is not even mentioned in Plictho, a celebrated work on dyeing published in Italy in 1548. The Dutch were the people who first imported it from India, and made its importance known in Europe. Even as late as the middle of the seventeenth century, its use was restricted in different countries. It was prohibited in England during the reign of Queen Elizabeth; and the prohibition was not taken off till the reign of Charles II. It was prohibited also in Saxony. In the edict it is spoken of as a corrosive substance, and called *food for the Devil.* Colbert restricted the French dyers to a certain quantity of it.‡‡ Soon after its importance began to be generally understood, it was cultivated in Mexico and the West Indies with such success that the indigo from these countries was preferred to every other; but within these few years the East Indian indigo, owing entirely to the enlightened exertions of some of our own countrymen, has recovered its character, and is now imported in considerable quantities to Britain.

Indigo is a fine light friable substance of a deep blue colour. Its texture is very compact, and the shade of its surface varies according to the manner in which it has been

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* Schreber's Sammlungen, i. 68.   † In the Halle Newspaper.
‡ Schreber's Samml. viii. 448.   § De Indo Germanico ex Glasto.
|| See Saltzer, Schweigger's Jour. iii. 417; Gehlen, ibid. v. 191, and vi. 1, and viii. 136.
** Jour. de Phys. lxvi. 373.   †† Plinii, Lib. xxxv. c. 6.
‡‡ See Bancroft on Permanent Colours, and Berthollet on Dyeing.

Book IV. prepared. The principal tints are copper, violet, and blue; the lightest indigo is the best : but it is always more or less mixed with foreign substances, partly owing, doubtless to the carelessness of the preparation, and partly to the bodies which the plant containing indigo yields to water. From the analysis of Bergman, to whom we are indebted for one of the most complete treatises on the properties of indigo which has yet appeared, the purest indigo which he could procure was composed of the following constituents :

> 47 pure indigo
> 12 gum
> 6 resin
> 22 earth
> 13 oxide of iron
> ———
> 100 *

The earth consisted of

> 10·2 barytes
> 10·0 lime
> 1·8 silica
> ———
> 22·0 †

But in all probality the earth differs in different specimens; for Proust found magnesia in considerable quantity in the specimens which he examined.‡ The 47 parts of blue pigment are alone entitled to the name of indigo; and to them therefore we shall confine our attention in this section.

Chevreul has lately published the result of his experiments on Guatimala indigo, which shows that the indigo of commerce is a still more complex substance than Bergman found it.

Constituents of common indigo. Hot water digested on indigo became yellow. This liquid being distilled gave out ammonia, and let fall a greenish matter which became blue upon exposure to the air, and possessed the properties of indigo. After this matter has separated, flocks precipitated of a green colour, to which Chevreul has given the name of *green matter*. It is scarcely soluble in water, but dissolves in alkaline leys

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* Bergman, v. 36.   † Ibid. v. 33.
‡ Nicholson's Journal, iii. 325.

 und becomes reddish. When the alkali is saturated by an
acid the colour becomes green, and when the liquid is
concentrated the green matter precipitates in flocks. Alco-
hol dissolves it and becomes reddish; but when spread thin
upon any substance it still looks green. Alcohol being
poured into the water from which the green matter had pre-
cipitated, a substance fell of a brownish-yellow colour and
a bitter and astringent taste, and which burnt on coals,
emitting the odour of empyreumatic vinegar.

The indigo thus treated was digested in alcohol. The
alcohol dissolved; 1. *green matter*; 2. *red matter*; 3. *indigo.*
The *red matter* agrees with the *green* in all its properties
except colour. The colour does not change by solution in
alkaline leys and alcohol.

The indigo in the third place was treated with muriatic
acid which dissolved, 1. *iron*; 2. *carbonate of lime*; 3. *red
matter.*

The following table exhibits the substances taken from
Guatimala indigo by these processes, and of consequence
its composition:

Water ......{ ammonia
disoxygenized indigo 12
green matter
bitter matter

Alcohol .....{ green matter 30
red matter
indigo

Muriatic acid.{ red matter 6
carbonate of lime 2
oxide of iron and alumina 2
silica................... 3
pure indigo 45
                        ——
                Total 100

All indigos do not yield the same substances nor the
same proportions. In some the *green matter* has a brown
colour.*

Indigo is a soft powder, of a deep blue inclining to
purple, without either taste or smell. It undergoes no
change though kept exposed to the air. Water does not
dissolves any part of it, nor produce any change upon it.

Action of water.

* Chevreul, Jour. de Phys. lxv. 309.

Book IV. Bergman however found, that indigo, when kept long under water, underwent a kind of putrefaction, or at least exhaled a fetid odour.*   When heat is applied to indigo it emits a bluish-red smoke, and at last burns away with a very faint white flame, leaving behind it the earthy parts in the state of ashes.†   The purple smoke, as Chevreul ascertained, crystallizes in needles, and is indigo unaltered. Hence the easiest method of obtaining pure indigo is to sublime it in a platinum crucible.

Neither oxygen nor the simple combustibles have any effect upon indigo, except it be in a state of solution; and the same remark applies to the metallic bodies.

Of alkalies.   The fixed alkaline solutions have no action on indigo, except it be newly precipitated from a state of solution.   In that case they dissolve it with facility.   The solution has at first a green colour, which gradually disappears, and the natural colour of the indigo cannot be again restored. Hence we see, that the alkalies when concentrated decompose indigo.‡   Pure liquid ammonia acts in the same way.   Even carbonate of ammonia dissolves precipitated indigo, and destroys its colour; but the fixed alkaline carbonates have no such effect.§

Earths.   Lime-water has scarcely any effect upon indigo in its usual state; but it readily dissolves precipitated indigo. The solution is at first green, but becomes gradually yellow.   When the solution is exposed to the air, a slight green colour returns, as happens to the solution of indigo in ammonia; but it soon disappears.|| The effect of the other alkaline earths upon indigo has not hitherto been tried; but it cannot be doubted that they would act nearly as lime-water, but with more energy.   The other earths seem to have but little action on indigo in any state.

Acids.   The action of the acids upon indigo has been examined with most attention, and it certainly exhibits the most important phenomena.

Sulphuric acid.   When diluted sulphuric acid is digested over indigo, it produces no effect except that of dissolving the impurities; but concentrated sulphuric acid dissolves it readily.   One part of indigo, when mixed with eight parts of sulphuric

* Opusc. v. 29.   † Ibid. p. 31.   ‡ Ibid. 24.
§ Ibid. || Ibid. 25.

acid, evolves heat, and is dissolved in about 24 hours. The solution of indigo is well known in this country by the name of *liquid blue*. Bancroft calls it *sulphate of indigo*. While concentrated, it is opaque and black; but when diluted, it assumes a fine deep blue colour, and its intensity is such, that a single drop of the concentrated sulphate is sufficient to give a blue colour to many pounds of water.* Bergman ascertained the effect of different reagents on this solution with great precision. His experiments threw light, not only on the properties of indigo, but upon the phenomena that take place when it is used as a dye-stuff. The following is the sum of these experiments :

1. Dropped into diluted water. No change.

2. Dropped into sulphurous acid. Colour at first blue, then green, and very speedily destroyed.

3. In weak nitric acid it experiences no change.

4. In muriatic acid. No change.

5. In weak tartaric acid. Becomes gradually green and in 144 hours had assumed a very pale yellow colour. Colour not restored by alkalies.

6. In vinegar. Becomes green, and in four weeks the colour disappeared.

7. In weak potash. Becomes green and then colourless.

8. In weak carbonate of potash. The same changes, but more slowly. If the solution be very weak, the colour of the indigo is not destroyed.

9. Soda. The same as potash.

10. In ammonia and its carbonate. Colour becomes green, and then disappears.

11. In a weak solution of sulphate of soda. Colour after some weeks becomes green.

12. In nitre, common salt, and sal ammoniac. No change.

13. In tartrate of potash. Became green and then colourless.

14. In a solution of sugar. Became green and at last yellowish.

15. In alum. No change.

16. In sulphate of copper. No change.

* Bergman, v. 7.

17. In sulphate of iron. Colour became green, and in three weeks disappeared.

18. In the sulphurets. Colour destroyed in a few hours.

19. Realgar, white oxide of arsenic, and orpiment, produced no change.

20. Black oxide of manganese destroyed the colour completely.

21. In the infusion of madder. Colour became green, and at last yellow.

22. In the infusion of woad. The same changes, but more speedily. *

Blue colour of indigo owing to oxygen. From these experiments, it is obvious that all those substances which have a very strong affinity for oxygen give a green colour to indigo, and at last destroy it. Hence it is extremely probable, that indigo becomes green by giving out oxygen. Of course it owes its blue colour to that principle. This theory was first suggested by Mr. Haussman, and still farther confirmed by Berthollet.† Now it is only when green that it is in a state capable of being held in solution by lime, alkalies, &c. in which state it is applied as a dye to cloth. The cloth, when dipped into the vat containing it thus dissolved, combines with it, and the blue colour is restored by exposure to the atmosphere. It may be restored equally by plunging the cloth into chlorine dissolved in water. Hence the restoration is probably owing to oxygen. Hence then the reason that sulphurous acid, the vegetable acids, sulphate of iron, give sulphate of indigo a green colour.

From these experiments, we see also that the colour of indigo is destroyed by the addition of those substances which part with oxygen very readily, as the black oxide of manganese. In that case the indigo is destroyed, for its colour cannot be again restored. When the sulphate of indigo is poured into boiling water, it affords a green-coloured solution; but with cold water a deep blue solution. What is called smoking sulphuric acid dissolves indigo much more readily than the pure acid, and evolves much

* Bergman, v. 3.
† See Jour. de Phys. 1788; Berthollet's Notes on Poerner sur l'Art de la Teinture, p. 173; and Berthollet on Dyeing.

more heat during the solution. Bucholz has shown, that by boiling sulphur in pure sulphuric acid, it acquires the property of dissolving indigo as readily as the smoking acid.*

Nitric acid attacks indigo with great violence; the evo- Action of lution of abundance of heat and nitrous gas. When of the nitric acid. specific gravity 1·52, it even sets fire to indigo. This fact was discovered by Mr. Woulfe. He communicated it to Rouelle, who exhibited it in his lectures. Sage first published an account of it.† When the acid is diluted, the action is still violent, unless the proportion of water be considerable. Mr. Hatchett poured upon 100 grains of indigo an ounce of nitric acid diluted with an equal quantity of water. The action was so rapid, that he found it necessary to add another ounce of water. When the ef- Forms tan- fervescence had nearly subsided, the liquid was placed on a nin, sand bath for some days, and evaporated to dryness. Water poured upon the residuum dissolved a considerable portion of it, and formed a beautiful deep yellow solution of an intense bitter taste. This solution contains only a very small portion of oxalic acid; but with a solution of isinglass it forms a copious yellow insoluble precipitate, and of course contains a portion of artificial tannin. With ammonia, crystals precipitate, consisting of *bitter principle* combined with ammonia. ‡

When four parts of nitric acid are boiled upon one part Bitter prin- of indigo, the pigment soon loses its colour, and is dis- ciple, solved. The solution becomes yellow, and a thin layer of a resinous matter appears on the surface. If the process be now stopped, the resinous matter becomes firm by cooling. If this matter be removed, and the solution evaporated to the consistence of honey, redissolved in hot water, and filtered, potash throws down yellow spicular crystals, consisting of *bitter principle* combined with potash. These crystals have the curious property of detonating with a purple light when wrapped up in paper and struck with a hammer; the resin, by treating it with fresh nitric acid, may be converted into the same bitter principle. If the process be And ben- zoic acid.

* Gehlen's Jour. iii. 1.   † Proust, Nicholson's Jour. iii. 328.
‡ Hatchett's Additional Experiments on Artificial Tannin, Phil. Trans. 1805.

stopped sooner than the point mentioned above, yellow crystals are obtained, which are more soluble in water, and which sublime in white needles, having all the properties of benzoic acid. These curious facts were ascertained by Fourcroy and Vauquelin.*

Thus it appears, that by treating indigo with nitric acid, it is converted into tannin, oxalic acid, benzoic acid, and *bitter principle.*

Action of other acids. Muriatic acid does not act upon indigo in its common state, but it readily dissolves indigo precipitated from the sulphate, and forms a blue-coloured solution. The same phenomena are exhibited by the phosphoric, acetic, tartaric acids, and probably by all except the acid supporters.†

Chlorine destroys the colour of indigo as readily as nitric acid, and obviously for the same reason.‡

Alcohol dissolves a small proportion of indigo, but it gradually precipitates again unless *red matter* be present, in which case the solution is permanent.§

Indigo is not acted upon by ether or oils, at least if the experiments of Bergman be accurate.||

Fermentation. When indigo is mixed up with bran, woad, and other similar substances which readily undergo fermentation, it assumes a green colour during the fermentation, and is then easily dissolved by lime or potash. It is by this process that it is usually rendered proper for dyeing.

Action of heat. When indigo is distilled, it yields products different from any other vegetable substance, if the accuracy of Bergman is to be trusted. He distilled 576 grains in a small retort connected with a pneumatic apparatus. He obtained the following products:

19 grains carbonic acid gas.
173 ——— of a yellow acid liquid containing ammonia.
53 ——— oil.
331 ——— charcoal.
———
576 **

He observed no other gas but carbonic acid. The experiment ought to be repeated: if it prove true, no other

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* Phil. Mag. xxiii. 256.   † Bergman, v. 22.   ‡ Ibid.
§ Chevreul, Jour. de Phys. lxv. 309. || Opusc. v. 35.
** Bergman, v. 35.

vegetable substance agrees with it in this respect except gallic acid. The oil was black, and had the smell of tobacco. It dissolved readily in alcohol. The quantity of charcoal appears enormous; but Bergman's experiment was made with common indigo; therefore 158 grains of earth and iron are to be subtracted from the sum. This decomposition indicates the presence of oxygen, carbon, hydrogen, and azote in indigo. The proportion of the two first constituents is uncommonly great.

Chevreul subjected common indigo to distillation. The products obtained were, 1. ammoniacal water. 2. Sulphur, probably combined with oily hydrogen. 3. A thick brown oil containing carbonate and acetate of ammonia. 4. Prussiate and hydrogureted sulphuret of ammonia. 5. A purple substance crystallized in silky threads on the dome of the retort. It was pure indigo. 6. A bulky charcoal yielding prussic acid when coloured with potash. 7. Gases not examined.

Such are the properties of indigo, as far as they have been ascertained. To descant on its importance is quite unnecessary. It is perhaps the most valuable, and certainly the most permanent, of all the dye-stuffs.

SECTION XIX.

OF GLUTEN.

If wheat flour be kneaded into a paste with a little water, Extraction. it forms a tenacious, elastic, soft, ductile mass. This is to be washed cautiously, by kneading it under a small jet of water till the water no longer carries off any thing, but runs off colourless; what remains behind is called *gluten*. It was discovered in 1742 by Beccaria, an Italian philosopher, to whom we are indebted for the first analysis of wheat flour.*

1. Gluten, when thus obtained, is of a grey colour, ex- Properties. ceedingly tenacious, ductile, and elastic, and may be extended to twenty times its original length. When very thin,

* Collect. Academ. xiv. 1.

it is of a whitish colour, and has a good deal of resemblance to animal tendon or membrane. In this state it adheres very tenaciously to other bodies, and has often been used to cement together broken pieces of porcelain. Its smell is peculiar. It has scarce any taste, and does not lose its tenacity in the mouth. In the air, it assumes a brown colour, and becomes as it were covered with a coat of oil.

When exposed to the air, it gradually dries; and when completely dry, it is pretty hard, brittle, slightly transparent, of a dark brown colour, and has some resemblance to *glue*. It breaks like a piece of glass, and the edges of the fracture resemble in smoothness those of broken glass; that is to say, it breaks with a *vitreous* fracture.

Soluble in water.

Fresh gluten imbibes water, and retains a certain quantity of it with great obstinacy. To this water it owes its elasticity and tenacity. When boiled in water it loses both these properties.

2. When fresh gluten is macerated for a considerable time in cold water the liquid becomes opaque, and contains small films suspended, which do not soon subside. By repeated filtrations it becomes transparent; but it holds in solution a little gluten, which renders it frothy, and gives it the property of precipitating when mixed with chlorine or the infusion of nutgalls. Thus gluten is to a certain extent soluble in cold water. When the water is heated, the gluten separates in the state of yellow flakes.*

When kept moist, it very soon begins to decompose, and to undergo a species of fermentation. It swells, and emits air-bubbles, which Proust has ascertained to consist of hydrogen and carbonic acid gases.† It emits also a very offensive odour, similar to what is emitted by putrefying animal bodies. Cadet kept gluten in a vessel for a week in a damp room. Its surface became covered with byssi, the fermentation just mentioned had commenced, and the odour was distinctly acid. In 24 days, on removing the upper crust, the gluten was found converted into a kind of paste, of a greyish white colour, not unlike bird-lime. In

* Fourcroy and Vauquelin, Annales de Mus. d'Hist. Nat. No. xxxvii. p. 3.   † Jour. de Phys. lvi. 108.

that state he gave it the name of *fermented gluten.** If the gluten be still left to itself, it gradually acquires the smell and the taste of *cheese.* This curious fact was first ascer- tained by Rouelle junior. In that state it is full of holes, and contains the very same juices which distinguish some kinds of cheese. Proust ascertained that it contains ammonia and vinegar; bodies which Vauquelin detected in cheese: and ammonia robs both equally of their smell and flavour.†

Fourcroy and Vauquelin have examined the changes which gluten sustains when left for some months to putrify under water. When left in that liquor, at the temperature of 54°, it swells, becomes sour and fetid, and rises to the surface, giving out carbonic acid. The water acquires the property of giving out a red colour to paper stained with litmus. The fixed alkalies disengage ammonia, and chlorine and infusion of nutgalls throw down a precipitate, indicating the presence of gluten in solution. When sugar is dissolved in this water, the liquid assumes the properties of vinegar, without fermentation or contact of the atmosphere. If the gluten be put again into water at the same temperature, the fermentation goes on, carbonic acid is disengaged, and the liquid slightly reddens litmus paper. The reagents indicate the presence of gluten and ammonia. The gluten, which forms a pellicle on the surface of the liquid, becomes first purple-coloured, and then blackish-grey, and exhales the fetid odour of putrifying mucous membranes. The water is now blackish; it gives a brown colour to nitrate of silver, blackens nitrate of mercury, becomes milky, and loses its smell when mixed with chlorine, and is not precipitated by infusion of nutgalls. After three months putrifaction, the gluten was greatly diminished; it had a brown colour, and exhaled only a weak smell. When dried it formed lumps, which emitted the odour of the earth from a burial ground. They softened under the fingers, and burned like fat. In alcohol it partly dissolved, leaving behind it a substance which resembled woody fibre in its properties.‡ Thus by putrifaction gluten is converted into *carbonic acid, ammonia,* a *fatty matter,* and a substance analogous to *woody fibre.*

* Ann. de Chim. xli. 315.   † Proust, Jour. de Phys. lvi. 100.
‡ Ann. de Mus. d'Hist. Nat. No. xxxvii. 4.

3. Fresh gluten does not sensibly dissolve in alcohol, which even throws it down from water; yet in certain cases this liquid forms a solution of gluten in very small proportion. I poured two ounces of alcohol, of the specific gravity 0·837, upon 100 grains of pearl barley ground to a coarse powder, and allowed it to stand un touched for two years. On evaporating the liquid, it left behind it a yellow matter, which partly resembled an oil. Alcohol digested upon this substance took up the yellow matter and left *gluten*, easily recognizable by its properties. On trying the same experiment with wheat flour, no gluten was taken up, but only a yellow matter, which possessed the properties of *bitter principle*.

Action of alcohol.

When the *fermented* gluten of Cadet is triturated with a little alcohol into a mucilage, and then mixed with a sufficient quantity of that liquid, a portion of it is dissolved. This solution constitutes an excellent varnish, possessed of considerable elasticity. It may be spread over paper or wood; and when dry resists other bodies, as well as most varnishes. In this state, too, it may be employed to cement china; and triturated with paints, especially vegetable colours, it forms a very good ground. When this solution is mixed with a sufficient quantity of lime, it forms a very good lute; and bits of linen dipped in it adhere very strongly to other bodies.*

4. Ether does not sensibly dissolve gluten.

5. Acids act upon gluten differently according to the peculiar properties of each.

Acids.

Concentrated acetic acid dissolves it readily in considerable quantity, and without altering its nature. The solution is muddy, but permanent; and the gluten may be thrown down by means of alkalies. This acid dissolves the fermented gluten of Cadet; and the solution may be substituted for the solution in alcohol as a varnish; but it does not answer to mix it with colours.†

Concentrated sulphuric acid renders it violet-coloured, and at last black; inflammable air escapes, and charcoal, water, and a portion of ammonia, are formed.‡ When nitric acid is poured on it, and heat applied, there is a quan-

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* Cadet, Ann. de Chim. xli. 316.   † Ibid.
‡ Fourcroy, vii. 304.

tity of azotic gas emitted, as Berthollet discovered; and by continuing the heat, some little oxalic acid is formed,* and likewise malic acid, while a number of yellow-coloured oily flakes make their appearance in the solution.

Muriatic acid dissolves gluten with facility when its action is assisted by heat. When gluten is placed in chlorine it softens, and seems to dissolve, but soon coagulates again in yellow-coloured flakes, which become transparent and greenish-coloured by drying. When heated, they exhale chlorine, and assume the appearance of common gluten.† Chlorine has the property of precipitating gluten from water in the state of yellowish-white flakes.

6. Alkalies dissolve gluten when they are assisted by Alkalies. heat. The solution is never perfectly transparent. Acids precipitate the gluten from alkalies, but it is destitute of its elasticity.‡ Alkalies, when much concentrated, form with it a kind of soap, converting it into oil and ammonia; which last is dissipated during the trituration.

7. Gluten is precipitated from water, and from some of Nutgalls, its other solutions, by the infusion of nutgalls. The colour of the precipitate is usually yellowish-brown, and it does not dissolve though the solution be heated.

8. The action of the metallic oxides and their salts upon gluten has not been tried.

It has a strong affinity for the colouring matter of vegetables, and likewise for resinous bodies.

9. When moist gluten is suddenly dried, it swells amaz- Heat. ingly. Dry gluten, when exposed to heat, cracks, swells, melts, blackens, exhales a fetid odour, and burns precisely like feathers or horn. When distilled, there come over water impregnated with ammonia and an empyreumatic oil; the charcoal which remains is with difficulty reduced to ashes.

10. The properties of this substance clearly point out a resemblance between it and animal matter; and the phenomena of its fermentation and destructive distillation show us that oxygen, hydrogen, carbon, and azote, are constituents of it. Proust first observed that the vapour which it

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* Vauquelin, Ann. de Chim. vi. 278.
† Fourcroy and Vauquelin, Ann. de Mus. d'Hist. Nat. No. xxxvii. 3.
‡ Fourcroy.

emits, while fermenting, blackens silver and lead, and of course contains sulphur.

11. Like all other vegetable principles, gluten is susceptible of various shades of properties, which constitute so many species. In wheat flour it occurs in the greatest abundance, and from it we can extract it with the greatest ease: but the sagacity and industry of Rouelle and Proust have detected its presence in many other vegetable substances. Rouelle found it in the leaves of all the vegetable substances which he examined. The exactness of this opinion was called in question by Fourcroy, who treated the experiments of Rouelle with contempt; but it has been examined, and confirmed by very decisive experiments of Proust.

Green fecula contains gluten.

When the juice of cabbage leaves, cresses, scurvy-grass, and other similar plants, is extracted by pressure and passed through a cloth, it still continues far from transparent. Its muddiness is owing to a fine soft silky-green powder suspended in it, which subsides to the bottom so slowly as to take at least a week before it is deposited. This green powder has been distinguished by the name of the *green fecula* of plants. Rouelle first examined it with attention, and ascertained its properties; and the subject has been carried still farther by Proust. The slowness with which it subsides shows that its specific gravity does not differ much from that of water. When once it has fallen, it is insoluble. This substance consists chiefly of three principles: 1. A green matter to which it owes its colour, separated by digestion in alcohol, and which possesses the properties of a *resin*. 2. A substance which consists chiefly of *woody fibres*, and which is left behind when the fecula is digested in potash. 3. A species of gluten, which constitutes the greatest part of it, and to which it owes its characteristic properties.

When the juice of the plants is exposed to a heat of about 130°, the green fecula undergoes a kind of coagulation, concreting into large flakes, which subside very quickly. At this temperature albumen is not altered by heat. This is the method commonly taken to *clarify* these juices. We see from it, that the fecula was united to the water by a very small force, which the addition of heat weakened sufficiently to enable the gluten to cohere. This

coagulation by heat takes place how diluted soever the juices are with water; which is by no means the case with albumen. It is thrown down also by the addition of a little alcohol, by all acids, by ammonia, by sulphureted hydrogen gas, or by throwing into the liquid crystals of carbonate of potash, magnesia, common salt, muriate of potash, nitre, sal ammoniac, &c.

When separated from water it soon dries, and becomes elastic, and somewhat of the appearance of horn; and in that state is scarcely softened by hot water. When treated like gluten, it gradually acquires the cheesy taste and smell. When kept under water it very soon begins to putrify, and exhales a gas which blackens silver and solutions of lead. This speedy putrifaction in stagnant water takes place when flax and hemp are steeped. These substances contain green fecula in their rind, and the putrifaction occasions the separation of the whole, which could not otherwise be accomplished. The water which has been allowed to remain for a whole year over green fecula contains sulphureted hydrogen, carbonate of ammonia, and gluten seemingly held in solution by the ammonia. The stench of putrifaction still continues even after the water has been boiled.*

12. The number of plants containing gluten is very consi- Plants containing gluten. derable. Proust found it in acorns, chesnuts, horse-chesnuts, rue, barley, rye, peas, and beans; and in apples and quinces. He found it also in the leaves of cabbage, sedums, cress, hemlock, borage, saffron, &c.; in the berries of the elder, the grape, &c.; in the petals of the rose, &c.† It occurs also in several roots: Proust could find none in the potatoe.

13. Gluten must be considered as one of the most useful of the vegetable principles. It constitutes an essential ingredient in wheat, and is the substance which renders flour of wheat so fit for forming bread. It seems also to constitute the essential part of yeast. Its uses as a varnish, a ground for paint, &c., pointed out by Cadet, likewise deserve attention.

Albumen and *gluten* have been shown by Link to resemble each other so closely that they cannot be considered as distinct principles.‡

* Proust, Jour. de Phys. lvi. 97. † Ibid.
‡ Annals of Philosophy, vii. 455.

SECT. XX.

OF POLLENIN.

THIS is a name given by Dr. John to a peculiar sub-
stance found in the pollen of the *pinus abies, pinus sylvestris,
lycopodium clavatum*, and supposed by him to constitute the
characteristic constituent of every species of pollen. It
seems to have been first recognised in 1806, by Bucholz, in
the pollen of the lycopodium.* From the experiments of
Fourcroy and Vauquelin, it appears also to constitute a
portion of the pollen of the phœnix dactilifera. John's
analysis of the pinus sylvestris, in which he gives the cha-
racters of pollenin, as they had been previously given by
Bucholz, may be found in the fourth volume of his *Chemical
Researches.*

Properties.   Pollenin has a yellow colour, and is destitute of taste and
smell. It is not altered by exposure to the air.

It is insoluble in water, alcohol, ether, fat and volatile
oils, and likewise in petroleum.

According to John it dissolves in alkaline leys, and the
solution has a brown colour. But in the trials of Bucholz
this solution did not take place.

When exposed to the heat of a candle it burns with rapi-
dity and flame, as is the case with the pollen of the lycopo-
dium clavatum.

When exposed to the air it speedily assumes the smell
and taste of cheese, and soon runs into the putrifactive
fermentation, containing a considerable quantity of ammo-
nia. When distilled it yields a good deal of ammonia.

The remaining properties of this substance have not been
investigated. It is obvious, however, from the preceding
facts that pollenin approaches very nearly to gluten.

SECT. XXI.

OF FIBRIN.

THAT peculiar substance which constitutes the fibrous
part of the muscles of animals has been called *fibrin* by

* Gehlen's Jour. vi. 599.

chemists. A substance resembling it, as it exists in the blood, has been detected by Vauquelin in the juice of the papaw tree. Fibrin then must be ranked among vegetable substances.

The *papaw tree*, the *carica papaya* of botanists, grows in Peru, &c.; and in the Isle of France, where the milky juice that exudes from it is said to be employed with efficacy against the *Guinea-worm*. Two specimens of this juice were brought from that island to Paris by Charpentier de Cossigny. In the one, the juice had been evaporated to dryness, and was in the state of an extract; in the other, the juice was preserved by being mixed with an equal bulk of rum. Both were subjected to a chemical analysis by Vauquelin. The first was of a yellowish-white colour, and semitransparent. Its taste was sweetish. It had no smell, and was pretty solid; but attracted moisture when kept in a damp place. The second was reddish-brown, and had the smell and taste of boiled beef. When the first specimen was macerated in cold water, the greatest part of it dissolved. The solution frothed with soap. The addition of nitric acid coagulated it, and rendered it white; and when boiled, it threw down abundance of white flakes.*

When the juice of the papaw is treated with water, the greatest part dissolves; but there remains a substance insoluble, which has a greasy appearance. It softens in the air, and becomes viscid, brown, and semitransparent. When thrown on burning coals it melted, let drops of grease exude, emitted the noise of meat roasting, and produced a smoke which had the odour of fat volatilized. It left behind it no residue. This substance was the *fibrin*. The resemblance between the juice of the papaw and animal matter is so close, that one would be tempted to suspect some imposition, were not the evidence that it is really the juice of a tree quite unexceptionable.†

The properties of fibrin are the following :

1. It is tasteless, fibrous, elastic, and resembles gluten.
2. It is insoluble in water and in alcohol.
3. It is not dissolved by diluted alkalies.
4. But acids dissolve it without difficulty.
5. With nitric acid it gives out much azotic gas.

* Ann. de Chim. xliii. 267.   † Ibid.

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6. When distilled it yields much carbonate of ammonia and oil.

7. It soon putrifies when kept moist, becomes green; but does not acquire any resemblance to cheese.

A fuller description of this substance must be reserved for the next book, as it belongs rather to the animal than vegetable kingdom.

SECT. XXII.

OF OILS.

THERE are two species of oils; namely, *fixed* and *volatile;* both of which are found abundantly in plants.

1. Fixed oil is only found in the seeds of plants, and is almost entirely confined to those which have two cotyledons; as linseed, almonds, beech-nut, poppy seed, rape seed, &c. Sometimes, though rarely, it is found in the pulp which surrounds the stone of certain fruits. This is the case with the olive, which yields the most abundant and most valuable species of fixed oil. The bicotyledinous seeds, besides oil, contain also a mucilaginous substance; and they have all the character of forming, when bruised in water, a milky liquid, known by the name of *emulsion.*

The following is a list of the plants yielding the fixed oils which usually occur in commerce.*

List of fixed oils.

1. Linum usitatissimum et perenne.   Linseed oil
2. Corylus avellana
3. Juglans regia   } .... Nut oil.
4. Papaver somniferum .... Poppy oil.
5. Cannabis sativa .... Hemp oil.
6. Sesamum orientale .... Oil of Sesamum.
7. Olea Europea .... Olive oil.
8. Amygdalus communis .... Almond oil.
9. Guilandina Mohringa .... Oil of behen.
10. Cucurbita pepo et melapepo ... Cucumber oil
11. Fagus sylvatica .... Beech oil.
12. Sinapis nigra et arvensis ...... Oil of mustard.
13. Helianthus annuus et perennis . Oil of sunflower.
14. Brassica napus et campestris .. Rape seed oil.
15. Ricinus communis .... Castor oil.

* See Gren's Handbuch, ii. 166.

16. Nicotiana tabacum et rustica ..		Tobacco seed oil.		Chap. I.
17. Prunus domestica		Plum kernel oil.		
18. Vitis vinifera		Grape seed oil.		
19. Theobroma cacao		Butter of cacao.		
20. Laurus nobilis		Laurel oil.		
21. Arachis hypogæ..............		Ground nut oil.*		

2. Volatile oils are found in every part of plants except the cotyledons of the seeds, where they never occur. The root, the stem, the leaves, the flower, the rind or pulp of the fruit of a variety of plants, are loaded with volatile oils, from which they are extracted by expression or by distillation. The number of these oils is so great that it baffles all description. Almost every plant which is distinguished by a peculiar odour contains a volatile oil, to which it is indebted for that odour.

The following table contains a pretty copious list of plants which yield volatile oils. The part of the plant from which it is extracted, and the English name of the oil, are added in separate colums.†

Plants.	Parts.	Oils of	Colour.	
1. Artemisia absynthium	Leaves	Wormwood	Green	List of volatile oils.
2. Acorus calamus	Root	Sweet flag	Yellow	
3. Myrtus Pimenta	Fruit	Jamaica pep.§	Yellow	
4. Anethum graveolens	Seeds	Dill	Yellow	
5. Angelica archangelica	Root	Angelica		
6. Pimpinella anisum	Seeds	Anise	White	
7. Illicium anisatum	Seeds	Stellat. anise	Brown	
8. Artemisia vulgaris	Leaves	Mugwort		
9. Citrus aurantium	Rind of the fruit	Bergamotte	Yellow	
10. Meloleuca leucodendra	Leaves	Cajeput	Green	
11. Eugenia caryophyllata	Capsules	Cloves §	Yellow	
12. Carum carvi	Seeds	Caraways	Yellow	
13. Amomum cardamomum	Seeds	Card. seeds	Yellow	
14. Carlina acaulis	Roots		White	
15. Scandix chaerefolium	Leaves	Chervil	Sulph. yel.	
16. Matricaria chamomilla	Petals	Chamomile	Blue	
17. Laurus cinnamomum	Bark	Cinnamon §	Yellow	
18. Citrus medica	Rind of the fruit	Lemons	Yellow	
19. Cochlearia officinalis	Leaves	Scurvy grass	Yellow	
20. Copaifera officinalis	Extract	Copaiba	White	
21. Coriandrum sativum	Seeds	Coriand. seed	White	
22. Crocus sativus	Pistils	Saffron §	Yellow	
23. Piper cubeba	Seeds	Cubeb pep.	Yellow	

* Nicholson's Jour. vi. 224.   † See Gren's Hanbuch, ii. 204.
§ The oils marked § sink in water.

Plants.	Parts.	Oil of	Colour.
24. Laurus culilaban	Bark	Culilaban	Brown yel.
25. Cuminum cyminum	Seeds	Cummi	Yellow
26. Inula helenium	Roots	Elecampane	White
27. Anethum fæniculum	Seeds	Fennel	White
28. Croton eleutheria	Bark	Cascarilla	Yellow
29. Maranta galanga	Roots	Galanga	Yellow
30. Hyssopus officinalis	Leaves	Hyssop	Yellow
31. Juniperus communis	Seeds	Juniper	Green
32. Lavendula spica	Flowers	Lavender	Yellow
33. Laurus nobilis	Berries	Laurel	Brownish
34. Prunus laurocerasus	Leaves	Lauroceras.§	
35. Levisticum ligusticum	Roots	Lovage	Yellow
36. Myristica moschata	Seeds *	Mace	Yellow
37. Origanum majorana	Leaves	Majorum	Yellow
38. Pistacia lentiscus	Resin	Mastich	Yellow
39. Matricaria parthenium	Plant	Motherwort	Blue
40. Melissa officinalis	Leaves	Balm	White
41. Mentha crispa	Leaves		White
42. ———— piperitis	Leaves	Peppermint	Yellow
43. Achillea millefolium	Flowers	Millefoil	Blue and green
44. Citrus aurantium	Petals	Neroli	Orange
45. Origanum creticum	Flowers	Spanish hop	Brown
46. Apium petroselinum	Roots	Parsley	Yellow
47. Pinus sylvestris et abies	Wood & resin.	Turpentine	Colourless
48. Piper nigrum	Seeds	Pepper	Yellow
49. Rosmarinus officinalis	Plant	Rosemary	Colourless
50. Mentha pulegium	Flowers	Pennyroyal	Yellow
51. Genista canariensis	Root	Rhodium	Yellow
52. Rosa centifolia	Petals	Roses	Colourless
53. Ruta graveolens	Leaves	Rue	Yellow
54. Juniperus sabina	Leaves	Savine	Yellow
55. Salvia officinalis	Leaves	Sage	Green
56. Santalum album	Wood	Santalum §	Yellow
57. Laurus sassafras	Root	Sassafras	Yellow
58. Satureia hortensis	Leaves	Satureia	Yellow
59. Thymus serpillum	Leaves and flower	Thyme	Yellow
60. Valeriana officinalis	Root	Valerian	Green
61. Kæmpferia rotunda	Root	Zedoary	Greenish blue
62. Amomum Zinziber	Root	Ginger	Yellow
63. Andropogon schænanthum		Sira	Brown

Several of the gum resins, as *myrrh* and *galbanum*, yield likewise an essential oil, and likewise the balsams, as *benzoin*, &c.

§ The oils marked § sink in water.
* They yield also a fixed oil.

SECT. XXIII.

OF WAX.

THE upper surface of the leaves of many trees is covered with a varnish, which may be separated and obtained in a state of purity by the following process :

Digest the bruised leaves, first in water and then in alco- How ob-
hol, till every part of them which is soluble in these liquids tained from
be extracted. Then mix the residuum with six times its plants.
weight of a solution of pure ammonia, and, after sufficient
maceration, decant off the solution, filter it, and drop into
it, while it is incessantly stirred, diluted sulphuric acid, till
more be added than is sufficient to saturate the alkali. The
varnish precipitates in the form of a yellow powder. It
should be carefully washed with water, and then melted over
a gentle fire.*

Mr. Tingry first discovered that this varnish possessed
all the properties of *bees wax*.† Wax, then, is a vegetable
product. Several plants contain wax in such abundance as
to make it worth while to extract it from them. But let us,
in the first place, consider the properties of bees wax, the
most common and important species. This substance, as
Huber has demonstrated, contrary to the generally received
opinion, is prepared by the bees from honey or sugar, the
latter yielding the greatest proportion of it. ‡

1. Wax, when pure, is of a whitish colour; it is desti- Properties
tute of taste, and has scarcely any smell. Bees wax indeed of bees
has a pretty strong aromatic smell; but this seems chiefly wax.
owing to some substance with which it is mixed; for it dis-
appears almost completely by exposing the wax, drawn out
into thin ribands, for some time to the atmosphere. By
this process, which is called *bleaching*, the yellow colour of
the wax disappears, and it becomes very white. Bleached
wax is not affected by the air.§

2. The specific gravity of unbleached wax varies from

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* Hermbstadt, Med. and Phys. Jour. iii. 372.
† Enc. Meth. Forets et Bois, i. 100.
‡ Nicholson's Jour. ix. 182.
§ Sennebier, Ann. de Chim. xii. 60. and Jour. de Phys. xxxviii. 56.

Book IV. 0·9600 * to 0·9650 ;† that of white wax from 0·8203 to
0·9662. †

3. Wax is insoluble in water; nor are its properties al-
tered though kept under that liquid.

4. When heat is applied to wax it becomes soft; and at
the temperature of 142°, if unbleached, or of 155° if
bleached,‡ it melts into a colourless transparent fluid, which
concretes again, and resumes its former appearance as the
temperature diminishes. If the heat be still farther in-
creased, the wax boils and evaporates; and if a red heat be
applied to the vapour, it takes fire and burns with a bright
flame. It is this property which renders wax so useful for
making candles.

Action of alcohol. 5. Wax is scarcely acted on by alcohol when cold, but
boiling alcohol dissolves it. This was known to Neumann,§
and has been lately verified by Dr. Bostock.‖ Rather
more than 20 parts of alcohol are necessary to dissolve 1
part of wax; and as the solution cools, the greater part of
the wax precipitates, and the remainder is thrown down by
water. **

6. Ether has but little action on wax while cold ; but when
assisted by heat, it takes up about $\frac{1}{20}$th of its weight of it,
and lets the greatest part precipitate on cooling.††

Dr. John ascertained that when bees wax, or the wax of
the myrica cordifolia is digested in a sufficient quantity of
boiling alcohol, it is divided into two distinct substances.
One of these substances is taken up by the boiling alcohol
while the other remains undissolved. To the first of these
bodies he has given the name of *cerin* to the second that of
myricin.

Cerin. *Cerin* he distinguishes by the following properties. It is
soluble in fixed and volatile oils : from the last it precipitates
in greazy looking grains. Insoluble in water, cold alcohol,
and ether; soluble in hot alcohol and ether, and precipitating
again as the liquids cool. Melts between 108° and 140°.

* Bostock, Nicholson's Jour. iv. 130.
† Fabroni, Crell's Annals, 1797, ii. 125.
‡ Bostock, Nicholson's Jour. i. 71.
§ Neumann's Chemistry, p. 331.   ‖ Nicholson's Jour. iv. 133.
** Nicholson's Jour. iv. 133.   †† Id. ibid.

Of the specific gravity 1·000. Of the consistence of wax. Chap. I. Unites with caustic alkalies, and forms a soap.

The characters of *myricin* are as follows. Insoluble in Myricin. water, ether, and alcohol, both hot and cold. Soluble in fixed and volatile oils : does not precipitate from the former of these. Melts between 100° and 140°. Somewhat glutinous; but of the consistence of wax. Specific gravity 0·900.*

Chevreul has given the name of *cerin* to a substance which he extracted from cork, and which possessed the following properties. It is white and in small needles. It does not melt in boiling water; but becomes soft and sinks to the bottom of that liquid; while wax melts at 145° and swims upon the surface of water. When heated or distilled, it undergoes nearly the same changes as wax. It is rather more soluble in alcohol than wax. Nitric acid gradually dissolves it, and converts a portion of it into oxalic acid. It does not dissolve in an alcoholic solution of potash.†

7. Wax combines readily with fixed oils when assisted by heat, and forms with them a substance of greater or less consistency according to the quantity of oil. This com- position, which is known by the name of *cerate*, is much Cerate. employed by surgeons.

The volatile oils also dissolve it when heated. This is well known, at least, to be the case with oil of turpentine. A part of the wax precipitates usually as the solution cools, but of a much softer consistence than usual, and therefore containing oil.

8. The fixed alkalies combine with it, and form a com- Action of pound which possesses all the properties of common soap. Alkalies. When boiled with a solution of fixed alkalies in water, the liquid becomes turbid, and after some time the soap sepa- rates and swims on the surface. It is precipitated from the alkali by acids in the state of flakes, which are the wax very little altered in its properties.‡ Punic wax, which the an- cients employed in painting in encausto, is a soap composed of 20 parts of wax and one of soda. § Its composition was ascertained by Mr. Lorgna.||

* John's Chemische tabellen der Pflanzenanalysen, p. 9.
† Annals of Philosophy, ix. 53. ‡ Nicholson's Jour. iv. 132.
§ Pliny, lib. xxi. c. 14. || Jour. de Phys. Nov. 1785.

Book IV.   When boiled with liquid ammonia, it forms a kind of soapy emulsion. As the mixture cools, the greatest part of the compound rises to the surface in the state of white flakes. This soap is scarcely soluble in water.*

9. The acids have but little action on wax; even chlorine, which acts so violently on most bodies, produces no other change on it than that of rendering it white. This property which wax possesses, of resisting the action of acids, renders it very useful as a lute to confine acids properly in vessels, or to prevent them from injuring a common cork.

10. Lavoisier endeavoured to ascertain the composition of bees wax, by burning a quantity of it in oxygen gas, and determining the proportions of carbonic acid, and water formed. But pneumatic chemistry had not at that time made sufficient progress to enable him to give his experiments the requisite degree of precision. Gay-Lussac and Thenard analysed it by burning a determinate quantity along with chlorate of potash in a proper vessel, and ascertaining the quantity of carbonic aid formed.†   According to their experiments 100 parts of wax are composed of

Composition.

Oxygen .... 5·544
Hydrogen ...... 12·672
Carbon .... 81·784

As we are ignorant of the number which represents the weight of an atom of wax, we cannot from this analysis determine the number of atoms of each of these bodies that enter into its composition. But the smallest number of atoms, which will nearly correspond with the proportions obtained by -GayLussac and Thenard, are,

1 Atom oxygen   = 1   .... 5·48
20 Atoms carbon   = 15   .... 82·19
18 Atoms hydrogen = 2·25 .... 12·33
——   ———   ———
39   18·25   100·00

According to this supposition wax is a compound of 39 atoms, and the weight of an integrant particle of it is 18·25. From the experiments of Chevreul on soaps, there is some reason for believing that the weight of an atom of

* Bostock, Nicholson's Jour. iv. 134.
† Recherches Physico-chimiques, ii. 316.

wax is nearly double the number here assigned, or 36. If this number were accurate its true constituents would be,

$$
\begin{array}{rl}
2 \text{ atoms oxygen} & = \ 2 \\
40 \text{ atoms carbon} & = 30 \\
32 \text{ atoms hydrogen} & = \ 4 \\
\hline
& \quad 36
\end{array}
$$

11. Wax possesses all the essential properties of fixed oil. We must therefore consider it as a fixed oil rendered concrete. Now that species of fixed oils, distinguished by the epithet *fat*, have the property of becoming concrete, and assuming the appearance of wax, when exposed long to the air, in consequence, it is supposed, of the absorption of oxygen. Hence probably the difference between wax and fixed oils consists in the oxygen which it contains as a component part. The wax at its first formation was in all probability in the state of a fixed oil; but by the absorption of oxygen it gradually concreted into wax. Wax, then, may be considered as a fixed oil satured with oxygen.

12. It is natural to suppose, if this theory be just, that fixed oil will occur in plants in various states of hardness: and this accordingly is the case. Sometimes it is of the consistency of butter, and this is denominated a *butter*; thus we have the butter of *cacao*, the butter of *coco*, the butter of *galam*. Sometimes it is of a greater consistency, and then is denominated *tallow*; thus we have the tallow of the *croton*, extracted by boiling water from the fruit of the *croton sebifera*. When its consistency is as great as possible, it then takes the appellation of *wax*. Thus we have the *myrtle wax* of America, extracted from the seeds of the *myrica cerifera*, and the *pela* of the Chinese. The species of wax, then, which exist in the vegetable kingdom, may possibly be as numerous as the fixed oils. Let us take a view of some of the most remarkable.

Bees wax is the species whose properties have been described in the former part of this section.

13. The myrtle wax of North America is obtained from the *myrica cerifera*. We are indebted to Dr. Bostock * and Mr. Cadet † for a very exact account of its properties and extraction. The *myrica cerifera* is a shrub which grows

Varieties of wax.

Myrtle wax.

* Nicholson's Jour. iv. 130. † Ann. de Chim. xliv. 160.

Book IV. abundantly in Louisiana and other parts of North America. It produces a berry about the size of a pepper corn. A very fertile shrub yields nearly seven pounds. The berries are picked off, thrown into a kettle, and covered with water to the depth of about half a foot. The kettle is then boiled, and the berries stirred and squeezed against the sides of the vessel. The wax which they contain is melted out and swims on the surface. It is skimmed off, passed through a cloth, dried, melted again, and cast into cakes. From the observations of Cadet, we learn that the wax forms the outer covering of the berries. The wax thus obtained is of a pale-green colour. Its specific gravity is 1·0150. It melts at the temperature of 109° : when strongly heated it burns with a white flame, produces little smoke, and during the combustion emits an agreeable aromatic odour. Water does not act upon it. Alcohol, when hot, dissolves $\frac{1}{20}$th of its weight, but lets most of it fall again on cooling. Hot ether dissolves about $\frac{1}{4}$th of its weight ; and when slowly cooled, deposits it in crystalline plates, like spermaceti. The ether acquires a green-colour, but the wax becomes nearly white. Oil of turpentine, when assisted by heat, dissolves it sparingly. Alkalies act upon it nearly as on bees wax. The same remark applies to acids. Sulphuric acid, when assisted by heat, dissolves about $\frac{1}{12}$th of its weight, and is converted into a thick dark-brown mass.[*] Mr. Hatchett has detected a substance precisely similar to myrtle wax in *lac*.[†] It probably exists in many vegetables.

Brazil wax.   14. Mr. Brande in 1811, published a chemical examination of wax from Brazil, the produce of an unknown tree in that country. It had a greenish colour, was insoluble in water, but soluble in alcohol, ether, and oils. Its specific gravity was 0·980. It melted at the temperature of 206°. It could not be made to form a soap with the fixed alkalies ; but answered remarkably well for candles.[‡]

Wax from rose and lavender oil.   15. Dr. Macculloch found a waxy substance in the oil of roses and of lavender. It was precipitated from both by cold, and likewise by the addition of alcohol. Its colour is white ; it has a greasy feel, swims on sulphuric ether,

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    * Bostock, Nicholson's Jour. iv. 130.
    † Analytical Experiments on Lac, Phil. Trans. 1804.
    ‡ Nicholson's Jour. xxxi. 14.

and crystallizes in shining scales. It melts at 96°. It dissolves in alcohol and ether, and seems to approach nearer spermaceti in its properties than wax.* Chap. I.

16. The Chinese extract a wax from various vegetables, which they manufacture into candles, and of which they form many of the delicate ornaments which are brought to Europe.†

17. Wax has been detected by Proust in the green fecula of many plants; the cabbage for instance. He thinks that it forms a constituent of the pollen of all flowers, and that the bees collect it along with the gluten of the pollen, which, according to him, serves them for food.‡ But there is undoubted evidence that wax is actually formed by bees. The observations of Mr. John Hunter led him to conclude that it comes from under the scaly rings which cover their hinder parts. In the green fecula of plants.

Proust has also detected wax covering the rind of resins, plums, oranges, and other similar fruits.§ In short, it seems to be one of the most abundant of vegetable principles.

SECT. XXIV.

OF CAMPHOR.

THE substance called *camphor*, though unknown to the Greeks and Romans, seems to have been long known in the East. When it was first brought to Europe does not appear, though it seems to have been introduced by the Arabians. Ætius is the first person who takes notice of it. It is mentioned in the writings of Paracelsus, in such a manner as to lead to the supposition that it was in common use in his time. Chemists sometimes arranged it among resins, sometimes among volatile oils, || till Neumann published his dissertation on it in 1725.** He there examined its properties in detail, and demonstrated that they differed History.

* Phil. Mag. xxxix. 123.
† See Phil. Trans. 1753, p. 253; in which Father d'Incarville gives some account of the tallow-tree, and mode of extracting the tallow or wax.
‡ Jour. de Phys. lvi. 87, and 111. § Ibid.
|| Hoffmann, Observ. Phys. Chym. Selec. p. 44.
** Phil. Trans. xxxii. 321.

Book IV. from those of every other substance; and concluded in consequence, that camphor must be considered as a peculiar vegetable principle. To Neumann, then, we are indebted for the first correct experiments on the properties of camphor.

How procured. It comes to Europe chiefly from Japan. It is obtained from *laurus camphora*, a tree common in the East, by distilling the wood along with water in large iron pots, on which are fitted earthen heads stuffed with straw. The camphor sublimes, and concretes upon the straw in the form of a grey powder.* It is afterwards refined in Europe by a second sublimation. The vessels are of glass, and somewhat of the shape of a turnip, with a small mouth above loosely covered with paper. According to Ferber, about ¼th of pounded chalk is mixed with the crude camphor;† but others assure us that there is no addition whatever employed. According to Lewis, nothing more is necessary than a proper regulation of the fire;‡ and Professor Robison, who witnessed the process as well as Neumann, informs us, that the camphor in the subliming vessel is in a liquid state, which it could scarcely be if quicklime were employed, at least in any considerable quantity.§

Properties. 1. Camphor thus refined is a white brittle substance, having a peculiar aromatic odour, and a strong hot acrid taste. Its specific gravity is 0·9887. ||

It is not altered by atmospheric air; but it is so volatile, that if it be exposed during warm weather in an open vessel, it evaporates completely. When sublimed in close vessels it crystallizes in hexagonal plates or pyramids. **

2. It is insoluble in water; but it communicates to that liquid a certain portion of its peculiar odour. ††

Action of alcohol. 3. It dissolves readily in alcohol, and is precipitated again by water. According to Neumann, well rectified alcohol dissolves three-fourths of its weight of camphor.

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* Neumann's Chem. p. 319.   † Gren's Handbuch, ii. 219.
‡ Neumann, ibid.   § Black's Lectures, ii. 351.
|| According to Brisson. Dr. Shaw states it at 0·996, (Shaw's Boyle, ii. 346;) and this has been copied into most of the recent chemical books. Probably it varies in its density considerably.
** Romieu.
†† From the experiments of Cadet it appears, that a French pint of water dissolves about 16 grains of camphor, and that the camphor may be precipitated by pure potash. Ann. de Chim. lxii. 132.

By distillation the alcohol passes over first, and leaves the camphor. This property affords an easy method of purifying camphor. Dissolve the camphor in alcohol, distil off the spirit, and melt the camphor into a cake in a glass vessel.* If the alcoholic solution of camphor be diluted with water as much as possible, without causing the camphor to precipitate, small crystals of camphor resembling feathers gradually form. †

4. Camphor is soluble also in oils, both fixed and volatile. If the solution be made by means of heat, as it cools part of the camphor precipitates, and assumes the form of plumose or feather-like crystals. ‡

Oils.

5. Camphor is not acted on by alkalies, either pure or in the state of carbonates. Pure alkalies indeed seem to dissolve a little camphor; but the quantity is too small to be perceptible by any other quality than its odour. § Neither is it acted on by any of the neutral salts which have hitherto been tried.

Alkalies.

6. Acids dissolve camphor without effervescence, and in general it may be precipitated unaltered from the recent solution.

Acids.

To Mr. Hatchett we are indebted for an accurate investigation of the action of sulphuric acid on camphor. Upon a hundred grains of powdered camphor he poured an ounce of sulphuric acid. The camphor immediately became yellow, and gradually dissolved while the acid changed, first to brownish-red, and afterwards to brown. In about an hour the liquid became blackish-brown, and began to emit abundance of sulphurous acid gas. In four hours the whole appeared like a thick black liquid, and no other smell except that of sulphurous acid could be distinguished in it. As during two days no farther alteration took place, the alembic containing the solution was put upon a sand bath moderately warm, by which means an additional quantity of sulphurous acid gas was driven off. After two days the liquid was slowly mixed with six ounces of water. It

Sulphuric acid.

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* This process, proposed by Lewis (Neumann's Chem. p. 320,) is surely preferable to that of Trommsdorf, who precipitates the camphor by water from the alcohol, and then melts it into a cake. See Gren's Handbuch, ii. 220.

† Romieu, Mem. Par. 1756, p. 41.   ‡ Romieu, ibid.

§ Bouillon la Grange. Ann de Chim. xxiii. 154.

became reddish-brown, a considerable coagulum of the same colour subsided, the sulphurous acid smell became imperceptible, and was succeeded by a smell similar to that of a mixture of the oils of lavender and peppermint. The whole was now slowly distilled. The water which came over had the same smell as the original liquid, and there floated over it a little yellowish oil. A blackish-brown mass remained behind, not acted on by water; but alcohol extracted a resinous substance, and acquired a blackish-brown colour. What remained was charcoal. Thus, by the action of sulphuric acid, the camphor was decomposed and converted into oil, blackish-brown resin, and charcoal. The proportion of each was as follows:

Yellow oil . . . . 3 grains.
Charcoal. 53
Resinous substance 49
_____
105

Making an increase of five grains, either from water which was retained by the resinous-like substance, or from oxygen with which it had combined.

The resinous-like substance, thus obtained, was in reality a species of artificial tannin. It was very brittle, had the odour of caromel, and an astringent taste. It dissolved in cold water, and the solution precipitated iron, lead, tin, and lime, dark brown. It precipitated gold in the metallic state, threw down isinglass in the state of a blackish insoluble substance, and had the property of converting skin into leather. A small quantity of nitric acid converted it into the artificial tannin obtained from charcoal by nitric acid. *

From the farther researches of Chevreul on this subject, it appears that when sulphuric acid is distilled off camphor there is formed, 1. A volatile oil which has the odour of camphor: 2. A charry matter which is a combination of sulphuric acid and a hydrogureted charcoal. 3. An astringent substance which is likewise a compound of sulphuric acid and a charcoal still more hydrogureted than the preceding. The charry residuum is not sensibly soluble

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* Hatchett's additional Experiments on artificial Tannin, Phil. Trans. 1805.

in water. When distilled it gives sulphurous acid, carbonic acid, and leaves a residue which is a compound of carbon and sulphur.*

Nitric acid dissolves camphor readily, and in great abundance. The solution separates into two portions; that which contains the camphor, and most of the acid, floats upon the top of the other in the form of a very pale yellow oil. This solution is known by the name of *oil of camphor*. Water and several metals precipitate the camphor unaltered.† Alcohol combines with the oil of camphor. When this solution of camphor in nitric acid is long kept, a portion of the camphor separates in crystals, and swims on the surface, and a small portion is converted into camphoric acid.‡

Muriatic, sulphurous, and fluoric acids, in the state of gas, dissolve camphor. When water is added, the camphor appears unaltered in flakes, which swim on the surface of the water. § It is dissolved also by water impregnated with carbonic acid gas, ‖ by acetic acid,** and probably by all acids.

7. When heat is applied to camphor it is volatilized. If the heat be sudden and strong, the camphor melts before it evaporates; and it melts, according to Venturi, at the temperature of 300°; according to Romieu, at 421°.†† It catches fire very readily, and emits a great deal of flame as it burns, but it leaves no residuum. It is so inflammable that it continues to burn even on the surface of water. When camphor is set on fire in a large glass globe filled with oxygen gas, and containing a little water, it burns with a very bright flame, and produces a great deal of heat. The inner surface of the glass is soon covered with a black powder which has all the properties of charcoal; a quantity of carbonic acid gas is evolved; the water in the globe acquires a strong smell, and is impregnated with carbonic acid and camphoric acid. ‡‡

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* Ann de Chim. lxxiii. 167.   † Neumann's Chemistry, p. 321.

‡ Planche found these changes in a vial of oil of camphor, which had been kept unopened for 14 years. Ann. de Chim. xliii. 346.

§ Fourcroy.   ‖ Jour. de Phys. lii. 67.

** Phil. Mag. xv. 156. Aromatic vinegar consists chiefly of this compound.   †† Mem. Par. 1756, p. 444.

‡‡ Bouillon la Grange, Ann. de Chim. xxiii. 168.

If two parts of alumina and one of camphor be formed into a paste with water, and distilled in a glass retort, there comes over into the receiver (which should contain a little water, and communicate with a pneumatic apparatus) a volatile oil of a golden yellow colour, a little camphoric acid, which dissolves in the water, and a quantity of carbonic acid gas and carbureted hydrogen gas, which may be collected by means of a pneumatic apparatus. There remains in the retort a substance of a deep black colour, composed of alumina and charcoal. By this process, from 122·284 parts of camphor M. Bouillon la Grange, to whom we are indebted for the whole of the analysis of camphor, obtained 45·856 parts of volatile oil and 30·571 parts of charcoal. The proportion of the other products was not ascertained.*

From this analysis, M. Bouillon la Grange concludes that camphor is composed of volatile oil and charcoal or carbon combined together. We learn from his experiments, that the ultimate ingredients of camphor are carbon and hydrogen; and that the proportion of carbon is much greater than in oils.

Species of camphor :

8. There are several species of camphor which have been examined by chemists, and which differ considerably from each other in their properties. The most remarkable are *common camphor*, the *camphor of volatile oils*, and the *camphor* obtained by treating *oil of turpentine* with *muriatic acid.*

1. Common camphor;

9. Common camphor, obtained by distillation from the *laurus camphora*, is the substance which has been described in the preceding part of this Section. In Borneo and Sumatra camphor is procured from the *laurus sumatrensis*; but as none of this camphor is brought to Europe, we do not know how far it agrees with common camphor in its properties. The *laurus cinnamomum* likewise yields camphor.

2. Camphor from oils;

10. The second species of camphor seems to exist in a great variety of plants, and is held in solution by the volatile oils extracted from them. Neumann obtained it from oils of thyme, marjoram, cardomum;† Hermann, from

* Bouillon la Grange, Ann. de Chim. xxiii. 157.
† Phil Trans. 1725, p. 321.

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oils extracted from various species of mint.* Cartheuser obtained it from the roots of the *muranta galanga, kæmpferia rotunda, amomum zinziber, laurus cassia,* † and rendered it probable that it is contained in almost all the labiated plants. It has been supposed to exist in these plants combined with volatile oil. Proust has shown how it may be extracted, in considerable quantity, from many volatile oils. ‡ All that is necessary, is to expose the oil to the open air at a temperature between 22° and 54°; the oil gradually evaporates, and the camphor crystallizes. By this process he obtained from the oil of rosemary $\frac{1}{10}$th of its weight of camphor, from that of sweet marjoram $\frac{1}{10}$th, from oil of sage $\frac{1}{8}$th, and from oil of lavender more than $\frac{1}{4}$th. By distilling the oil in a water-bath, some degrees under the boiling point, till one-third of the oil comes over, part of the camphor is found crystallized in the still vessel. This being removed, and the oil again distilled as before, more camphor crystallizes. By three such processes the whole of the camphor is obtained from the oil. The camphor is then purified by mixing it with a little dry lime, and subliming it.

From the observations of Mr. John Brown, there is reason to believe that the camphor from oil of thyme differs from common camphor in several respects. It does not appear to form a liquid solution either with nitric or sulphuric acid; nor is it precipitated from nitric acid in powder like common camphor, but in a glutinous mass. §

11. The artificial camphor yielded by oil of turpentine, when saturated with muriatic acid gas, was discovered by Mr. Kind, apothecary in Eutin, while employed in making a medicine called the *liquor arthriticus Pottii.* He put a quantity of oil of turpentine into a Woulfe's bottle, and caused a current of muriatic acid gas, separated from common salt by sulphuric acid, to pass through it. The salt used was of the same weight with the oil of turpentine. At first the oil became yellow, then brown, and at last became almost solid, from the formation of a great number of

3. Artificial camphor.

How procured.

* Junker, Conspectus Chemiæ, ii. 100.

† De Genericis quibusdam Plantarum Princip. 1754; as quoted by Gren, Handbuch, ii. 221.

‡ Ann. de Chim. iv. 179.   § Phil. Trans. 1725, xxxiii. 361.

crystals in it, which possessed the properties of camphor.[*] This curious experiment was repeated by Trommsdorf with a similar result. He examined the camphoric crystals obtained, and found them in most respects to agree with common camphor, though in some they differed.[†] The society of apothecaries at Paris, on being informed of these particulars, appointed Messrs. Cluzel, Chomet, and Boullay, to examine the subject. The result of their labours has been given to the world by Boullay.[‡] They ascertained the proportion of camphor yielded by oil of turpentine, the best dose of muriatic acid gas, examined the properties of the camphoric production, and endeavoured to explain the way in which it had been formed. The experiment of Kind was repeated by Hagen in 1804;[§] and more lately, a set of experiments on the same subject was made by Gehlen, Schuster, and Pesth, chiefly in order to elucidate the theory of the process.[||] Thenard has repeated them with the same object.[**]

The proportion of muriatic gas found to answer best, is what can be separated by sulphuric acid and heat from a quantity of common salt equal in weight to the oil of turpentine employed. The camphor produced amounts nearly to one-half of the oil of turpentine. The French apothecaries put into Woulfe's bottle four pounds of the oil of turpentine, and into a tubulated retort four pounds of common salt, and two pounds of sulphuric acid, and drove off the muriatic acid gas by means of heat. It was totally absorbed by the oil, the bulk of which was augmented by $\frac{1}{10}$th, while it became at the same time very hot. Its colour became brown; it retained its transparency; and drops of oil gradually formed at the bottom of it. In 24 hours it deposited regular crystals; which, being separated from the brown liquid with which they were mixed, and dried on blotting paper, weighed 24 ounces. The liquor being left for some days in a cellar, deposited four ounces more of the same crystals; and by exposure to an artificial cold of about 14°, two ounces more were obtained, making a total 30 ounces, or $1\frac{7}{8}$lb. from the four pounds of oil of turpen-

* Trommsdorf's Jour. de Pharmacie, xi. 132 ; as quoted in Gehlen's Jour. vi. 459.   † Ibid.   ‡ Ann. de Chim. li. 270.
    § Gehlen's Jour. ii. 237. || Ibid. vi. 470.
    ** Mem. d'Arcueil, ii. 29.

tine. No additional crystals were obtained by increasing the quantity of gas; but the French chemists did not find that the produce of camphor was diminished by this augmentation, as had been concluded by Trommsdorf from his trials.

The camphor thus procured was very white; it had a peculiar odour, in which that of the oil of turpentine could be distinguished. When washed with water, it became beautifully white, and gave no longer signs of containing an acid, but still had the smell of oil of turpentine. Water containing some carbonate of potash deprived it of part of this odour, but not the whole. When mixed with its own weight of charcoal powder, wood-ashes, quicklime, or porcelain clay, and sublimed, it was obtained in a state of purity.

Its smell when pure resembles that of common camphor, but is not so strong. Its taste also resembles that of camphor. It swims on water, to which it communicates its taste, and burns upon its surface. It dissolves completely in alcohol, and is precipitated by water. Nitric acid, of the specific gravity 1·261, had no action on it, though it readily dissolves common camphor; but concentrated nitric acid dissolves it with the disengagement of nitrous gas; and water does not precipitate it from its solution as it does common camphor. Acetic acid does not dissolve it. When heated it sublimes without decomposition; and when set on fire burns like camphor.

Such are the properties of this artificial camphor, as far as they have been investigated. We see from them that it resembles common camphor, except as far as regards the action of acids. In the experiment of Thenard, the residual liquid was not brown but colourless. He ascribes the brown colour of it, in preceding experiments, to the oil of turpentine used containing some resin mixed with it, whereas his had been purified by distilling it. According to him the oil of turpentine is not decomposed by this process. The residual liquid, he thinks, may be owing to the presence of some foreign oil in oil of turpentine. When this residual liquid is exposed to the air for some days it loses its acid properties, though it still contains abundance of acid. But the acid is neutralized by the oil.

Gehlen ascertained that neither fluoric acid gas, sulphur-

Book IV. ous acid gas, nor ammoniacal gas, produce any such decomposition in oil of turpentine. Neither is any such change produced by the action of chlorine gas;* but when oil of turpentine is distilled slowly at a heat of 122°, a number of crystals of camphor sublime from it. † No other oils tried yielded camphor when impregnated with muriatic acid gas. ‡

12. Camphor is much used in medicine. It is a powerful stimulant; it is considered as peculiarly efficacious in diseases of the urinary organs; it is often serviceable in mania, and procures sleep when every other medicine fails.

SECT. XXV.

OF BIRD-LIME.

THE vegetable principle to which I give the name of *bird-lime*, was first examined by Vauquelin, who found it Discovery. possessed of properties different from every other. It was found collected on the epidermis of a plant brought to Europe by Michaud, and called *robinia viscosa* by Cels; constituting a viscid substance, which made the fingers adhere to the young twigs. § From the analysis of *bird-lime* by Bouillon la Grange, it is obvious that it owes its peculiar properties to the presence of an analogous substance, which indeed constitutes the essential part of that composition.‖ Hence the reason why I have given the name of *bird-lime* to the principle itself.

1. Natural   1. Natural bird-lime (or that which exudes spontane-
bird-lime.   ously from plants) possesses the following properties :

Its colour is green; it has no sensible taste or smell; is extremely adhesive; softens by the heat of the fingers, and sticks to them with great obstinacy. When heated it melts, swells up, and burns with a considerable flame, leaving a bulky charcoal behind it. It does not dissolve in water; alcohol has but little action on it, especially when cold. By the assistance of heat it dissolves a portion of it; but

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* Boullay, Ann. de Chim. li. 283.   † Boullay, Ibid.
‡ Ibid.   § Ann. de Chim. xxviii. 223.
‖ Nicholson's Jour. xiii. 144.

on cooling, allows the greatest part to precipitate again. When exposed to the air it continues glutinous, never becoming hard and brittle like the resins.

It combines readily with oils. Ether is its true solvent, dissolving it readily without the assistance of heat. The solution is of a deep green colour. The alkalies do not combine with it; the effect of the acids was not tried.* These properties are sufficient to distinguish bird-lime from every other vegetable principle.

It is not unlikely that the viscid substance which covers the stem of the *lychnis viscaria, saxifraga tridactylites,* and a few other plants common in this country, consists of this vegetable principle. It has not hitherto, as far as I know, been examined by any chemist.

2. Artificial bird-lime is prepared from different sub- stances in different countries. The berries of the misletoe are said to have been formerly employed. They were pounded, boiled in water, and the hot water poured off. At present bird-lime is usually prepared from the middle bark of the holly. The process followed in England, as described by Geoffroy, is as follows : The bark is boiled in water seven or eight hours till it becomes soft. It is then laid in quantities in the earth, covered with stones, and left to ferment or rot for a fortnight or three weeks. By this fermentation, it changes to a mucilaginous consistency. It is then taken from the pits, pounded in mortars to a paste, and well washed with river water. Bouillon la Grange informs us, that at Nogent le Rotrou bird-lime is made by cutting the middle bark of the holly into small pieces, fermenting them in a cool place for a fortnight, and then boiling them in water, which is afterwards evaporated. At Commerci various other plants are used. †

Bouillon la Grange made bird-lime for the purpose of analysis by the following process. He bruised a sufficient quantity of the middle bark of the holly, boiled it in water for four or five hours, and then deposited it in pits placed in earthen pans, where it continued, being moistened occasionally with water till it became viscous. Lastly, it was freed from all heterogeneous substances by washing it with

* Vauquelin, Ann. de Chim. xxviii. 254.
† Nicholson's Jour. xiii. 145.

pure water. Thus prepared, it resembled the bird-lime of Commerci very exactly.*

Its colour is greenish, its flavour sour, and its consistence gluey, stringy, and tenacious. Its smell is similar to that of linseed oil. When spread on a glass plate and exposed to the air and light it dries, becomes brown, loses its viscidity, and may be reduced to powder; but when water is added to it, the glutinous property returns. It reddens vegetable blues.

When gently heated it melts and swells, and emits an odour like that of animal oils. When heated on red hot coals, it burns with a lively flame, and gives out a great deal of smoke, leaving a white ash, composed of carbonate of lime, alumina, iron, sulphate, and muriate of potash.

Water has little action on bird-lime. When boiled in water the bird-lime becomes more liquid, but recovers its original properties when the water cools. The water, by this treatment, acquires the property of reddening vegetable blues, and when evaporated leaves a mucilaginous substance, which may be likewise separated by alcohol.

A concentrated solution of potash forms with bird-lime a whitish magma, which becomes brown by evaporation, while ammonia separates. The compound thus formed is less viscid than bird-lime, and in smell and taste resembles soap. In alcohol and water it dissolves almost completely, and possesses properties similar to those of soap.

Weak acids soften bird-lime and partly dissolve it; strong acids act with more violence. Sulphuric acid renders it black; and when lime is added to the solution, acetic acid and ammonia separate. Nitric acid cold has little effect; but when assisted by heat it dissolves the bird-lime; and the solution, when evaporated, leaves behind it a hard brittle mass. By treating this mass with nitric acid, a new solution may be obtained, which by evaporation yields malic and oxalic acids, and a yellow matter which possessed several of the properties of wax. Cold muriatic acid does not act on bird-lime; hot muriatic acid renders it black.

Bird-lime, when treated with chlorine, became white, and is divided into hard compact masses, having unaltered bird-lime in their centre. This white substance

* Bouillon la Grange, Nicholson's Jour. xiii. 145.

may be pulverised; it is insoluble in water, does not melt when heated; and when treated with nitric acid, it neither becomes yellow, nor does it yield resin.

Acetic acid softens bird-lime, and dissolves a certain portion of it. The liquid acquires a yellow colour. Its taste is insipid. When carbonate of potash is dropped into this solution, no precipitate falls. By evaporation it yields a resinous-like substance.

Some of the metallic oxides are reduced when heated with bird-lime. Litharge combines with it, and forms a kind of plaster.

Alcohol of the specific gravity 0·817 dissolves bird-lime at a boiling heat. On cooling it lets fall a yellow matter similar to wax. The filtered liquid is bitter, nauseous, and acid. Water precipitates a substance similar to resin.

Sulphuric ether dissolves bird-lime readily, and in great abundance. The solution is greenish. When mixed with water, an oily substance separates, which has some resemblance to linseed oil. When evaporated a greasy substance is obtained, having a yellow colour and the softness of wax. Oil of turpentine dissolves bird-lime readily.

Such are the properties of artificial bird-lime, as far as they have been investigated by Bouillon la Grange.* It is obvious that it contained acetic acid, mucilage, and several alkaline and earthy bodies, which must be considered as foreign substances. When these are removed, the close analogy between artificial and natural bird-lime is sufficiently obvious.

SECT. XXVI.

OF RESINS.

It is at present the opinion of chemists, that *resins* stand in the same relation to the *volatile* oils that *wax* does to the *fixed*. Wax is considered as a fixed oil saturated with oxygen; resins, as volatile oils saturated with the same principle.

The resins are very numerous; and on account of the

* Nicholson's Jour. xiii. 146.

Book IV. various purposes to which they are applied, and the peculiarity of their properties, constitute one of the most important genera of vegetable substances. Till lately they have been very much overlooked by chemists, who satisfied themselves with picking up doubtful information from artists and manufacturers. Many erroneous opinions concerning them have of course been admitted into every system of chemistry. The subject has lately engaged the attention of Mr. Hatchett, whose happy talent for observation peculiarly fitted him for the task. To that gentleman I am indebted for some of the most important facts in this section.

Origin. Resins often exude spontaneously from trees; they often flow from artificial wounds, and not uncommonly are combined at first with volatile oil, from which they are separated by distillation. The reader can be at no loss to form a notion of what is meant by *resin*, when he is informed that common *rosin* furnishes a very perfect example of a resin, and that it is from this substance that the whole genus derived their name: for rosin is frequently denominated *resin*.

I. Resins may be distinguished by the following properties :

Properties. 1. They are solid substances, naturally brittle; have a certain degree of transparency, and a colour most commonly inclining to yellow. Their taste is more or less acrid, and not unlike that of volatile oils; but they have no smell unless they happen to contain some foreign body. They are all heavier than water. They are all non-conductors of electricity; and when excited by friction, their electricity is negative.

Specific gravity. 2. Their specific gravity varies considerably. The following table exhibits a view of the specific gravity of such of the resins as have been hydrostatically examined.*

Elemi . . . . 1·0182
Anime . . . . 1·0284
Highgate resin . . 1·046†

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* The specific gravities in the text were ascertained by Brisson. The older writers differ so much from each other, that there is reason to suspect that the substances tried were not always those to which we at present give the same names.　　　　† By my trials.

Copal .... 1·069 *
Tacamahac ...... 1·0463
Rosin .... 1·0727
Mastich .... 1·0742
Sandarich ...... 1·0920
Lac .... 1·1390
Labdanum........ 1·1862

3. When exposed to heat they melt; and if the heat be Action of increased they take fire, and burn with a strong yellow heat. flame, emitting at the same time a vast quantity of smoke.

4. They are all insoluble in water whether cold or hot; Water. but when they are melted along with water, or mixed with volatile oil, and then distilled with water, they seem to unite with a portion of that liquid; for they become opaque, and lose much of their brittleness. This at least is the case with common rosin.

5. They are all, with a few exceptions, soluble in alcohol, Alcohol especially when assisted by heat. The solution is usually and ether. transparent; and when the alcohol is evaporated, the resin is obtained unaltered in its properties. Alcohol, according to Tingry, never takes up more than one-third of its weight of resin. When the solution is mixed with water, it becomes milky, and the resin falls in the state of a white powder. They are soluble also in sulphuric ether.

6. Several of them are soluble in fixed oils, especially in Oils. the drying oils. The greater number are soluble in the volatile oils; at least in oil of turpentine, the one commonly employed.

7. Mr. Hatchett first examined the action of fixed alka- Alkalies. lies on resins, and ascertained, contrary to the received opinion of chemists, that alkaline leys dissolve them with facility. He reduced a quantity of common rosin to powder, and gradually adding it to a boiling lixivium of carbonate of potash, a perfect solution was obtained of a clear yellow colour, which continued permanent after long exposure to the air. The experiment succeeded equally with carbonate of soda, and with solutions of pure potash or soda. Every other resin tried was dissolved as well as *rosin.* Nothing can afford a more striking proof than this, of the necessity of repeating the experiments of our predecessors before we

* By my trials.

Book IV. put implicit confidence in their assertions. Mr. Hatchett's discovery must lead to very important consequences. The well-known fact, that the soap-makers in this country constantly mix *rosin* with their soap; that it owes its yellow colour, its odour, and its easy solubility in water to this addition, ought to have led chemists to have suspected the solubility of resins in alkalies. No such consequence, however, was drawn from this notorious fact.

These alkaline solutions of resins have the properties of soap, and may be employed as detergents. When mixed with an acid, the resin is separated in flakes, usually of a yellow colour, and not much altered in its nature.

Ammonia acts but imperfectly upon resins, and does not form a complete solution of any of those bodies hitherto tried.

Acids.   8. It was the received opinion of chemists that acids do not act upon resins. This opinion seems to have been founded on the known effects of nitric acid upon oils, and on the old theory derived from that action, that resins are compounds of an oil and an acid.[*] Mr. Hatchett first ascertained this opinion also to be erroneous, and showed that most of the acids dissolve resins with facility, producing different phenomena according to circumstances.

Sulphuric acid,   When sulphuric acid is poured upon any of the resins in powder, it dissolves them in a few minutes. At first the solution is transparent, of a yellowish-brown colour, and of the consistency of a viscid oil, and the resin may be precipitated nearly unaltered by the addition of water. If the solution be placed on a sand bath, its colour becomes deeper, sulphurous acid gas is emitted, and it becomes very thick, and of an intense black.[†] If the solution, some time after it is completed, and before it has acquired the deep black colour, be edulcorated, and the residuum digested in alcohol, and the alcohol afterwards separated by distillation, the residue is in part soluble in cold water, and the portion dissolved possesses the properties of artificial tannin.[‡] Thus it appears, that sulphuric acid dissolves resins, but gradually acts upon them after the solution is completed, converting

* See Hoffman, Observ. Phys. Chim. Select. p. 55.

† Hatchett on an Artificial Tanning Substance, Phil. Trans. 1805.

‡ Hatchett's Third Series of Experiments, ibid. 1806.

them first into artificial tannin, and afterwards reducing
them to charcoal: for the last black state of the solution is
owing to the evolution of this substance. The charcoal thus
formed is dense, and burns rather like mineral than vege-
table coal. Its quantity is also very considerable. The
following table exhibits a view of the proportion of char-
coal obtained by Mr. Hatchett, by digesting different
resins in sulphuric acid, edulcorating the residue, and sepa-
rating the tannin by means of alcohol and water.* The
quantity of resin employed was always 100 grains.

Copal	67 grains.
Mastich	66
Elemi	63
Tacamahac	62
Amber	56
Rosin	43

Charcoal
evolved.

The quantity of charcoal formed by this process is very
remarkable. The same substances, when charred in the
usual way by exposure to a red heat in close vessels, yield
very little charcoal. The following table exhibits the
quantity obtained by Mr. Hatchett from 100 grains of
several of them.†

Mastich	4·50 grains
Amber	3·50
Rosin	0·65

Nitric acid likewise dissolves the resins with facility, but Nitric acid.
not without changing their nature. Mr. Hatchett was first
led to examine the action of this acid on resins, by observ-
ing that resins are thrown down by acids from their solu-
tions in alkalies in the state of a curdy precipitate; but
when nitric acid is added in excess, the whole of the preci-
pitate is redissolved in a boiling heat. This remarkable
fact, which did not hold when sulphuric or muriatic acids
were used, led him to try whether the resins were soluble
in nitric acid. He poured nitric acid of the specific gravity
1·38, on powdered rosin in a tubulated retort; and by re-
peated distillation formed a complete solution of a brownish
yellow colour. The solution took place much sooner in an

* Hatchett's Third Series of Experiments, Phil. Trans. 1806.
† Hatchett, ibid.

Book IV. open matrass than in close vessels. The solution continues permanent, though left exposed to the air. It becomes turbid when water is added; but when the mixture is boiled, the whole is redissolved. When Mr. Hatchett collected the precipitate thrown down by water by filtration, he found that it still possessed several of the properties of resin. The resin is thrown down from nitric acid by potash, soda, and ammonia; but an excess of these alkalies redissolves the precipitate, and forms brownish orange-coloured liquids. When Mr. Hatchett dissolved resin in boiling nitric acid, the solution was attended with a copious discharge of nitrous gas; and when the powdered resin was thrown into cold nitric acid, a considerable effervescence soon took place, and a porous mass was formed, commonly of a deep orange colour.

When the digestion of nitric acid upon a resinous substance is continued long enough, and the quantity of acid is sufficient, the dissolved resin is completely changed; it is not precipitated by water; and by evaporation, a viscid substance of a deep yellow colour is obtained, equally soluble in water and alcohol, and seemingly intermediate between resin and extractive.* If the abstraction of nitric acid be repeated, this substance gradually assumes the properties of artificial tannin.† Thus it appears that nitric acid gradually alters the nature of resin, producing a suite of changes which terminate in artificial tannin, upon which nitric acid has no action.

Tannin formed.

Acetic acid. Muriatic acid and acetic acid dissolve resin slowly, and it may be precipitated again from them unaltered. Mr. Hatchett, to whom we are indebted for the knowledge of all these solutions, recommends acetic acid as an excellent solvent of resins for vegetable analyses. He employed it himself with much address in his analysis of the different varieties of lac.‡

Distilla-
tion.
9. When resins are subjected to destructive distillation, we obtain, according to Gren, carbureted hydrogen and carbonic acid gas, a very small portion of acidulous water, and much empyreumatic oil. The charcoal is light and brilliant, and contains no alkali.§

* Hatchett on an Artificial Tanning Substance, Phil. Trans. 1805.
† Hatchett's Additional Experiments on Artificial Tannin, Phil. Trans. 1805.   ‡ Phil. Trans. 1804.   § Handbuch, ii. 140.

10. When volatile oils are exposed for some time to the action of the atmosphere, they acquire consistency, and assume the properties of resins. During this change they absorb a quantity of oxygen from the air. Westrumb put 30 grains of oil of turpentine into 40 cubic inches of chlorine gas. Heat was evolved; the oil gradually evaporated, and assumed the form of yellow resin. * Mr. Proust observed, that when volatile oil is exposed to the air, it is partly converted into a resin, and partly into a crystallized acid; usually the benzoic or the camphoric. Hence we see that the oil is converted into two distinct substances. During this change oxygen is absorbed; and Fourcroy has observed that a portion of water is also formed.† It is probable, from these facts, that resin is volatile oil deprived of a portion of its hydrogen, and combined with oxygen. The experiments of Mr. Hatchett have added much to the plausibility of this theory.

No doubt the different resins contain different proportions of oxygen, carbon, and hydrogen, which are the only constituents. Hitherto only two resins have been analysed with the requisite precision to enable us to estimate the number of atoms which enter into their composition. These are common *rosin* and *copal*. Rosin, according to the analysis of Gay-Lussac and Thenard, is composed of

Oxygen . . . . . . 13·337
Carbon . . . . . . 75·944
Hydrogen . . . . 10·719
_____
100·000‡

The smallest number of atoms which correspond with this analysis are the following:

2 atoms oxygen	=	2	. . . . . .	13·44
15 atoms carbon	=	11·25	. . . . . .	75·63
13 atoms hydrogen . .	=	1·625	. . . . . .	10·93
30		14·875		100·00

Whether this table exhibits its real constitution cannot

* Crell's Annals, i. 1790.   † Fourcroy, viii. 16.
‡ Recherches Physico-chimiques, ii. 313.

Book IV. be known till the weight of an atom of rosin be determined by combining it with substances with which it enters into combination in definite proportions. But we are sure that its weight is either 14·875, or some multiple of that number. From this composition, we see that it may by heat be totally converted into

Water .... 2·25
Olefiant gas .. ,.. 9·625
Carbon .... 3·000
_____
14·875

Copal, according to the experiments of the same chemist, is composed of

Oxygen ...... 10·606
Carbon ...... 76·811
Hydrogen .... 12·583
_____
100·000*

The smallest number of atoms which correspond with this analysis are

2 atoms oxygen .... = 2 ...... 10·81
19 atoms carbon .... = 14·25 ...... 77·02
18 atoms hydrogen .. = 2·25 ...... 12·17
___   _____   _____
39   18·5   100·00

Copal, according to this analysis, contains 5 atoms of hydrogen and 4 of carbon more than rosin. It may be resolved into

Water .... 2·25
Olefiant gas .... 14·00
Carbon .... 2·25
_____
18·50

11. Hermsbstadt affirms, that to know whether any vegetable substance contains resin, we have only to pour some sulphuric ether upon it in powder, and expose the infusion to the light. If any resin be present, the ether will assume a brown colour.

* Recherches Physico-chimiques, ii. 314.

II. Having now described the general properties of resinous bodies, it will be proper to take a more particular view of those of them which are of the most importance, that we may ascertain how far each possesses the general characters of resins, and by what peculiarities it is distinguished from the rest. The most distinguished of the resins are the following :

1. *Rosin.*—This substance is obtained from different spe- cies of *fir ;* as the *pinus abies, sylvestris, larix, balsamea.* It is well known that a resinous juice exudes from the *pinus sylvestris,* or common Scotch fir, which hardens into tears. The same exudation appears in the *pinus abies,* or spruce fir. These tears constitute the substance called *thus,* or common frankincense. When a portion of bark is stripped off these trees, a liquid juice flows out, which gradually hardens. This juice has obtained different names, according to the plant from which it comes. The *pinus sylvestris* yields *common turpentine ;* the *larix, Venice turpentine ;* the *balsamea, balsam of Canada,* &c. All these juices, which are commonly distinguished by the name of turpentine, are considered as composed of two ingredients; namely, oil of turpentine and rosin. When the turpentine is distilled, the oil comes over, and the rosin remains behind. When the distillation is continued to dryness, the residuum is known by the name of common rosin, or colophonium ; but when water is mixed with it while yet fluid, and incorporated by violent agitation, the mass is called *yellow rosin.* During winter the wounds made in the fir trees become encrusted with a white brittle substance called *barras,* or *galipot,* consisting of rosin united to a small portion of oil. The yellow rosin made by melting and agitating this substance in water is preferred for most purposes; because it is more ductile, owing probably to its still containing some oil.* The properties of rosin are those which have been detailed in the former part of this Section. Its uses are numerous and well known.

2. *Mastich.*—This resin is obtained from the *pistacea lentis-* *cus;* a tree which grows in the Levant, particularly in the island of Chios. When transverse incisions are made into this tree, a fluid exudes, which soon concretes into yellowish

* See Neumann's Chemistry, p. 286.

Book IV. semitransparent brittle grains.*   In this state it is sold under the name of mastich.   It softens when kept in the mouth, but imparts very little taste.   This has induced surgeons to employ it to fill up the cavities of carious teeth, which it does tolerably well.   When heated, it melts and exhales a fragrant odour.   Its taste is slight, but not unpleasant.   In Turkey great quantities of it are said still to be chewed for sweetening the breath, and strengthening the gums.   It is to this use of the resin as a masticatory that it is supposed to owe its name.†   Mastich does not dissolve completely in alcohol; a soft elastic substance separates during the solution.   This substance, in Neumann's experiments, amounted to about $\frac{1}{12}$th of the mastich ; ‡ but in those made more lately by Mr. Matthews, it was nearly a fifth.§   The nature of this insoluble portion was first examined by Kind,|| who found it possessed of all the properties of caoutchouc.   These experiments have lately been repeated by Mr. Matthews with a similar result.**   Mr. Brande, however, has observed, that when this insoluble substance is dried it becomes brittle, in which respect it differs from caoutchouc.   He has observed also, that by passing a current of chlorine gas through the alcoholic solution of mastich, a tough elastic substance is thrown down, precisely similar to the original insoluble portion.††   When mastich is distilled either with water or alcohol, nothing considerable comes over with these liquids; but Hoffman ascertained, that if the resin be first mixed in a mortar with its own weight of carbonate of potash, and afterwards distilled with alcohol, the liquid comes over both with the smell and taste of mastich.‡‡   With the other agents it exhibits the phenomena described in the former part of this section.

Contains caoutchouc. (margin note)

Sandarach. (margin note)   3. *Sandarach.*—This resin is obtained from the *thuya ar-*

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* See Neumann's Chemistry, p. 297.   † Ibid. p. 298.
‡ Ibid.   § Nicholson's Jour. x. 247.
|| Crell's Annals, 1794, ii. 185.   ** Nicholson's Jour. x. 247.
†† Phil. Mag. xxv. 111. From these experiments, together with those of Dr. Wollaston on this substance, there can be little doubt that it is a peculiar vegetable principle. It may be characterized thus : brittle, semitransparent, fusible like resins, insoluble in water and alcohol, soluble in ether.
‡‡ Hoffmann, Observ. Phys. Chim. Select. p. 68.

ticulata, which grows in Barbary.* It exudes spontane-
ously, and is usually in the state of small round tears of a
brown colour, and semitransparent, not unlike mastich,
but rather more transparent and brittle. When chewed it
does not soften as mastich does, but crumbles to powder.
Mr. Matthews found it almost completely soluble in eight
times its weight of alcohol. The residue was extraneous
matter.† It does not dissolve in tallow or oil, as common
resin does.‡ Mr. Hatchett found it soluble in alkalies and
acids with the same phenomena as common resin.§

4. *Elemi.*—This resin is obtained from the *amyris ele-* Elemi.
mifera; a tree which grows in Canada and Spanish Ame-
rica. Incisions are made in the bark during dry weather,
and the resinous juice which exudes is left to harden in the
sun. It comes to this country in long roundish cakes
wrapped in flag leaves. It is of a pale yellow colour, se-
mitransparent; at first softish, but it hardens by keeping.
Its smell is at first strong and fragrant, but it gradually di-
minishes. Neumann found that alcohol dissolved $\frac{15}{16}$ths of
this substance; the remainder consisted chiefly of impuri-
ties, and was partly taken up by water. Both water and
alcohol, when distilled with it, come over strongly impreg-
nated with its flavour. Along with the water there comes
over a fragrant volatile oil, which amounts to about $\frac{1}{16}$th
of the resin employed.‖

5. *Tacamahac.*—This resin is obtained from the *fagara* Tacama-
octandra, and likewise, it is supposed, from the *populus bal-* hac.
samifera. It comes from America in large oblong masses
wrapt in flag leaves. It is of a light brown colour, very
brittle, and easily melted when heated. When pure it has
an aromatic smell between that of lavender and musk.
When distilled along with water or alcohol, nothing comes

* Thenard, Traité de Chimie, iii. 225.
† Nicholson's Jour. x. 246.   ‡ Ibid.
§ Giese, an apothecary of Augsburg, announced in Scherer's Journal
for 1802, p. 536, that sandarach does not dissolve completely in alcohol;
that the residue amounts to about one-fifth of the whole. This residue
he considers as a peculiar substance. Mr. Matthews proved, by a set of
experiments, that the whole of this statement is inaccurate. I have no
doubt that Giese employed mastich instead of sandarach, and that the
insoluble substance detected was caoutchouc.
‖ Neumann's Chem. p. 296.

Book IV. over with these liquids. When pure it dissolves completely in alcohol, and water has no action on it.*

Animé.   6. *Animé.*—This resin is obtained from the *hymenæa courbaril*, or locust tree, which is a native of North America. Animé resembles copal very much in its appearance; but is easily soluble in alcohol, which copal is not: this readily distinguishes them. It is said to be very frequently employed in the making of varnishes. Alcohol dissolves it completely. Water, according to the experiments of Neumann, dissolves about $\frac{1}{16}$th of it; and when the decoction is evaporated, it leaves an unctuous mass, which makes the fingers oily. Alcohol distilled over it acquires both the smell and taste of animé. Water distilled from it shows on its surface a small quantity of volatile oil.†

Ladanum.   7. *Ladanum* or *labdanum.*—This resin is obtained from the *cystus creticus*, a shrub which grows in Syria and the Grecian Islands. The surface of this shrub is covered with a viscid juice, which, when concreted, forms ladanum. It is collected while moist by drawing over it a kind of rake with thongs fixed to it. From these thongs it is afterwards scraped with a knife. It is always mixed with dust and sand, sometimes in great abundance. The best is in dark coloured masses, almost black, and very soft, having a fragrant odour and a bitterish taste. The impurities, even in the best kinds, amount to about $\frac{1}{4}$th. Water dissolves rather more than $\frac{1}{12}$th of the pure portion, and the matter taken up is said to possess gummy properties. When distilled with water, a small quantity of volatile oil rises. Alcohol likewise comes over impregnated with the taste and smell of labdanum.‡

Botany Bay resin.   8. *Botany Bay resin.*—This resin is said to be the produce of the *acarois resinifera;* a tree which grows abundantly in New Holland, especially near Botany Bay. Specimens of it were brought to London about the year 1799, where it was tried as a medicine. Some account was given of it in Governor Philips's Voyage,§ and in White's Journal of a Voyage to New South Wales; ‖ but it is to Professor Lichtenstein that we are indebted for an account of its chemical properties. He obtained specimens from

* Neumann's Chem. p. 295.   † Ibid. p. 297.   ‡ Ibid. p. 295.
§ Duncan's New Dispensary, p. 60.   ‖ Appendix, p. 245.

London, and published the result of his experiments in Crell's Journal.*

The resin exudes spontaneously from the trunk of the singular tree which yields it, especially if the bark be wounded. It is at first fluid, but becomes gradually solid when dried in the sun. According to Governor Philips, it is collected usually in the soil which surrounds the tree, having doubtless run down spontaneously to the ground. It consists of pieces of various sizes of a yellow colour, unless when covered with a greenish grey crust. It is firm, yet brittle; and when pounded, does not stick to the mortar nor cake. In the mouth it is easily reduced to powder without sticking to the teeth. It communicates merely a slight sweetish astringent taste. When moderately heated, it melts; on hot coals it burns to a coal, emitting a white smoke, which has a fragrant odour somewhat like storax. When thrown into the fire, it increases the flame like pitch. It communicates to water the flavour of storax, but is insoluble in that liquid. When digested in alcohol, two-thirds dissolve: the remaining third consists of one part of extractive matter, soluble in water, and having an astringent taste; and two parts of woody fibre and other impurities, perfectly tasteless and insoluble. The solution has a brown colour, and exhibits the appearance and the smell of a solution of benzoin. Water throws it down unaltered. When distilled, the products were water, and empyreumatic oil, and charcoal; but it gives no traces of any acid, alkali, or salt, not even when distilled with water.

Twelve parts were boiled in a solution of pure soda in water.† Two parts of the resin were dissolved; the remaining ten parts were floating on the solution, cohering together in clots. No crystals were obtained by evaporating part of the solution; and when sulphuric acid was dropped into another portion, resin separated unaltered. When mixed with twice its weight of nitric acid, the resin swims unaltered on the surface; but when heat is applied, a considerable effervescence takes place. The digestion was continued till the effervescence stopped, and the resin swam on the surface of the liquid collected together in clots. It was then separated by filtration. It had lost $\frac{1}{12}$th of its

* 1799, ii. 242.

† By pure sodasalze, it is impossible to say whether Lichtenstein means the carbonate of soda or pure soda.

Book IV. weight. The resin thus treated had acquired a bitterish taste, was not so easily melted as before, and alcohol was capable of dissolving only one-half of it. The solution was brown, tasted like bitter almonds; and when mixed with water, let fall a yellow resinous precipitate of a very bitter taste. The insoluble portion mixed with water, but formed a turbid liquid, which passed through the filter. The nitric acid solution separated from the resin by filtration was transparent; its colour was yellow; its taste bitter; and it tinged substances dipped into it of a yellow colour. By evaporation it yielded oxalic acid, and deposited a yellow earthy-like powder. This last substance was insoluble in water, and scarcely soluble in alcohol. Its taste was exquisitely bitter like quassia. It mixed with the saliva, and readily stained the skin and paper yellow. The residuum continued bitter and yellow; but yielded no precipitate with potash and nitrate of lime.*

I have been thus particular in my account of Lichtenstein's experiments, on account of the very curious results which he obtained. Had he employed stronger reagents and greater heat, he would have most probably anticipated the curious discoveries of Hatchett. The bitter substance, into which he converted this resin by nitric acid, deserves particular attention. He suspects that it is capable of producing the same changes on all the resins: a conjecture which he verified with regard to *colophonium*, as he found it to yield equally a yellow bitter substance. We now know from the experiments of Hatchett, that the action of nitric acid on the resins terminates in the formation of artificial tannin, which possesses a very bitter taste.

Black poplar resin. 9. *Black poplar resin.*—In the year 1770, the black poplar was pointed out, in a German periodical work, as a tree from which abundance of wax could be obtained. It was even said, that a manufactory of candles from the wax of this tree had been established in Italy. This account having been revived in 1804, Schræder was induced to make a set of experiments on the subject. He found, that when the buds of this tree are boiled in water and properly pressed, they yield about $\frac{1}{8}$th of their weight of a yellowish-white substance, which possesses the properties of a resin, and resembles, according to him, the yellow resin of Botany Bay. When digested in water, a coloured

* Lichtenstein, Crell's Jour. 1799, ii. 242.

solution is obtained, which reddens litmus paper, which be- comes muddy by cooling, and which when evaporated deposits small crystals.*

10. *The green resin,* which constitutes the colouring matter of the leaves of trees, and almost all vegetables, is insoluble in water, and soluble in alcohol. From the experiments of Proust we learn, that when treated with chlorine it assumes the colour of a withered leaf, and acquires the resinous properties in greater perfection. †

11. *Copal.*—This substance, which deserves particular attention from its importance as a varnish, and which at first sight seems to belong to a distinct class from the resins, is obtained, it is said, from the *thus copallinum,* a tree which is a native of North America; but the best sort of copal is said to come from Spanish America, and to be the produce of different trees. No less than eight species are enumerated by Hernadez. ‡

Copal is a beautiful white resinous substance, with a slight tint of brown. It is sometimes opaque, and sometimes almost perfectly transparent. When heated it melts like other resins; but it differs from them in not being soluble in alcohol, nor in oil of turpentine without peculiar management. Neither does it dissolve in the fixed oils with the same ease as the other resins. It resembles gum animé a little in appearance; but is easily distinguished by the solubility of this last in alcohol, and by its being brittle between the teeth, whereas animé softens in the mouth.§ The specific gravity of copal varies, according to Brisson, from 1·045 to 1·139. I found it 1·069. Mr. Hatchett found it soluble in alkalies and nitric acid with the usual phenomena; so that in this respect it agrees with the other resins. The solution of copal in alkalies he found indeed opalescent, but it is nevertheless permanent. It deserves attention, that he found rosin, when dissolved in nitric acid, and then thrown down by an alkali, to acquire a smell resembling that of copal.

When copal is dissolved in any volatile liquid, and spread thin upon wood, metal, paper, &c. so that the volatile men-

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* Schræder, Gehlen's Jour. vi. 598.　　+ Jour de Phys. lvi. 106.

‡ Lewis, Neumann's Chem. p. 299. From Dr. Roxburgh's account it appears that the Indian tree *Valeria indica* yields a resin possessing properties intermediate between those of copal and amber. Nicholson's Jour. xxvii. 72.　　　　　　　　§ Ibid.

Book IV. struum may evaporate, the copal remains perfectly trans-
parent, and forms one of the most beautiful and perfect
varnishes that can well be conceived. The varnish thus
formed is called *copal varnish*, from the chief ingredient in
it. This varnish was first discovered in France, and was
long known by the name of *vernis martin*. The method of
preparing it is concealed; but different processes for dis-
solving copal in volatile menstrua have been from time to
time made public. The following are the most remarkable
of these :

Solution in When copal is kept melted till a sour smelling aromatic
linseed oil. odour has ceased to proceed from it, and then mixed with
an equal quantity of linseed oil, which has been deprived
of all colour by exposure to the sun, it unites with the oil,
and forms a varnish which must be dried in the sun.*

Japanners' I have been informed by a very ingenious japan manu-
varnish. facturer in Glasgow, that the copal varnish used by the
English japanners is made as follows : four parts by weight
of copal in powder are put into a glass matrass and melted.
The liquid is kept boiling till the fumes, condensed upon
the point of a tube thrust into the matrass, drop to the
bottom of the liquid without occasioning any hissing noise,
as water does. This is a proof that all the water is dissi-
pated, and that the copal has been long enough melted.
One part of boiling hot linseed oil (previously boiled in a
retort without any litharge) is now poured into it, and well
mixed. The matrass is then taken off the fire, and the
liquid, while still hot, is mixed with about its own weight
of oil of turpentine. The varnish thus made is transpa-
rent, but it has a tint of yellow, which the japanners en-
deavour to conceal by giving the white ground on which
they apply it a shade of blue. It is with this varnish that the
dial plates of clocks are covered after having been painted
white.

Solution in When copal is treated with oil of turpentine in close
oil of tur- vessels, the vapour being prevented from escaping, exerts a
pentine. greater pressure, and the heat rises above the boiling point.
This additional heat is said to enable the oil to dissolve
the copal. The solution, mixed with a little poppy oil,
forms a varnish which is distinguished from the *vernis mar-
tin* merely in having a very slight tinge of brown. †

The method of dissolving copal in oil of turpentine,

* Dr. Black's Lectures, ii. 359.   † Ibid.

published by Mr. Sheldrake, seems to depend upon the same principle with the last solution. On two ounces of copal, broken into small pieces, is poured a mixture of four ounces of ammonia with a pint of oil of turpentine. The whole is kept boiling very gently, so that the bubbles may be counted as they rise. If the heat be allowed to diminish, or if it be raised too high, the process stops, and cannot be again resumed. The matrass, in which the mixture is boiled, is stopped with a cork, secured in its place by a brass wire, and perforated by a pin. When the copal is nearly dissolved, the process is stopped, and the whole allowed to cool before uncorking the matrass. This varnish has a deep colour; but when spread thin and allowed to dry, it becomes colourless. Its defect is the difficulty with which it dries. This defect Mr. Sheldrake remedies by throwing the solution into its own weight of nut oil, rendered drying by white lead, and agitating till the turpentine is separated.

To dissolve copal in alcohol, Mr. Sheldrake dissolves half an ounce of camphor in a pint of that liquid, and pours the solution on four ounces of copal. The matrass is placed in a sand bath, and the process is conducted exactly as the one last described. The solution thus formed contains a great deal of copal, and forms a varnish which is perfectly colourless; but considerable heat is necessary to drive off the camphor.

Mr. Sheldrake has lately favoured the public with another and easier method of dissolving copal. This method is as follows:

" Provide a strong vessel made of tin or other metal; it should be shaped like a wine bottle, and capable of holding two quarts; it will be convenient to have a handle strongly rivetted to the neck; the neck should be long and have a cork fitted to the mouth, but a notch or small hole should be made in the cork, that when the spirit is expanded by heat, a small portion may force its way through the hole, and thus prevent the vessel from bursting.

" Dissolve half an ounce of camphor in a quart of spirit of turpentine, and put it into the vessel; take a piece of copal the size of a large walnut, reduce it to a coarse powder or very small pieces; put them into the tin bottle, fasten the cork down with a wire, and set it as quick as possible upon a fire so brisk as to make the spirit boil almost imme-

diately; then keep it boiling very gently for about an hour, when so much of the copal will be dissolved as will make a very good varnish ; or, if the operation has been properly begun, but enough of copal has not been dissolved, it may be again put on the fire, and by boiling it slowly for a longer time, it may be at last brought to the consistence desired."*

Van Mons relates another process much simpler than any of the above, which he says was taught him by Mr. Demmenie, a Dutch artist. It consists in exposing copal to the action of the steam of alcohol. A long necked matrass is filled one-fourth full of strong alcohol, and a piece of copal is suspended above the surface of the liquid at some little distance; the top of the matrass is covered with a condensator; the alcohol is kept boiling : the copal softens, and drops down into the alcohol like oil. When these drops no longer dissolve, the process must be stopped. The solution thus obtained is perfectly colourless. Copal may be dissolved in oil of turpentine by the same process.†

Demmenie's process.

The following method of making copal varnish has been recommended by Professor Lenormand. Drop upon the pieces of copal pure essential oil of rosemary. Those pieces that are softened by the oil are fit for the purpose, the others not. Reduce them to a fine powder, put this powder into a glass vessel not thicker than a finger breadth, pour oil of rosemary over it, and stir it about with a glass rod. In a short time the whole is converted into a very thick liquid. Pour alcohol on this liquid by little at a time, incorporating it, by gently agitating the vessel, till it is of the requisite thinness for use. ‡

Lenormand's process.

12. *Highgate resin.*—This substance was dug up at Highgate, near London, during the late attempt to run a tunnel through the hill. It was in small amorphous masses of different sizes. Colour a muddy-yellowish light-brown. Semi-transparent. Lustre resinous, and surface smooth, as if it had been long agitated in water. It was less easily broken than common rosin, but much more easily than copal. Softer than copal. Has a resinous and aromatic smell, especially when heated. When heated it melts and may be rendered as liquid, as water without altering its colour. When in lumps it is insoluble in water, alcohol, potash ley, acetic

* Nicholson's Jour. ix. 157.   Jour. de Chim. iii. 218.
‡ Nicholson's Jour. xxiv. 67.

acid. But ether renders it opaque and white, and quite tender; it loses its cohesion and crumbles into powder upon the least pressure between the fingers. The ether at the same time dissolves a portion which it deposits when mixed with water. Nitric acid partly dissolves and partly converts it into a red coloured substance. Water throws down the dissolved portion in the state of bitter-tasted white flocks. Sulphuric acid readily chars it when assisted by heat. When in a state of a fine powder alcohol dissolves a small portion of it. It is insoluble in potash ley.*

13. *Lac.*—This is a substance deposited on different species of trees in the East Indies, by an insect called *chremes lacca*, constituting a kind of comb or nidus. It has been imported into Europe, and extensively used from time immemorial; but it is only of late years that correct information concerning it has been obtained. For what relates to the natural history of the insect, and the mode of forming the lac, we are indebted to Mr. Ker,† Mr. Saunders,‡ and Dr. Roxburgh.§ Though very often employed in the arts, it was neglected by chemists. Geoffroy junior, indeed, published a dissertation on it, but it contains few chemical experiments. He merely subjected it to distillation, and obtained products which he thought similar to those given by wax in the same circumstances.‖ This led him to consider it as a species of wax, an opinion followed by Neumann;** but Junker,†† and most of the subsequent chemical writers, place it among the resins. Mr. Hatchett has lately examined it with his usual address, and ascertained its composition and properties.‡‡ To him we are indebted for almost every thing which we know respecting its chemical nature.

There are various kinds of lac distinguished in commerce. *Stick lac* is the substance in its natural state, encrusting small twigs. When broken off and boiled in water it loses its red colour, and is called *seed lac*. When melted and reduced to the state of a thin crust, it is called *shell lac*. Stick lac is of a deep red colour, and yields to

History.

Varieties.

* Annals of Philosophy. iii. 9.   † Phil. Trans. 1781, p. 376.
‡ Phil. Trans. 1789, p. 107.   § Ibid. 1791, p. 228.
‖ Mem. Par. 1714, p. 121; and Martine's translation of the Memoires of the French Academy, v. 4.
** Chemistry, p. 334.   †† Conspectus Chemiæ, ii. 70.
‡‡ Analytical Experiments on Lac, Phil. Trans. 1804.

Book IV. water a substance which is used as a red dye. The other two varieties are brown.

Properties. Water dissolves the greatest part of the colouring matter of lac, which varies from 15 to ½ per cent. Alcohol dissolves the greatest part of the resin, which constitutes the chief ingredient in the composition of lac. Ether acts more feebly. Sulphuric acid dissolves and gradually chars lac ; nitric acid dissolves, and then produces the same changes on it as on other resinous bodies. Muriatic and acetic acids likewise act as solvents. A solution of borax in water readily dissolves lac. The best proportions are 20 grains of borax, 100 grains of lac, and four ounces of water. This solution, mixed with lamp black, constitutes Indian ink ; and may indeed be employed for many of the purposes of varnish. The fixed alkalies readily dissolve lac, but not the volatile. When placed on a hot iron it melts, and emits a thick smoke with an odour rather pleasant, leaving a spongy coal. When distilled, it yields water slightly acidulous, and a thick butyraceous oil. The gases emitted are a mixture of carbonic acid and carbureted hydrogen. Stick lac yields also some carbonate of ammonia ; but the other two varieties none. The following table exhibits the constituents of the different varieties of lac, according to the analysis of Mr. Hatchett :

Constituents.

	Stick Lac.	Seed Lac.	Shell Lac.
Resin	68	88·5	90·9
Colouring matter ..	10	2·5	0·5
Wax	6	4·5	4·0
Gluten	5·5	2·0	2·8
Foreign bodies....	6·5	—	—
Loss	4·0	2·5	1·8
	100	100	100

The resin is less brittle than those bodies usually are. The colouring matter possesses the properties of extractive; the wax is analogous to myrtle wax, and the gluten closely resembles the gluten of wheat.*

Uses. The uses to which lac is applied in India are very numerous. In Europe it forms the basis of sealing-wax; which is made by melting lac with different proportions of turpentine and some colouring matter, as ivory-black, for

* Hatchett, Phil. Trans. 1804.

black sealing-wax; vermilion for red, &c. It constitutes
also the basis of many varnishes and lackers. This last
name indeed is derived from the word *lac*.[*]

14. *Amber.*—This substance is undoubtedly of vegetable Amber.
origin; and though it differs from resins in some of its
properties, yet it agrees with them in so many others, that
it may, without impropriety, be referred to them. For
the chemical investigation of the properties of this sub-
stance, we are chiefly indebted to the labours of Hoffmann,[†]
Bourdelin,[‡] Stockar de Neuforn,[§] Heyer,[||] and more
lately it has occupied the attention of Mr. Hatchett. The
best account of amber varnish which I have seen is by Nils
Nystrom in the Stockholm Transactions for 1797.[**]

Amber is a brittle, light, hard substance, usually nearly Properties.
transparent; sometimes nearly colourless, but commonly
yellow or even deep brown. It has considerable lustre.
Its specific gravity is 1·065. It is tasteless, and without
smell, except when pounded or heated, when it emits a
fragrant odour. When heated it softens; but, as far as is
known, cannot be melted without losing some of its
weight, and altering its appearance. In a strong heat it
burns, leaving a small quantity of ashes, the nature of
which has not yet been ascertained. Water has no action
on it; but alcohol, by long digestion, dissolves about one-
eight of the amber, and forms a coloured solution, which
when concentrated becomes milky when mixed with water.
The precipitate possesses the properties of a resin. The
residuum of the amber is not acted on by alcohol. Though
amber be roasted before the action of the alcohol, the
tincture is still formed. Hence we learn that the resinous
part of amber is not expelled by a melting heat.[††] When Action of
amber is treated with a boiling fixed alkali, it is almost alkalies.

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[*] A detailed account of the method of making several of these is
given by Dr. Lewis in his Philosophical Commerce of the Arts, p. 223.

[†] Obs. Phys. Chem. p. 60 and 198.

[‡] Sur le Succin. Mem. Par. 1742, p. 192.

[§] Specimen. Chem. Med. Inaugur. de Succino in Genere et speciatim
de Succino Fossili Wisbolzensi, 1760. This tract contains a very co-
pious set of experiments; which, however, do not always agree with
those of other chemists. Wasserberg's Treatise on Amber is chiefly an
abridgment of Stockard's.

[||] Chemische versuche mit Bernstein, 1787.

[**] I have seen the paper only through the medium of Crell's Journal.
It is inserted in Crell's Annals, 1799, ii. 171 and 253.   [††] Heyer.

Book IV. completely dissolved, according to Hoffman, and the compound possesses the qualities of soap ; for it is soluble in water and alcohol, and not thrown down by water. Mr. Hatchett found that the alkalies act only partially on amber, extracting a yellow tincture. Probably this ingenious chemist did not continue the process long enough ; for I have accidentally ascertained, that a weak solution of potash is capable of dissolving amber completely without the assistance of heat, provided it be allowed to act for a sufficient time. I had formed a weak solution of potash (I believe subcarbonate) as nearly as possible of the specific gravity of amber, and I had put into it some amber powder, to show the supposed currents of Count Rumford during the heat of the liquid. On examining the infusion about a month after, I found the amber all lying at the bottom of the phial. I added more alkali to restore the equilibrium. Some time after the amber was again at the bottom, and it was necessary to add more alkali. By this time the solution had acquired a yellow colour. I therefore explained the sinking of the amber, by supposing that the potash had dissolved a portion of it, and that this had altered the specific gravity of the solution. Not knowing at the time that any experiments had been made on the subject, I put aside the phial to ascertain the result. Three years after only two or three particles of the amber at most could be detected, the rest having dissolved completely.

Of acids. The weaker acids have no action on amber. Sulphuric acid converts it into a black resinous mass. Nitric acid acts upon it ; when assisted by heat, nitrous gas is emitted. The amber is first converted into a light resinous substance, and at last dissolves completely. Heyer, who first made this experiment, could obtain neither oxalic nor acetic acid by the action of nitric acid on amber. That nitric acid is really capable of dissolving amber has been lately verified by the experiments of Hatchett, who found it soluble with the same phenomena as resins in general.

Amber varnish. Neither fixed nor volatile oils have any action on amber unless it has been previously roasted or exposed to a melting heat. When thus treated, it combines with oils, and the solution forms *amber varnish*. The process recommended by Nystrom is this : amber is to be spread on a flat-bottomed iron pan, and placed on an equal coal fire till it melt ; it is then to be withdrawn, covered with a plate of

copper and iron, and allowed to cool. If the process be properly conducted, the amber will have lost half of its weight. If the fire be too strong, the amber will be scorched and rendered useless. If it be too low, the amber will not melt, but be reduced to a brown crust, which answers well enough for a varnish, provided it be exposed to heat till it is reduced to one-half of the original weight. One part of this roasted amber is to be mixed with three parts of linseed oil (rendered drying by litharge and white vitriol), and the mixture exposed to a gentle heat till the amber is dissolved: it is then to be withdrawn from the fire, and when nearly cold four parts of oil of turpentine are to be added. The whole is then allowed to settle, and the clear portion is passed through a linen cloth.

When amber is distilled, there comes over carbureted hydrogen and carbonic acid gas, an acidulous water, then an oil, at first thin and transparent, but becoming gradually darker and thicker. Towards the end of the process the succinic acid sublimes. From the observations of Vogel, it appears that a portion of the yellow matter which is obtained by this distillation possesses the properties of wax very nearly.*

15. *Resin from bitumen.* Mr. Hatchett ascertained, that Resin from when asphalt, mineral caoutchouc, and other similar bodies, bitumen. are digested a sufficient time in nitric acid, they furnish a considerable portion of a brown substance, which possesses many of the properties of resins. Kilkenny coal, and every other variety of coal which contains no bitumen, is converted by nitric acid into artificial tannin, but yields no resin; while common coal furnishes both. Thus it appears that bitumen, when treated with nitric acid, has the property of yielding a species of resin.

This substance has a pale brown-colour like that of Properties. Spanish snuff; its internal fracture is dark-brown, and it has a resinous lustre. When heated it does not readily melt; but when inflamed emits a resinous odour, mixed with that of fat oils, and leaves a coal much more bulky than the original substance. Alcohol dissolves it. Water throws down a part from the solution; but a portion remains undissolved, which acts on reagents like *extractive*. The taste is bitter. Hence this substance appears to be intermediate between extractive and resin. When digested with nitric

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* Gehlen's Jour. v. 272.

Book IV. acid it is readily converted into artificial tannin; and when digested with sulphuric acid it is converted into charcoal.*

I have now enumerated the most remarkable of the resinous bodies with which we are acquainted. There are indeed many of the substances employed in medicine, which undoubtedly contain resins; for example, *aloes, jalap, snakeroot, arnica,* &c.; but as these have not yet been chemically examined, it would be in vain to dwell upon them.

SECT. XXVII.

OF GUAIACUM.

Origin.   THIS substance is obtained from the *guaiacum officinale,* a tree which is a native of the West Indies, and yields a very hard heavy wood. The resin exudes spontaneously, and is also driven out artificially by heating one end of the wood in billets previously bored longitudinally; the melted resin runs out at the extremity farthest from the fire. This substance has been used in medicine for a considerable time, having been originally recommended in venereal diseases. Nothing is known concerning its original introduction into Europe.

It was considered by chemists as a resin, till Mr. Hatchett observed, that when treated with nitric acid it yielded products very different from those of resinous bodies.† This induced Mr. William Brande to examine its chemical properties in detail.‡ To his valuable paper we are indebted for almost all the accurate information which we possess respecting its chemical nature.

Properties.   1. Guaiacum is a solid substance, resembling a resin in appearance. Its colour differs considerably, being partly brownish, partly reddish, and partly greenish; and it always becomes green when left exposed to the light in the open air.§ It has a certain degree of transparency, and breaks

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* Hatchett's Third Series of Experiments on Artificial Tannin, Phil. Trans. 1806.

† Second Series of Experiments on Artificial Tannin, Phil. Trans. 1805.

‡ Chemical Experiments on Guaiacum, Phil. Trans. 1806, and Phil. Mag. xxv. 105.

§ Wollaston, Nicholson's Jour. viii. 294.

with a vitreous fracture. When pounded it emits a pleasant balsamic smell, but has scarcely any taste, although when swallowed it excites a burning sensation in the throat. When heated it melts, and diffuses at the same time a pretty strong fragrant odour. Its specific gravity is 1·2289.*

2. When guaiacum is digested in water a portion of it is Action of dissolved, the water acquiring a greenish-brown colour and water, a sweetish taste. The liquid, when evaporated, leaves a brown substance, which possesses the properties of *extractive*; being soluble in hot water and alcohol, but scarcely in sulphuric ether, and forming precipitates with muriates of alumina, tin, and silver. This extractive amounts to about nine parts in the hundred of guaiacum.†

3. Alcohol dissolves guaiacum with facility, and forms a Alcohol. deep-brown coloured solution. Water renders this solution milky by separating the resin. Muriatic acid throws down the guaiacum of an ash-grey, and sulphuric acid of a pale-green colour. Acetic acid and the alkalies occasion no precipitate. Liquid chlorine throws it down of a fine pale-blue, which does not change when dried. Diluted nitric acid occasions no change at first; but after some hours the liquid becomes green, then blue, and at last brown, and at that period a brown coloured precipitate falls down. If water be mixed with the liquid when it has assumed a green or a blue-colour, green and blue precipitates may be respectively obtained.‡

4. Sulphuric ether does not act so powerfully on guaiacum Ether, as alcohol. The solution obtained by means of it exhibits the same properties when treated with reagents as that in alcohol.§

5. The alkaline solutions, both pure and in the state of Alkalies. carbonates, dissolve guaiacum with facility. Two ounces of a saturated solution of potash dissolved about 65 grains of guaiacum; the same quantity of ammonia only 25 grains; or guaiacum dissolves in about 15 parts of potash and 38 parts of ammonia. Nitric acid threw down from these solutions a brown precipitate, similar to what is obtained when the alcoholic solution is mixed with the same acid. Muriatic acid and diluted sulphuric acid throw down a flesh-

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* Brande, Phil. Mag. xxv. 105.　　　† Ibid.
‡ Ibid. p. 106.　　　　　　　　　　§ Ibid. p. 106.

Book IV.

Action of acids.

coloured curdy precipitate, which in its properties approaches the nature of extractive.*

6. Most of the acids act upon guaiacum with considerable energy.

Sulphuric acid dissolves it, and forms a deep-red liquid, which deposits while fresh a lilac-coloured precipitate when mixed with water. When heat is applied the guaiacum is charred.

Nitric acid dissolves guaiacum completely without the assistance of heat, and with a strong effervescence. When the solution is evaporated, it yields a very large quantity of oxalic acid.† No artificial tannin appears to be formed, but rather a substance possessing the properties of extractive. Diluted nitric acid converts guaiacum into a brown substance, similar to the precipitate obtained by nitric acid from the alcoholic solution of guaiacum. This brown matter possesses the properties of a resin.‡

Muriatic acid acts but slightly, as the guaiacum soon melts into a blackish mass, which is not acted upon.§

Distillation.

7. When guaiacum is distilled, 100 parts of it yielded to Mr. Brande the following products:

Acidulous water	5·5
Thick brown oil	24·5
Thin empyreumatic oil	30·0
Charcoal	30·5
Gases, consisting of carbonic acid and carbureted hydrogen	9·0
Loss	0·5
	100·0

The coal when incinerated left three grains of lime, but no alkaline substance.‖

8. Such are the properties of guaiacum, as far as they have been hitherto ascertained. From the preceding detail, it is obvious that guaiacum in many respects coincides with the resins; but it differs from them in three particulars so remarkable, that we cannot avoid considering it as a distinct substance.

* Brande, Phil. Mag. xxv. 109.

† Hatchett, Second Series of Experiments on Artificial Tannin, Phil. Trans. 1806.

‡ Brande, Phil. Mag. xxv. 107.   § Ibid.   ‖ Ibid.

The first of these is the great quantity of charcoal
which it leaves when distilled in close vessels. This Mr.
Brande found to amount to above 30 per cent.; while the
resins, in like circumstances, hardly ever leave more than
15 per cent. of charcoal, and often not nearly so much. It
is possible, however, and indeed not improbable, that this
difference is to be ascribed to the different degrees of heat
employed.

The second peculiarity is the action of nitric acid on
guaiacum. This acid does not dissolve the resins without
the assistance of heat, but converts them into a brown brittle
mass; whereas it dissolves guaiacum completely. The
action of this acid on the resins terminates in the forma-
tion of artificial tannin, whereas its action on guaiacum
terminates in the formation of oxalic acid. This striking
difference is alone sufficient to warrant a separation of
guaiacum from the resins.

The third peculiarity is the remarkable suite of changes
of colour which guaiacum undergoes when its solutions are
treated with nitric acid and chlorine. Dr. Wollaston
first observed that guaiacum becomes green when exposed
to light, provided air have access to it ; and that the colour
is again removed by the application of heat.*   Hence it is
probable that oxygen occasions the change. This opinion
is much strengthened by the experiments of Mr. Brande.
When guaiacum was put in contact with oxygen gas, it
became green sooner than in the open air. When put Forms
into chlorine gas it became first green, then blue, and lastly oxides.
brown; and ammonia, when left in contact with it, restored
again its green colour. In like manner, by treating the
alcoholic solution of guaiacum with nitric acid, green, blue,
and brown precipitates are obtained, according to the length
of time that the acid is allowed to act upon it. These facts
give considerable plausibility to the opinion of Mr. Brande,
that the changes of colour are owing to the combinations of
oygen with the guaiacum ; that the green contains the least,
and the brown the most oxygen, while the blue is inter-
mediate.†   Thus guaiacum, in its changes of colour, bears
some resemblance to indigo. Mr. Brande has remarked a
coincidence also between guaiacum and the green resin of
the leaves of plants.

* Nicholson's Jour. viii. 295.   † Brande, Phil. Mag. xxv. 107.

SECT. XXVIII.

OF BALSAMS.

THE term *balsam* or *balm* was originally confined to a thick fragrant juice obtained from the *amyris Gileadensis*, and afterwards applied by chemists to all substances which possessed the same degree of consistence and a strong smell, whether natural or artificial. Bucquet restricted the term to those resinous-like substances which yield benzoic acid when heated. This new meaning of the word, which has been adopted by chemists in general, has introduced into the class of balsams several substances which were formerly considered as resins. The word *balsam* originally implied a substance possessing a certain degree of fluidity; but now there are two classes of balsams; the one fluid, and the other solid and brittle.

Definition. A balsam, then, is a substance which possesses the general properties of a resin; but which, when heated or digested in acids, yields a portion of benzoic acid. Chemists, in general, have considered them as combinations of a resin with benzoic acid; but Mr. Hatchett has made it probable, that the acid is formed at the time of its separation.*

Properties. They are soluble in water; but when boiled in that liquid often give out a portion of benzoic acid. Alcohol and ether dissolve them readily. The strong acids likewise dissolve them; and during the solution a portion of benzoic acid is separated. Nitric acid, in some cases, evolves likewise traces of prussic acid. The alkalies act upon them

Division. nearly as on the resins. They may be divided into two classes; namely, *liquid* and *solid* balsams.

I. LIQUID BALSAMS.

The liquid balsams at present known are five in number; namely,

1. Opobalsamum.	4. Peru.
2. Copaiva.	5. Styrax.
3. Tolu.	

Opobalsa-   1. *Opobalsamum* or *balm of Gilead.*—This balsam is obmum.   tained from the *amyris Gileadensis*, a tree which grows in

* Second Series of Experiments on Artificial Tannin, Phil. Trans. 1806.

Arabia, especially near Mecca. It is so much valued by the Turks that it is seldom or never imported into Europe. We are of course ignorant of its composition. It is said to be at first turbid and white, and of a strong aromatic smell, and bitter, acrid, astringent taste; but by keeping, it becomes limpid and thin, and its colour changes first to green, then to yellow, and at last it assumes the colour of honey, and the consistence of turpentine.*

2. *Copaiva.*—This balsam is obtained from the *copaifera* Copaiva. *officinalis;* a tree which grows in South America, and some of the West Indian islands. It exudes from incisions made in the trunk of the tree. The juice thus obtained is transparent, of a yellowish colour, an agreeable smell, a pungent taste, at first of the consistence of oil, but it gradually becomes as thick as honey. Its specific gravity is 0·950.† When mixed with water and distilled, there comes over with the water a very large portion of volatile oil. Lewis Yields oil obtained half the original weight of this oil.‡ Schonberg, from eight ounces of copaiva, obtained 3¼ of oil by this process.§ It was colourless, very limpid, of the specific gravity 0·900; had the taste and smell of copaiva, but rather stronger. It dissolved in eight parts of alcohol; but the copaiva itself is a good deal more soluble.‖ The oil ceases to come over before all the water has passed into the receiver. The residuum, of course, consists of two substances; namely, the watery portion, and a greyish-yellow And resin; substance, lying at the bottom of the vessel, which, on exposure to the air, dries, and becomes brittle and transparent. When heated it melts, and possesses the characters of a resin. When distilled it yielded a yellowish thick oil, some acidulous water, and a gas; one-sixth of which was carbonic acid, and the remainder seemed to possess the characters of olefiant gas.** From these facts, which have been long known, it was concluded, that copaiva is a compound of a resin and a volatile oil, which passes over at a heat inferior to that of boiling water; but the experiments But is decomposed of Schonberg have rendered it much more probable, that the balsam is decomposed when distilled along with water, and that both the oil and resin are new products.

* This is the account of Professor Alpinus, as quoted by Lewis, Neumann's Chem. p. 284. † Schonberg, Gehlen's Jour. vi. 494.
‡ Neumann's Chem. p. 285. § Gehlen's Jour. vi. 494.
‖ Schonberg's Gehlen's Jour. vi. 494. ** Schonberg, ibid. 497.

Book IV.   When distilled on a water bath, nothing comes over but a few drops of water, and one or two drops of oil.*   If the

Distillation. vessel be kept at a temperature between 234° and 257°, scarcely any thing more is obtained than when the distillation is conducted over a water bath.   At the temperature of 504° the balsam begins to boil gently, a gas is extricated, and drops begin to pass more rapidly into the receiver.   At 550° it boils briskly, and the distillation goes on rapidly. There passes into the receiver a limpid yellowish oil, occasionally mixed with a drop or two of water.   As the distillation proceeds the oil becomes more and more yellow. At this period the balsam is as liquid as water, and boils without any frothing or swelling.   After this period the oil becomes yellow, and then brownish-red; but still continues pretty thin.   The first oil obtained by Schonberg from four ounces of copaiva, by this process, was $3\frac{1}{16}$ ounces.   The water had a sour taste, and reddened litmus paper.   The gas amounted to 81 ounce measures; $\frac{1}{9}$th of it was carbonic acid, the rest resembled olefiant gas. †

Action of nitric acid,   Nitric acid acts upon this balsam with considerable energy.   When one part of the balsam is mixed with four parts of nitric acid and two parts of water, and heated, a yellowish solution is formed, similar to the original balsam, but darker.   When distilled, there comes over with the liquid that passes into the receiver an apple-green oil, which lines the helm of the retort.   The nature of the residue was not examined.   Doubtless it would have been found to contain artificial tannin, provided a sufficient quantity of acid was employed. ‡

Similar to turpentine,   When treated with sulphuric acid, it yields a portion of artificial tannin. §

Whether this balsam yields benzoic acid has not been ascertained.   Its properties are rather against the probability of its doing so.   Indeed it bears a striking resemblance to turpentine in many respects; and ought, along with it, to constitute a class of bodies intermediate between volatile oils and resins, to which the name of *turpentines* might be given.

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* Schonberg, Gehlen's Jour. vi. p. 495.   † Id. ibid.
‡ Id. ibid. p. 499.
§ Hatchett, Third Series of Experiments on Artificial Tannin, Phil. Trans. 1806.

3. *Balsam of Tolu.*—This substance is obtained from the *toluifera balsamum,* a tree which grows in South America. The balsam flows from incisions made in the bark. It comes to Europe in small gourd shells. It is of a reddish brown colour and considerable consistence; and when exposed to the air, it becomes solid and brittle. Its smell is fragrant, and continues so even after the balsam has become thick by age. When distilled with water, it yields very little volatile oil, but impregnates the water strongly with its taste and smell. A quantity of benzoic acid sublimes, if the distillation be continued.[*]

Mr. Hatchett found it soluble in the alkalies like the rest of the balsams. When he dissolved it in the smallest possible quantity of lixivium of potash, it completely loses its own odour, and assumes a most fragrant smell, somewhat resembling that of the clove pink. " This smell," Mr. Hatchett observes, " is not fugitive, for it is still retained by a solution which was prepared in June, and has remained in an open glass during four months."

When digested in sulphuric acid, a considerable quan- tity of pure benzoic acid sublimes. When the solution of it in this acid is evaporated to dryness, and the residue treated with alcohol, a portion of artificial tannin is obtained; the residual charcoal amounts to 0·54 of the original balsam.[†]

Mr. Hatchett found that it dissolved in nitric acid with nearly the same phenomena as the resins; but it assumes the odour of bitter almonds, which leads him to suspect the formation of prussic acid. During the solution in nitric acid, a portion of benzoic acid sublimes. By repeated digestions it is converted into artificial tannin.[‡]

4. *Balsam of Peru.*—This substance is obtained from the *myroxylon peruiferum,* which grows in the warm parts of South America. The tree is full of resin, and the balsam is obtained by boiling the twigs in water. It has the consistency of honey, a brown colour, an agreeable smell, and a hot acrid taste. When boiled with water for some time, the liquid separated by the filter reddens vegetable

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[*] Lewis, Neumann's Chem. p. 285.
[†] Hatchett, Third Series of Experiments on Artificial Tannin, Phil. Trans. 1806. [‡] Ibid.

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blues,‘ and deposits crystals of benzoic acid on cooling. The water contains no other substance.* When distilled with water, it yields a very small quantity of reddish limpid oil. Hoffmann obtained only one part of oil from 16 of balsam.† Lichtenberg mixed two ounces of balsam with eight of water, and distilled. The first two ounces of water came over colourless, and had only a slight odour of the balsam. The next three were milky, smelt strongly of the balsam, and at the bottom of the receiver were some drops of colourless oil. The next $1\frac{1}{2}$ ounce were similar, but contained more oil. Between 50 and 60 grains of benzoic acid had sublimed into the neck of the retort. By increasing the heat $3\frac{1}{2}$ drachms of yellow oil came over, and a quantity of benzoic acid. A black shining coal remained in the retort.‡

Action of heat.

When this balsam is exposed to the heat of a water bath, only a drop or two of water and a few drops of oil can be obtained. § When placed in a sand bath, and exposed to a temperature gradually raised, nothing more comes over till the balsam is heated to 300°, when a portion of benzoic acid sublimes; and at 324°, drops of water and oil began to come over. At 550° the balsam begins to boil, and some gas is disengaged. At 594° the oil (mixed with a little water) comes over pretty fast. At 617° it comes over still more rapidly. Lichtenberg, to whom we owe these experiments, kept four ounces of balsam at that temperature for two hours, and obtained two ounces of a yellowish oil, and a crystallized mass of benzoic acid, which, together with the water, weighed $6\frac{1}{2}$ drachms. The gas obtained amounted to 58 ounce measures; of these, 38 were carbonic acid. The rest burnt like olefiant gas. By increasing the heat a brownish oil came over, and at last a black oil of the consistence of pitch, and 49 ounce measures of gas were extricated. Of these, six were carbonic acid; the residue burnt with a bluish white flame.‖

Of alkalies.

A saturated solution of carbonate of soda forms with this balsam a thick mass. When diluted with water and heated, a portion is dissolved. The solution, when saturated with

* Lichtenberg, Gehlen's Jour. vi. 489.
† Observ. Phys. Chym. Select. p. 71.   ‡ Gehlen's Jour. vi. 485.
§ Lichtenberg, Gehlen's Jour. vi. 485.   ‖ Ibid. p. 487.

sulphuric acid, deposits crystals of benzoic acid.   One part of the balsam, treated with one part of potash dissolved in four parts of water, formed an opaque solution, which gradually separated into two portions : the uppermost, a clear oil with some grey flakes at its lower surface ; the undermost, a dark brownish-red opaque solution.   This last solution, when saturated with sulphuric acid, lets fall a resinous-like substance, dissolved by boiling, while benzoic acid crystallized.*

Nitric acid acts upon the balsam with energy, and gives it an orange-yellow colour when assisted by heat.   When distilled with a sufficient quantity of this acid diluted, the liquid in the receiver smells of bitter almonds.   When supersaturated with carbonate of potash, and mixed with a solution of iron, a precipitate falls, which, when treated with muriatic acid, leaves prussian blue, and indicates the presence of prussic acid.   During the distillation benzoic acid sublimes.   The residue in the retort has a crystalline appearance, is light yellow, dissolves sparingly in boiling water, and precipitates on cooling in the state of a yellow powder.†   Such was the result of Lichtenberg's trials. Mr. Hatchett observed that the residue possessed the properties of artificial tannin.

When this balsam is treated with sulphuric acid, artificial tannin is also formed, and the residual charcoal amounts to no less than 0·64 of the original weight of the balsam. ‡

5. *Styrax.*—This is a semifluid juice, said to be obtained from the *liquidambar styraciflua,* a tree which grows in Virginia, Mexico, and some other parts of America.§   It is prepared, according to Mr. Petiver, in the island Cobross in the Red Sea, from the bark of a tree called *rosa mallos* by the natives, and considered by botanists as the same with the American species.   The bark of this tree is boiled in salt water to the consistence of bird-lime, and then put into casks.|| Bouillon la Grange has published an account of its properties.**   Its colour is greenish, its taste aromatic, and its smell agreeable.   It is easily volatilized by

* Lichtenberg, Gehlen's Jour. vi. 487.   † Gehlen's Jour. vi. 491.

‡ Hatchett, Third Series of Experiments on Artificial Tannin, Phil. Trans. 1806.

§ Lewis, Neumann's Chemistry, p. 291.

|| Phil. Trans. 1708, vol. xxvi. p. 44.   ** Ann. de Chim. xxvi. 203.

Book IV. heat. When treated with water, benzoic acid is dissolved. It is totally soluble in alcohol except the impurities. When exposed to the air it becomes harder, and absorbs oxygen. When distilled, it yields an acidulous water, having the odour of benzoic acid, a limpid colourless hot oil, a solid coloured oil, benzoic acid, and a mixture of carbonic acid and carbureted hydrogen. The charcoal is light and contains some oil.

II. SOLID BALSAMS.

The solid balsams at present known are only three in number; namely,

        1. Benzoin.
        2. Storax.
        3. Dragon's blood.

Benzoin.   1. *Benzoin.*—This substance is the produce of the *styrax benzoe*, a tree which grows in Sumatra, &c. and which has been described by Mr. Dryander.* Benzoin is obtained from this tree by incision; a tree yielding three or four pounds. It is a solid brittle substance, sometimes in the form of yellowish white tears joined together by a brown substance, and sometimes in the form of a brown substance not unlike common rosin. It has a very agreeable smell, which is increased by heating the benzoin. It has little taste. Its specific gravity is 1·092. This substance has been used in medicine for ages, and various processes have been pointed out by chemists for extracting benzoic acid from it; but the only person who has examined its properties in detail is Mr. Brande.†

Cold water has very little effect on benzoin, but boiling water takes up a portion of benzoic acid.

Action of alcohol, .   Alcohol dissolves it when assisted by a gentle heat, and forms a deep yellow solution inclining to reddish-brown. When this solution is diluted with water, the benzoin precipitates in the form of a white powder. It is precipitated also by muriatic and acetic acids, but not by the alkalies. A few drops of sulphuric acid likewise precipitate the benzoin; but an additional quantity redissolves it, and forms a liquid of the colour of port wine. When equal quantities of the alcoholic solution of benzoin and sulphuric acid are

* Phil. Trans. 1787, p. 307.   † Nicholson's Jour. x. 82.

mixed, a dark-pink precipitate falls. The liquid assumes a Chap. I. pink colour, which becomes lilac when diluted with water. Nitric acid occasions a strong effervescence, and forms a dark-red fluid with the alcoholic solution, but throws down no precipitate.*

Ether dissolves benzoin with facility, and the solution Ether, with reagents exhibits the same phenomena as the alcoholic.†

Nitric acid acts with violence on benzoin, and converts Acids, it into an orange-coloured mass. When assisted by heat the acid dissolves the benzoin; and as the solution cools, crystals of benzoic acid gradually separate. Mr. Hatchett ascertained that by this process a quantity of artificial tannin is formed.

Sulphuric acid dissolves benzoin, while benzoic acid (as Hatchett discovered) sublimes; the solution is at first a deep red. By continuing the digestion, a portion of artificial tannin is formed, and the charcoal evolved amounts to 0·48 of the benzoin dissolved.‡

Acetic acid dissolves benzoin without the assistance of heat. When heat is applied, the solution, as it cools, becomes turbid; owing to the separation of benzoic acid.§

Benzoin is dissolved by a boiling lixivium of the fixed Alkalies. alkalies; a dark-brown solution is formed, which becomes turbid after some days' exposure to the air. Ammonia likewise dissolves benzoin sparingly.||

When Mr. Brande exposed 100 grains of benzoin in a Distillaretort to a heat gradually raised to redness, the products tion. were,

Benzoic acid	9·0
Acidulous water	5·5
Butyraceous and empyreumatic oil	60·0
Charcoal	22·0
Carbureted hydrogen and carbonic acid	3·5
	100·0

Bucholz subjected 1500 grains of benzoin to a chemical analysis. He obtained the following substances.

* Brande, Nicholson's Jour. x. 82. † Ibid.
‡ Hatchett, Third Series of Experiments on Artificial Tannin.
§ Brande, Nicholson's Jour. x. 85. || Ibid. p. 86.

Book IV.   Resin 1250
            Benzoic acid. 187
            Substance similar to balsam of Peru 25
            Aromatic substance soluble in water and alcohol   8
            Woody fibres and impurities 30
                                                      ————
                                                      1500 *

Storax.   2. *Storax.*—This is the most fragrant of all the balsams, and is obtained from the *styrax officinalis,* a tree which grows in the Levant, and it is said also in Italy. Sometimes it is in the state of red tears; and this is said to be the state in which it is obtained from the tree. But common storax is in large cakes; brittle, but soft to the touch, and of a reddish-brown colour. This is more fragrant than the other sort, though it contains a considerable mixture of saw-dust. It dissolves in alcohol. When distilled with alcohol or with water, scarcely any oil is obtained. When distilled by the naked fire, it seems, from the experiments of Neumann, to yield the same products as benzoin.†

Dragon's   3. *Dragon's blood.*—This is a brittle substance of a dark-blood.
blood.   red colour, which comes from the East Indies. There are two sorts of it; one in small oval drops or tears of a fine deep-red, which becomes crimson when the tears are reduced to powder; the other is in larger masses, some of which are pale-red, and others dark. It is probably obtained from different kinds of trees; the *calamus draco* is said to furnish most of what comes from India. The *dracæna draco* and the *pterocarpus draco* are also said to furnish it.

Properties.   Dragon's blood is brittle and tasteless, and has no sensible smell. Water does not act upon it, but alcohol dissolves the greatest part, leaving a whitish-red substance, partially acted upon by water. The solution has a fine deep-red colour, which stains marble, and the stain penetrates the deeper the hotter the marble is. It dissolves likewise in oils, and gives them a deep-red colour also. When heated it melts, catches flame, and emits an acid fume similar to that of benzoic acid.‡ When digested with lime, a portion of it becomes soluble in water, and it acquires a bal-

* Ann. de Chim. lxxxiv. 319.   † Neumann's Chem. p. 290.
‡ Lewis, Neumann's Chem. p. 299.

samic odour. On adding muriatic acid to the solution, a
red resinous substance is precipitated, and slight traces of
benzoic acid only become perceptible.* Nitric acid acts
upon it with energy, changes it to a deep-yellow, a portion
of benzoic acid is sublimed, and a brown mass remains
soluble in water, and possessing the properties of artificial
tannin.† When treated with sulphuric acid no perceptible
portion of benzoic acid sublimes; but it is converted partly
into artificial tannin, while a quantity of charcoal is evolved,
amounting to 0·48 of the original dragon's blood employed.‡

SECT. XXIX.

OF GUM RESINS.

THIS class of vegetable substances has been long distin-
guished by physicians and apothecaries. It contains many
active substances much employed in medicine; and they
certainly possess a sufficient number of peculiar properties
to entitle them to be ranked apart. Unfortunately these
substances have not yet attracted much of the attention of
chemists. Their properties and constituents of course are
but imperfectly ascertained. Of late, however, they have
engaged the attention of M. Braconnot, who has recently
published a very detailed examination of several of them,
and has promised to examine in the same manner the whole
of the class.§ They may be distinguished by the following
characters.

They are usually opaque, or at least their transparency Properties.
is inferior to that of the resins. They are always solid,
and most commonly brittle, and have sometimes a fatty
appearance.

When heated they do not melt as the resins do; neither
are they so combustible. Heat, however, commonly softens
them, and causes them to swell. They burn with a flame.

They have almost always a strong smell, which in several

* Hatchett, Second Series of Experiments on Artificial Tannin, Phil.
Trans. 1806. † Hatchett, ibid.
‡ Hatchett, Third Series of Experiments on Artificial Tannin, Phil.
Trans. 1806. § Ann. de Chim. lxviii. 19.

instances is alliaceous. Their taste also is often acrid, and always much stronger than that of the resins.

They are partially soluble in water; but the solution is always opaque, and usually milky.

Alcohol dissolves only a portion of them. The solution is transparent; but when diluted with water it becomes milky; yet no precipitate falls, nor is any thing obtained by filtering the solution.

Vinegar and wine likewise dissolve them partially; and the solution, like the aqueous, is opaque or milky.

According to Hermbstadt, they are insoluble in sulphuric ether.

The action of alkalies on them has been examined only by Mr. Hatchett. All of them tried by that celebrated chemist dissolved readily in alkaline solutions when assisted by heat. We may therefore consider them as soluble in alkalies like resins.

From the experiments of Mr. Hatchett, we learn that the acids act on these bodies nearly as they do on the resins. Sulphuric acid dissolves them, and gradually converts them into artificial tannin and charcoal. The following are the quantities of charcoal obtained by this chemist from 100 grains of different gum resins digested in alcohol:

Ammoniac	58	Myrrh	40
Asafœtida	51	Gamboge	31
Olibanum	44		

Nitric acid acts upon them with energy; converting them first into a brittle mass, and then, with the assistance of heat, dissolving them. By evaporating this solution, Mr. Hatchett obtained, from ammoniac and asafœtida, a portion of artificial tannin; but he did not succeed in procuring it by the same means from olibanum, myrrh, and gamboge.*

Their specific gravity is usually greater than that of the resins.

Their other properties still continue unknown. They all either exude spontaneously from plants, or are obtained by incisions. At first they seem to be in a liquid state; but they gradually harden when exposed to the air and weather.

* Phil. Trans. 1806.

They have been usually considered by chemists as composed of gum and resin; but their properties are not consistent with that supposition. They all contain a volatile oil, or a substance intermediate between an oil and resin. To this substance we are to ascribe the milky solution which they form with water. The other constituent, in most cases, bears a much closer resemblance to extractive than to gum. Perhaps, then, we shall not err very far, if we consider the gum resins as composed of a gum or an extractive substance, and a body intermediate between oil and resin; to which last they owe their most peculiar properties.

The gum resins which have been hitherto applied to any useful purpose are the following:

1. *Galbanum.* It is obtained from the *bubon galbanum*, a perennial plant, and a native of Africa. When this plant is cut across a little above the root, a milky juice flows out, which soon hardens and constitutes galbanum. It comes to this country from the Levant, in small pieces composed of tears, agglutinated together, of a yellowish or white colour. Its taste is acrid and bitter, and its smell peculiar. Water, vinegar, and wine, dissolve part of it, but the solution is milky. Alcohol dissolves about $\frac{3}{5}$ths. When distilled it yields about half its weight of volatile oil, which has at first a blue colour. Its specific gravity is 1·212.*

Galbanum.

2. *Ammoniac.*—This substance is brought from the East Indies. Nothing certain is known concerning the plant which yields it; though from analogy it has been suspected to be a species of *ferula*.† It is in small pieces agglutinated together, and has a yellowish-white colour. Its smell is somewhat like that of galbanum, but more pleasant. Its taste is a nauseous sweet mixed with bitter. It does not melt. Water dissolves a portion of it; the solution is milky, but gradually lets fall a resinous portion. More than one-half is soluble in alcohol. This portion is a resin.

Ammoniac.

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* Brisson.

† Wildenow made the seeds vegetate which are observed in ammoniac. Of the plant produced he has formed a new genus under the name of *heracleum gummifera*. But as the roots of this plant were not observed to yield *ammoniac*, it is still doubtful how far it is the plant from which ammoniac is procured. See Ann. de Chim. lxix. 267.

Colour white, soft, and ductile. Melts when heated, and burns like a resin. When heated becomes harder, but not brittle. Nearly tasteless. Soluble in ether and in nitric acid. Precipitated from it in the form of an orange substance, partly resin, partly bitter. A portion remains, and gives the liquid a yellow colour. Taste of the solution slightly acid and bitter. Not precipitated by carbonate of soda, ammonia, nitrate of silver, nor acetate of lead. The orange substance has a bitter taste. When heated, readily swells and blackens, but does not flame. Burns without leaving any residuum. Lighter than water. When agitated in water, tinges it yellow, but does not all dissolve. The specific gravity of ammoniac is 1·207. Mr. Hatchett found it soluble in alkalies. Neither alcohol nor water, when distilled off it, bring over any thing.

According to the analysis of Braconnot, ammoniac is composed of the following ingredients :

Resin .... 70·0
Gum .... 18·4
Glutinous matter .. 4·4
Water .... 6·0
Loss .... 1·2
                  _____
                  100·0

The resin he found brittle and yellow. In these respects it differs from the resin which I extracted from ammoniac, which was soft, and continued so after being exposed to the air for two months. This difference is probably owing to the state of the ammoniac, sometimes it is brittle and yellow, at other times soft and white. It was in this last state that I examined it. Braconnot found the yellow matter into which this resin is converted by nitric acid soluble in hot alcohol and water. It had the property of dyeing silk a fine yellow colour, not altered by chlorine. The gum which he extracted from ammoniac possessed the properties of common gum as far as he examined them. It is transparent, yellowish, brittle, soluble in water, and precipitated by subacetate of lead, but not by the acetate, nor the nitrate of lead. The mercurial salts render the solution milky. By nitric acid it is converted into saclactic and oxalic acids, and furnishes also a little malic acid. The

glutinous matter was insoluble in water and alcohol; it Chap. I.
became black when dried, and yielded a yellow matter and
some oxalic acid when treated with nitric acid.*

3. *Aloes.*—This is the inspissated juice of the leaves of a Aloes.
variety of the *aloe perfoliata*, a plant which grows in Soco-
tora, an island in the East Indies. Aloes has a resinous
appearance, a reddish-yellow colour, a bitter taste, and an
aromatic smell. It has been recently examined by Bracon-
not, who found it composed cheifly of a peculiar matter
similar to that detected by Vauquelin in many febrifuge
barks, and to which Braconnot proposes to give the name
of *resinous bitter principle.†* Trommsdorf, on the other
hand, and Bouillon La Grange and Vogel, consider it as
composed of resin and a peculiar extractive matter.‡ Fa-
broni has discovered that the recent juice of the leaves of
the aloe has the property of absorbing oxygen, and of as-
suming a fine reddish purple, and of yielding a pigment
which he strongly recommends to the painter.§

4. *Olibanum.*—This substance is the frankincence of the Olibanum.
ancients. They obtained it, as Dioscorides informs us,
from Arabia and India. From Pliny we learn that the
tree which yielded it was neither known to the Greeks nor
Romans. At present olibanum is imported to London in
chests, containing each about a hundred weight. It comes
from different places, among others from the East Indies,
but the Indian olibanum is least esteemed. The tree which
yields this gum resin continues still doubtful. The proba-
bility is, that different species of trees furnish it in different
countries. Lamark is of opinion that the tree which yields
the Arabian olibanum is the *amyris gileadensis*. It is called
by the natives *soukiou*. According to Foerskal, it is the
amyris kataf. Mr. Colebrook has shown that the Indian
olibanum comes from the *boswellia serrata* of Roxbourgh, a
large tree, which grows on the mountains of India.||

Olibanum is a semitransparent, brittle, whitish-yellow
substance, usually covered externally by a whitish farinace-
ous substance, produced by the pieces rubbing against each
other. Its taste is acrid and aromatic, and when burnt, it

* Ann. de Chim. lxviii. 69.   † Ibid. lxviii. 18.
‡ Ibid. p. 11 and 155.   § Ibid. xxv. 301.
|| Asiatic Researches, ix. 377.

diffuses an agreeable odour. When heated, it melts with difficulty, but burns brilliantly, and leaves a whitish ash composed of phosphate of lime, carbonate of lime and sulphate, muriate and carbonate of potash. According to the analysis of Braconnot, it is composed of the following constituents:

Volatile oil 8
Resin 56
Gum 30
Matter like gum, insoluble in water and alcohol   5·2
Loss .... 0·8
                                                 ————
                                                 100·0*

The oil had a lemon-colour, and a smell similar to the oil of lemons.

The resin is reddish-yellow, brittle, tasteless, and very similar in appearance to rosin. Boiling water softens it; but a higher temperature is necessary to melt it. When burnt, it emits rather an agreeable odour. When heated to dryness with potash ley, it leaves a matter which is capable of forming a kind of emulsion with boiling water.

The gum possesses few peculiarities. The infusion of nutgalls occasions a precipitate in its aqueous solution. Nitric acid converts it partly into saclactic acid.†

Sagapenum.

5. *Sagapenum.*—The plant which yields this gum resin is not well known; but it is suspected to be the *ferula persica.* The substance itself is brought to Europe from Alexandria. It is commonly in tears agglutinated together. Colour yellow. Taste hot and bitter. Smell alliaceous. Softens between the fingers, but does not melt when heated. Sparingly soluble in water, but almost completely soluble in alcohol. When distilled with water it yields a little volatile oil. The water is strongly impregnated with the flavour of the sagapenum.‡

Asafœtida.

6. *Asafœtida.*—This substance is obtained from the *ferula asafœtida,* a perennial plant which is a native of Persia. When the plant is about four years old, its roots are dug up and cleaned. Their extremity being then cut off, a milky juice exudes, which is collected. Then another

* Ann. de Chim. lxviii. 60.   † Braconnot, Ann. de Chim. lxviii. 60.
‡ Neumann's Chem. p. 316.

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portion is cut off, and more juice exudes. This is conti-nued till the roots are exhausted. The juice thus collected soon hardens and constitutes *asafœtida*. It comes to Europe in small grains of different colours, whitish, reddish, violet, brown. Pretty hard, but brittle. Its taste is acrid and bitter; its smell strongly alliaceous and fetid. Alcohol, according to Neumann, dissolves about $\frac{3}{4}$ths of this substance; and water takes up nearly $\frac{1}{4}$th if applied before the spirit. A considerable portion of earthy matter remains undissolved. It yields a volatile oil, both when distilled with water and alcohol. This oil possesses the active properties of the asafœtida itself.[*] The specific gravity of the gum resin is 1·327.

7. *Scammony*.—This substance is obtained from the *convolvulus scammonia*, a climbing plant which grows in Syria, and was first correctly described by Dr. Russel.[†] The roots when cut yield a milky juice. This when collected and allowed to harden constitutes scammony. Colour dark grey or black. Smell peculiar and nauseous; taste bitter and acrid. With water it forms a greenish-coloured opaque liquid. Alcohol dissolves the greatest part of it. It is usually mixed with the expressed juice of the root, and frequently also with other impurities, which alter its appearance. In medicine it operates as a strong cathartic. Its specific gravity is 1·235.[‡]

Vogel and Bouillon La Grange have analysed the two varieties of scammony that come from Aleppo and from Smyrna. The scammony of Aleppo was composed of

Resin........................... 60
Gum............................ 3
Extractive...................... 2
Vegetable debris, earth, &c. 35
                                  ———
                                  100

The scammony of Smyrna was composed of

Resin................. 29
Gum.................. 8
Extractive............ 5
Vegetable debris, &c. 58
                        ———
                        100[§]

* Neumann's Chemistry, p. 312.
+ See an abridgment of his account by Dr. Lewis, Neumann's Chem. p. 303.   ‡ Brisson.   § Ann. de Chim. lxxii. 69.

8. *Opoponax.*—This substance is obtained from the *pastinaca opoponax*, a plant which is a native of the countries round the Levant. The gum resin, like most others, is obtained by wounding the roots of the plant. The milky juice, when dried in the sun, constitutes the opoponax. It is in lumps of a reddish yellow colour, and white within. Smell peculiar. Taste bitter and acrid. With water it forms a milky solution, and about one-half of it dissolves. Alcohol acts but feebly. When distilled with water or alcohol, these liquids acquire the flavour of opoponax, but no oil separates.* Its specific gravity is 1·622.†

When distilled it yields a brown oil, acetic acid in which a bituminous oil swims, the residual charcoal weighs $\frac{28}{100}$ of the opoponax distilled. When incinerated it left $\frac{37}{280}$ of its weight of ashes composed of

Carbonate of lime	18
Silica.......................	2
Carbonate ⎫	
Sulphate ⎬ of potash........	15
Muriate ⎭	
	—
	35

According to the analysis of Pelletier, to whom we are indebted for the preceding distillation, opoponax is composed of the following constituents :

Resin............	42·0
Gum......................	33·4
Wood.....................	9·8
Starch....................	4·2
Malic acid	2·8
Extractive	1·6
Caoutchouc	Trace
Wax......................	0·3
Volatile oil and loss	5·9
	———
	100·0‡

9. *Gamboge* or *Gumgutt.*—This substance is obtained from the *stalagmitis gambogioides*, a tree which grows wild in the East Indies. In Siam it is obtained in drops by

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* Neumann's Chem. p. 316.   † Brisson.
‡ Ann. de Chim. lxix. 90.

wounding the shoots; in Ceylon it exudes from wounds in
the bark. It is brought to Europe in large cakes. Its
colour is yellow; it is opaque, brittle, and breaks vitreous.
It has no smell, and very little taste. With water it forms
a yellow turbid liquid. Alcohol dissolves it almost com-
pletely; and when mixed with water becomes turbid, unless
the solution contain ammonia. In that case acids throw
down an insoluble yellow precipitate. It operates, when
taken internally, as a most violent cathartic. Its specific
gravity is 1·221.* It appears that it was brought to Europe
by the Dutch about the middle of the 17th century.† It
forms a fine yellow paint, and stains hot marble of a fine
lemon yellow.‡

Braconnot analysed it, and found it composed of one part
of a gum which possessed the properties of cherry tree
gum, and four parts of a reddish brittle resin which pos-
sessed the characteristic properties of the resins. It dis-
solved in alcohol and alkalies, and by nitric acid was
converted into a yellowish bitter matter. Chlorine de-
prived it of its dark colour, and a combination took place
between it and muriatic acid, in which it neutralized that
acid.§

10. *Myrrh.*—The plant from which this substance is ob- Myrrh.
tained is unknown. If we believe Bruce it belongs to the
genus of *mimosa*. It grows in Abyssinia and Arabia. It
is in the form of tears. Colour reddish yellow; when pure
somewhat transparent, but it is often opaque. Odour pe-
culiar. Taste bitter and aromatic. Does not melt when
heated, and burns with difficulty. With water it forms a
yellow opaque solution. The solution in alcohol becomes
opaque when mixed with water, but no precipitate appears.
By distillation with water it yields an oil heavier than
water; but nothing comes over with alcohol.|| Its specific
gravity is 1·360.** It is employed in medicine. Mr. Hat-
chett found it soluble in alkalies.

From the analysis of Braconnot it appears that myrrh is
composed of about

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* Brisson.
† See the Anatomia Essentiarum Vegetabilium of Angelus Sala, p. 31.
‡ Lewis, Neumann's Chem. p. 300.   § Ann. de Chim. lxviii. 33.
|| Lewis, Neumann's Chem. p. 317.   ** Brisson.

23 resin
77 gum
—
100

The resin is reddish, has a bitter taste and the peculiar odour of myrrh.   The gum according to Braconnot differs in its properties from every other gummy substance hitherto examined.   It has a dark brown colour; is at first soluble in water, but by boiling the liquid, or by exposing the gum to heat, it acquires cohesive properties, and becomes insoluble in water.   When distilled it yields ammonia, and when dissolved in nitric acid azotic gas is disengaged.   It is precipitated by the salts of lead, mercury, and tin, and it falls in combination with the oxides of these metals.*

But the result of the examination of myrrh by Pelletier differs materially from that of Braconnot.   According to him it is composed of

Resin containing some volatile oil. ... 34·68
Gum............................ 66·32
———
100·00

The resin owed its taste and solubility in water to the volatile oil, when deprived of which it became tasteless and insoluble in water and infusible at the temperature of 212°.   The gum possessed the properties of common gum.   It was soluble in water after the aqueous solution had been evaporated to dryness.   When treated with nitric acid it yielded oxalic acid but no saclactic acid.†

Euphor-
bium.
11. *Euphorbium.*—This substance is obtained from the *euphorbia officinalis*.   The milky juice which exudes from that plant, when dried in the sun, constitutes euphorbium.   It is brought from Africa in small yellow tears.   It has no smell, and is mostly soluble in alcohol.   Its specific gravity is 1·124.‡   It is considered as poisonous.

According to the analysis of Braconnot it is composed of

* Ann. de Chim. lxviii. 52.   † Ibid. lxxx. 45.
‡ Brisson.

Resin .... 37·0
Wax .... 19·0
Malate of lime .... 20·5
Malate of potash....... 2·0
Water .... 5·0
Woody matter .... 13·5
Loss .... 3·0
——————
100·0

The resin has peculiar properties. It is reddish and trans-
parent, excessively acrid, and possesses poisonous quali-
ties. It is insoluble in alkalies, but soluble in sulphuric
and nitric acid. These properties show it to be a peculiar
vegatable principle. The wax possesses the properties of
bees wax. The malate of lime had been mistaken for
gum.*

12. *Bdellium.*—This gum resin comes from Arabia, and Bdellium.
is supposed to be the produce of a species of *amyris*:
Though nothing certain has been published on that subject.
It is in yellowish transparent tears. When triturated be-
tween the teeth it becomes soft. Its taste is somewhat
acrid. When thrown upon burning coals it becomes soft,
and burns like a resin. Its specific gravity is 1·371.† Al-
cohol dissolves about three-fifths of its weight of bdellium,
the undissolved portion is a mixture of gum and cerasin.
According to the analysis of Pelletier its constituents are:

Resin 59
Gum .... 9·2
Cerasin .... 30·6
Volatile oil and loss .. 1·2
——————
100·0‡

13. Little is known concerning the substance called *ca-* Caranna.
ranna, reckoned among the gum resins. Its specific gra-
vity is 1·124.§ The substance extracted from ivy, and
known by the name of *gummi hederæ*, is considered at pre-
sent as a gum resin; but I do not know that it has been
chemically examined. Its specific gravity is 1·294.

* Ann. de Chim. lxviii. 44.   † Brisson.
‡ Ann. de Chim. lxxx. 39.   § Brisson.

Ipecacu-
an.

14. From the experiments made upon ipecacuan, the root of the *cephelis ipecacuanha*, especially by Dr. Irvine, we learn that it also contains a gum resin. The same remark applies to several other vegetable substances employed in medicine.

It deserves attention, that the gum resins, when subjected to destructive distillation, yield all of them a portion of ammonia; a proof that they all contain azote. In this respect they agree with extractive.

SECT. XXX.

OF CAOUTCHOUC.

History.

ABOUT the beginning of the 18th century, a substance called *caoutchouc* was brought as a curiosity from America. It was soft, wonderfully elastic, and very combustible. The pieces of it that came to Europe were usually in the shape of bottles, birds, &c. This substance is very much used in rubbing out the marks made upon paper by a black lead pencil; and therefore in this country it is often called *Indian-rubber*. Nothing was known of its production, except that it was obtained from a tree, till the French academicians went to South America in 1735 to measure a degree of the meridian. M. de la Condamine sent an account of it to the French Academy in the year 1736. He told them, that there grew in the province of Esmeraldas, in Brazil, a tree, called by the natives *Hhevé*; that from this tree there flowed a milky juice, which, when inspissated, was *caoutchouc*. Don Pedro Maldonado, who accompanied the French academicians, found the same tree on the banks of the Maragnon; but he died soon after, and his papers were never published. Mr. Fresnau, after a very laborious search, discovered the same tree in Cayenne. His account of it was read to the French Academy in 1751.*

Plants
yielding it.

It is now known that there are at least two trees in South America from which caoutchouc may be obtained; the *hævea caoutchouc*, and the *jatropha elastica*; and it is ex-

* Mem. Par. 1751, p. 319.

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ceedingly probable that it is extracted also from other species of *hævea* and *jatropha*. Several trees likewise which grow in the East Indies yield caoutchouc; the principal of these are, the *ficus indica*, the *artocarpus integrifolia*, and the *urceola elastica*; a plant discovered by Mr. Howison, and first described and named by Dr. Roxburgh.* Dr. Benjamin Smith Barton is said to have obtained it from the juice of the *similax caduca*, which grows abundantly in the neighbourhood of Philadelphia.† Mr. Woodcock found it in the milky juice of the *asclepias vincetoxicum*.‡

When any of these plants is punctured, there exudes from it a milky juice, which, when exposed to the air, gradually lets fall a concrete substance, which is caoutchouc.

If chlorine be poured into the milky juice, the caoutchouc precipitates immediately, and at the same time the acid loses its peculiar odour. This renders it probable that the formation of the caoutchouc is owing to its basis absorbing oxygen.§ If the milky juice be confined in a glass vessel containing common air, it gradually absorbs oxygen, and a pellicle of caoutchouc appears on its surface.||

Caoutchouc was no sooner known than it drew the attention of philosophers. Its singular properties promised that it would be exceedingly useful in the arts, provided any method could be fallen upon to mould it into the various instruments for which it seemed peculiarly adapted. Messrs. de la Condamine and Fresnau had mentioned some of its properties; but Macquer was the first person who undertook to examine it with attention. His experiments were published in the Memoirs of the French Academy for the year 1768. They threw a good deal of light on the subject; but Macquer fell into some mistakes, which were pointed out by Mr. Berniard, who published an admirable paper on caoutchouc in the 17th volume of the Journal de Physique. To this paper we are indebted for the greater number of facts at present known respecting caoutchouc. Mr. Grossart and Mr. Fourcroy having like-

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* Asiatic Researches, v. 167. London Edition.
† Phil. Mag. xl. 66.   ‡ Ibid. 125.
§ Fourcroy, Ann. de Chim. xi. 259.
|| Ibid.

wise added considerably to our knowledge of this singular substance; both of their treatises have been published in the 11th volume of the Annales de Chimie.

Properties.
Caoutchouc, when pure, is of a white colour,* and without either taste or smell. The blackish colour of the caoutchouc of commerce is owing to the method employed in drying it after it has been spread upon moulds. The usual way is to spread a thin coat of the milky juice upon the mould, and then to dry it by exposing it to smoke; afterwards another coat is spread on, which is dried in the same way. Thus the caoutchouc of commerce consists of numerous layers of pure caoutchouc alternating with as many layers of soot.

Caoutchouc is soft and pliable like leather. It is exceedingly elastic and adhesive; so that it may be forcibly stretched out much beyond its usual length, and instantly recover its former bulk when the force is withdrawn. It cannot be broken without very considerable force. Its specific gravity is 0·9335.†

Elasticity owing to latent heat.
To that acute philosopher Mr. Gough of Manchester, I am indebted for some very important experiments on the connexion between the temperature of caoutchouc and its elasticity. They have been since published in the second volume of the Manchester Memoirs, second series. It is necessary to premise, that Mr. Gough has been blind from an infant, and that therefore his sense of touch is peculiarly delicate; so much so, that he is an excellent botanist, and can distinguish plants with the utmost certainty by the feel: a power so extraordinary, that we who enjoy the advantage of sight can scarcely conceive how it can be acquired. Mr. Gough's experiments are as follows:

Take a thong of this substance two or three inches long, and a few lines in breadth and thickness; put it in warm water till it becomes quite pliant: then, holding it merely extended between the two hands, bring the edge of it in contact with the lips, and observe the temperature (of the variations of which that part of the face is a very nice

* I have some pieces of it from the East-Indies which had been allowed to inspissate in the open air. They are white, with a slight cast of yellow, and have very much the appearance and feel of white soap.
† Brisson.

judge); then remove the thong a few lines from the lips, and stretch it forcibly, and bring it again in contact with the lips, and a very sensible increase of temperature will be perceived. Allow it to relax to its former state, and the temperature will be perceived immediately to sink. If we stretch the thong again, and then plunge it immediately into cold water, keeping it extended for a minute or more in the liquid, on letting go one end it will be found to have lost much of its contractile power; for it will not return to its former dimensions. But if we plunge it into warm water, or warm it by holding it for some time in the shut hand, it will begin to contract again, and soon return to its former figure and size. These experiments are of great importance, as they furnish a very palpable and convincing proof that ductility is owing to latent heat as well as fluidity. They afford a fine illustration of Dr. Black's theory of latent heat. We see clearly that the elasticity of caoutchouc and the ductility of metals are different cases of one and the same thing.

Caoutchouc is not altered by exposure to the air; it is perfectly insoluble in water: but if boiled for some time its edges become somewhat transparent, owing undoubtedly to the water carrying off the soot; and so soft, that when two of them are pressed and kept together for some time, they adhere as closely as if they formed one piece. By this contrivance pieces of caoutchouc may be soldered together, and thus made to assume whatever shape we please.*

Caoutchouc is insoluble in alcohol. This property was Action of discovered very early, and fully confirmed by the experi- alcohol. ments of Mr. Macquer. The alcohol, however, renders it colourless.

Caoutchouc is soluble in ether. This property was first Ether. pointed out by Macquer. Berniard, on the contrary, found that caoutchouc was scarcely soluble at all in sulphuric ether, which was the ether used by Macquer, and that even nitric ether was but an imperfect solvent. The difference in the results of these two chemists was very singular; both were remarkable for their accuracy, and both were too well acquainted with the subject to be easily misled. The matter

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* Grossart, Ann. de Chim. xi. 153. See a method of making caoutchouc tubes by means of this property, Phil. Mag. xxii. 340.

was first cleared up by Mr. Cavallo. He found that ether, when newly prepared, seldom or never dissolved caoutchouc completely; but if the precaution was taken to wash the ether previously in water, it afterwards dissolved caoutchouc with facility. Mr. Grossart tried this experiment, and found it accurate.* It is evident from this that these chemists had employed ether in different states. The washing of ether has two effects. It deprives it of a little alcohol with which it is often impregnated, and it adds to it about one-tenth of water, which remains combined with it. Alcohol precipitates the caoutchouc from this solution.

When the ether is evaporated, the caoutchouc is obtained unaltered. Caoutchouc, therefore, dissolved in ether, may be employed to make instruments of different kinds, just as the milky juice of the *hævea;* but this method would be a great deal too expensive for common use.

Oils. Caoutchouc is soluble in volatile oils; † but, in general, when these oils are evaporated, it remains somewhat glutinous, and therefore is scarcely proper for those uses to which, before its solution, it was so admirably adapted.

Alkalies. It is said by Berniard to be insoluble in alkalies; but I find upon trial that this is a mistake. I was led to make the experiment by an accident. I employed a caoutchouc bottle fitted with a stop-cock in the usual way for holding ammonical gas. The gas very soon disappeared, though the bottle was perfectly air-tight, as I learned by plunging it in water. This induced me to fill it repeatedly with gas. In a short time it became evident that the gas had been absorbed by the bottle itself. It became soft and then glutinous, and never recovered its elasticity. I then tried the alkalies in general, and found that they were all capable of producing the same changes on caoutchouc, and even of dissolving it, though in a very minute proportion.

Acids. The acids act but feebly upon caoutchouc. Sulphuric acid, even after a very long digestion, only chars it superficially. The proportion of charcoal obtained in Mr. Hatchett's experiments was only 12 per cent. and he could observe no traces of artificial tannin.‡ But when heat is applied the caoutchouc is completely decomposed. When

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* Grossart, Ann. de Chim. xi. 147.   † Berniard.
‡ Third Series of Experiments on Artificial Tannin, Phil. Trans. 1806.

treated with nitric acid, there came over azotic gas, carbonic acid gas, prussic acid gas; and oxalic acid is said to be formed.* Muriatic acid does not affect it.† The other acids have not been tried.

Fabroni has discovered that rectified petroleum dissolves it, and leaves it unaltered when evaporated.‡

Heat.

When exposed to heat it readily melts; but it never afterwards recovers its properties, but continues always of the consistence of tar. It burns very readily with a bright flame, and diffuses a fetid odour. In those countries where it is produced, it is often used by way of candle.

When distilled it gives out ammonia. § It is evident from this, and from the effect of sulphuric and nitric acid upon it, that it is composed of carbon, hydrogen, azote, and oxygen; but the manner in which they are combined is unknown.

It seems to exist in a great variety of plants; but it is usually confounded with the other ingredients. It may be separated from resins by means of alcohol. It may be extracted from the different species of missletoe by water, with which, in the fluid state in which it exists in these plants, it readily combines. When mixed with gum or extractive, it may be separated by the following process: Digest a part of the plant containing it first in water and then in alcohol, till all the substances soluble in these liquids are extracted. Dry the residuum, and digest it in five times its weight of rectified petroleum. Express the liquid part by squeezing the substances in a linen cloth. Let this liquid remain several days to settle, then decant off the clear liquid part, mix it with a third part of water and distil; the caoutchouc remains behind.||

Plants containing it.

According to Bucholz, opium contains a considerable portion of caoutchouc.** That part of mastich which is insoluble in alcohol possesses the properties of caoutchouc, as has been formerly observed.

* Ann. de Chim. xi. 232.   † Berniard.
‡ Ann. de Chim. xi. 195; and xii. 156.
§ Ann. de Chim. xi. 232.
|| Hermbstadt, Med. and Phys. Jour. iii. 372.
** Ann. de Chim. xxxiv. 133.

SECT. XXXI.

OF COTTON.

Origin.

COTTON is a soft down which envelopes the seeds of various plants, especially the different species of *gossypium*, from which the cotton of commerce is procured. These plants are natives of warm climates; grow wild in Asia, Africa, and America, within the tropics; and are cultivated in the East and West Indies. The finest cotton, according to Mr. Edwards, is distinguished by the name of *green seed cotton*, from the colour of its seeds,* and is perhaps the produce of the *gossypium hirsutum*. There are two species of it; in one of which the cotton does not easily part from the seeds. But the cotton plant commonly cultivated is a shrub, of which Mr. Edwards enumerates five kinds; namely, the *common Jamaica*, the *brown bearded*, the *nankeen*, the *French* (*gossypium arboreum*,) and the *kidney cotton*.† When the seeds are ripe, the pods open and display the cotton, which is collected and separated from the seeds by means of rollers.

Cotton, when spun and woven into cloth, furnishes garments to a very considerable portion of the civilized world. The quantity annually brought into this country, and spun by machinery, is not less than 20 millions of pounds; and the number of individuals employed in manufacturing it cannot be less than 700,000. It constitutes therefore one of the most important of our manufactures.

Though no correct chemical investigation of the properties of cotton has hitherto been made, yet as its obvious qualities distinguish it sufficiently from every other vegetable substance, we must consider it as a peculiar vegetable principle; and I have introduced it here, in hopes that some person or other will be induced to examine its nature in detail. The following are the particulars at present known.

Properties.

This substance is in threads differing in length and in fineness. No asperities can be discovered on the surface of

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* History of the West Indies, ii. 264.

† Perhaps the first species are only varieties of the gossypium herbaceum.

these threads: but if Lewenhoeck's microscopical observations are to be trusted, they are all triangular, and have three sharp edges. Cotton differs considerably in colour; but when bleached it becomes of a fine white.

Cotton is tasteless and destitute of smell. It is completely insoluble in water, alcohol, ether, and oils, and in all the vegetable acids.

The diluted alkaline leys have no perceptible action on cotton; but when very strong they dissolve it if assisted by a sufficient degree of heat. The new products obtained by this solution have not been examined.

Cotton has a strong affinity for some of the earths, especially for alumina. Hence this substance is used to fix colours on cotton. The cloth is steeped in a solution of alum or acetate of alumina, and afterwards dyed.

Several of the metallic oxides also combine with it readily, and remain united with much obstinacy. Oxide of iron is one of the most remarkable. When cotton is dipped into a solution of iron in an acid, it comes out yellow, and the iron is neither separated by alkalies nor soap, nor even by acids, unless when the combination is quite recent. The colour gradually deepens by exposure to the air, owing no doubt to the oxidizement of the iron, unless the cloth be steeped in an aluminous solution, which prevents the colour from becoming disagreeable, probably by diluting it.* Oxide of tin also combines with cotton, and is frequently used as a mordant.

Cotton combines readily with tannin, and forms a yellow or brown compound. Hence the infusion of galls, and of other astringent substances, is often used as a mordant for cotton.

Nitric acid decomposes cotton when assisted with heat, and oxalic acid is formed; the other products have not been examined. Sulphuric acid likewise chars it. Chlorine gas bleaches it, and probably alters and dissolves it when applied in a concentrated state.

Cotton is extremely combustible, and burns with a clear lively flame. The ashes left behind, according to Neumann, contain some potash. When distilled it yields a great portion of acidulous water, and a small quantity of oil, but no ammonia.†

* See Chaptal, Ann. de Chim. xxvi. 266.
† Neumann's Chem. p. 430.

SECT. XXXII.

OF SUBER.

THIS name has been introduced into chemistry by Four-croy, to denote the outer bark of the *quercus suber*, or the common cork; a substance which possesses properties different from all other vegetable bodies.

It is exceedingly light, soft, and elastic; very combustible, burning with a bright white flame, and leaving a light black bulky charcoal; and when distilled it yields a little ammonia.

Properties.   When digested in water, a yellowish-coloured solution is obtained, seemingly containing extractive, as nearly the same proportion is taken up by alcohol.* Sulphuric acid readily chars it. Nitric acid gives it a yellow colour, corrodes, dissolves, and decomposes it; converting it partly into suberic acid, partly into a substance resembling wax, partly into artificial tannin, and partly into a kind of starchy matter.†

Fourcroy supposes, from some experiments which he does not relate, that the epidermis of all trees is a substance possessed of the same properties with cork; and perhaps we may conclude from the experiments of Link, that all vegetable membrane possesses nearly the same chemical characters. At least it agrees with cork in furnishing suberic acid when treated with nitric acid.‡

SECT. XXXIII.

OF MEDULLIN.

THIS is a name given by Dr. John to the pith of the sunflower (*helianthus annuus*,) the syringa vulgaris, &c.

According to him it is distinguished by the following properties.

Properties.   1. It is insoluble in water, ether, alcohol, and oils.

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* Neumann's Chemistry, p. 428.
† Bouillon La Grange, Ann. de Chim. xxiii. 50.
‡ Nicholson's Jour. xxiii. 155.

2. It is destitute of taste and smell.

3. Its structure is peculiar, being full of pores.

4. It is soluble in nitric acid; but instead of forming suberic acid, as is the case with suber, it furnishes a quantity of oxalic acid.

5. When distilled it furnishes a considerable quantity of ammonia, and leaves a charcoal having a metallic appearance and a colour similar to that of bronze.*

SECT. XXXIV.

OF WOOD.

ALL trees, and most other plants, contain a particular substance, well known by the name of *wood*. If a piece of wood be well dried, and digested, first in a sufficient quantity of water and then of alcohol, to extract from it all the substances soluble in these liquids, there remains only behind the *woody fibre*.

This substance, which constitutes the basis of wood, is composed of longitudinal fibres, easily subdivided into a number of smaller fibres. It is somewhat transparent; is perfectly tasteless; has no smell; and is not altered by exposure to the atmosphere.

It is insoluble in water and in alcohol. The fixed alkalies, when assisted by heat, give it a deep brown colour, render it soft, and decompose it. A weak alkaline solution dissolves it without alteration; and it may be thrown down again by means of an acid. By this property we are enabled to separate wood from most of the other vegetable principles, as few of them are soluble in weak alkaline leys. *Properties.*

When heated, it blackens without melting or frothing up, and exhales a disagreeable acrid fume, and leaves a charcoal which retains exactly the form of the original mass. When distilled in a retort, it yields an acid liquor of a peculiar taste and smell, distinguished by the name of pyrolignous, and formerly considered as a distinct acid; *Action of heat,*

* John's Chemische Tabellen der Pflanzen Analysen, p. 9.

but Fourcroy and Vauquelin ascertained that it is merely the acetic acid combined with an empyreumatic oil.*

By nitric acid Fourcroy converted the residuum of quin-quina, which does not seem to differ from the woody fibre, into oxalic acid ; at the same time there was a little citric acid formed, and a very small quantity of malic and acetic acids. Some azotic gas also was disengaged.

By this process he obtained from 100 parts of woody fibre

Oxalic acid	56·250
Citric acid.	3·905
Malic acid	0·388
Acetic acid	0·486
Azotic gas	0·867
Carbonate of lime	8·330
	70·226
Residuum	32·031
	102·257

There was likewise a quantity of carbonic acid gas dis-engaged, the weight of which was unknown. This increase of weight in the product was evidently owing to the oxygen derived from the nitric acid.†

When this residuum was distilled in a retort, 100 parts yielded the following products :

26·620 of a yellow liquid, containing alcohol, and an acid which had the smell of pyromucous.

6·977 of concrete oil, mostly soluble in alcohol.

22·995 charcoal
3·567 carbonate of lime } in the retort.

60·159
39·841 gas, half-carbonic acid, half-carbureted hydrogen.

100·000 ‡

* Mollerat has succeeded in France in making acetic acid from wood as pure as radical vinegar. It answers very well for aromatic vinegar, but possesses a little acrimony, which makes it less fit for the table. See Nicholson's Jour. xxiv. 70. Very good vinegar from wood is now made both in London and Glasgow. Animal charcoal is probably employed to remove the empyreumatic oil.

† Ann. de Chim. viii. 153.   ‡ Ibid. 151.

Several analyses of pure woody fibre were made by Gay- Lussac and Thenard, by burning it along with chlorate of potash and ascertaining the products. The result of their experiments gives its constituents as follows:

	Oak.	Beech.	Mean.
Oxygen	41·78	42·73	42·25
Carbon	52·53	51·45	52·00
Hydrogen	5·69	5·82	5·75
	100·00	100·00	100·00[*]

As we are unacquainted with the weight of an integrant particle of woody fibre, it is impossible from this analysis to deduce the number of atoms of which it is composed. But the smallest number that corresponds with the analysis is the following:

4 atoms oxygen	= 4	41·02
7 atoms carbon	= 5·25	53·86
4 atoms hydrogen	= 0·5	5·12
	9·75	100·00

Were these numbers the representation of the true constitution of wood, it would follow that it might yield more than half its weight of acetic acid. For if we suppose it deprived of 1 atom water and 3 atoms carbon, the residue would be acetic acid.

When wood is burnt with a smothered flame, it leaves as is well known, a quantity of charcoal behind it, which exhibits the exact form, and even the different layers of the original wood. As it is the wood alone which undergoes this change, while the other component parts of the plant are dissipated, we may form some notion of the relative proportion of wood which different plants contain, by the proportion of charcoal which they yield. Now, the quantity of charcoal yielded by 1·00 of different trees is, according to the experiments of Proust, as follows:

Black ash	0·25	Heart of oak	0·19
Guaiacum	0·24	Wild ash	0·17
Pine	0·20	White ash	0·17
Green oak	0·20		

[*] Recherches Physico-chimiques, ii. 294.

Book IV.   Count Rumford by continuing a very moderate fire for
96 hours converted different kinds of wood into charcoal,
and obtained a much greater proportion of charcoal than
was obtained in the preceding experiments of Proust. The
following table exhibits the weight of charcoal left in these
experiments by 1·00 of the different woods tried.*

Poplar . . . . . 0·4357	Maple . . . . . 0·4223
Lime . . . . . . 0·4359	Elm . . . . 0·4327
Fir . . . . 0·4418	Oak . . . . 0·4300

SECT. XXXV.

OF FUNGIN.

This is a name given by Braconnot to the fleshy part of
mushrooms, which he considers as a peculiar vegetable
principle.   It approaches in its chemical characters so
closely to woody fibre, that perhaps it would be better to
consider it merely as a variety of that substance. Fungin
is the substance which remains after the mushroom has been
deprived of every thing soluble, either in water or alcohol.
It is distinguished by the following properties.

Properties.   It is white, soft, and insipid, possesses but little elasticity,
and divides easily between the teeth.   In this state it con-
stitutes a nourishing article of food.

It is insoluble in water, alcohol, ether, and oils.

Action of   Alkalies have but little action on fungin; a property
alkalies,   which distinguishes it from woody fibre which is very rea-
dily dissolved even by a weak alkaline ley.   Yet when
boiled in a concentrated alkaline ley fungin is partly dis-
solved, and a saponaceous liquid is obtained from which the
acids throw down a flocky matter.

Of acids.   Ammonia dissolves a little of it when digested over fungin
and on exposure to the air allows it to precipitate again in
the state of white flocks.

Diluted sulphuric acid has no action on it; but concen-
trated sulphuric acid chars it while acetic and sulphurous
acids are evolved.

* Gilbert's Annalen der Physick, xlv. 25.

Muriatic acid, at first, seems to have no action on it, even though assisted by heat; but it gradually dissolves it and converts it into a gelatinous matter soluble in water. Potash dropped into the solution throws down the fungin, probably altered in its properties.

Chlorine gas converts it into a yellow matter which has an acrid taste while wet, but which it loses when dried. This yellow substance is a compound of fungin, muriatic acid, and a kind of adiporesinous matter.

Weak nitric acid disengages azote from it. When distilled with six times its weight of nitric acid it becomes yellow, swells considerably, and effervesces at first very much; but the violent action soon subsides. Prussic acid is formed by this process, together with a considerable quantity of oxalic acid, two fatty bodies resembling tallow and wax and a small quantity of yellow-bitter principle, and a yellow resinous looking substance.

When put into infusion of nutgalls it absorbs the greatest part of the tannin contained in that liquid, and acquires a fawn-colour.

When mixed with water and left to spontaneous putrifaction it emits, at first, the smell of putrid cheese; but this smell soon goes off. The liquid covering it, after an interval of three months, was neither acid nor alkaline; but held in solution a mucilaginous matter. The fungin still retained its original shape. When washed it is easily reduced to a pulp, which may be kneaded between the fingers; but has not the elastic consistence of gluten.

Fungin when dry burns with vivacity, and leaves a white ash consisting chiefly of posphate of lime.

Thirty-eight parts being distilled yielded 8 parts of a brown empyreumatic oil, and $11\frac{1}{2}$ parts of a liquid containing an excess of ammonia and holding in solution acetate of ammonia mixed with oil. The charcoal in the retort weighed 10 parts.* When fungin was distilled by Vauquelin, the liquid which he obtained contained ammonia; but it reddened vegetable blues, and therefore contained an excess of acetic acid as is the case with the liquid obtained from the distillation of wood.†

* Braconnot, Ann. de Chim. lxxix. 267.
† Ann. de Chim. lxxxv. 12.

SECT. XXXVI.

FOREIGN SUBSTANCES FOUND IN PLANTS.

THESE are substances which seem rather to belong to the mineral than the vegetable kingdom; but which require to be enumerated because they constantly make their appearance, though but in small quantity, chiefly in the vegetable juices. These substances may be arranged under four heads; namely, *acids, alkalies, earths,* and *metals.*

I. ACIDS.

The mineral acids found in plants are usually combined with a base constituting different salts. They are the phosphoric, silica, sulphuric, nitric, muriatic, and carbonic acids.

Phosphoric.   1. Phosphoric acid has been found in different plants, but only in very small quantities : it is almost constantly combined with lime or potash, though it exists free in the onion. Meyer found it in the leaves of many trees;* Thuren found phosphate of lime in the *aconitus napellus* ; † and Bergman found it in all kinds of grain.‡ Phosphate of potash exists in barley and other species of corn, and has, I presume, been often confounded with phosphate of lime.

Silica.   2. Silica exists in many plants, particularly in grasses and equisetums. Sir H. Davy has ascertained that it forms a part of the epidermis, or outermost bark of these plants; and that in some of them almost the whole epidermis is silica.

Parts Silica.

100 parts of the epid. of bonnet cane yielded .. 90
——————————————— bamboo .... 71·4
——— (arundo phragm.) common reed....... 48·1
——————————————— stalks of corn .... 6·5

The concretions which are sometimes found in the bamboo cane called tabasheer, have been ascertained by Mr. Macie to be composed of pure silica.§

Any attempt to enumerate the plants in which traces of

* Encyc. Meth. Phisiol. Veget. i. 100.   † Ann. de Chim. ii. 308.
‡ Bergman, v. 96.
§ Fourcroy and Vauquelin examined a tabasheer from the Andes, and found it composed of 70 silica and 30 potash. Gehlen's Jour. Second Series, ii. 112.

sulphuric, muriatic, nitric, and carbonic acids have been found would be superfluous. It may be sufficient to say that common salt is an ingredient in almost all plants that grow in the sea, and in many that vegetate on the sea-shore; that nitre exists in sun-flower, nitrate of soda in barley, and sulphate of lime in clover.

II. ALKALIES.

The only alkalies found in plants are potash and soda. Ammonia may indeed be obtained by distilling many vegetable substances, but it is produced during the operation. One or other of these alkalies is found in every plant which has hitherto been examined. The quantity indeed is usually very small. From the experiments of Vauquelin, it is probable that the alkalies are combined in plants with acetic and carbonic acids.
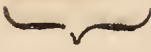
1. Potash is found in almost all plants which grow at a Potash. distance from the sea. It may be extracted by burning the vegetable, washing the ashes in water, filtrating the water, and evaporating it to dryness. It is in this manner that all the potash of commerce is procured.

The following table exhibits the quantity of ashes and potash which may be extracted from 100 parts of various plants:

	Ashes.	Potash.
Sallow	2·8	0·285*
Elm	2·36727	0·39†
Oak	1·35185	0·15343
Poplar	1·23476	0·07481

* Those marked † are from Kirwan, Irish. Trans. v. 164. The rest from Pertuis, Ann. de Chim. xix. 178. The following table by Redi, of the ashes and salts yielded by different plants, is worth inserting. It is printed in the Phil. Trans. for 1698 (vol. xx. p. 281.)

Pounds.	Vegetables.	Ashes. lbs.	oz.	dr.	Salts. oz.	dr.
100	Of dried flowers of oranges	4	6	0	0	5
800	Of gourds new gathered, which dried in the oven were 36 lbs	4	0	0	10	0
400	Red onions (being 720) roasted, the coals turned to 16 lbs. to the coals new added 4 oz. of sulphur	1	6	0	2	2
150	Eyebright fresh, and afterwards stilled and burnt	5	0	0	4	0
120	Distilled roses	4	0	1	0	0
100	Of maidenhair	9	0	0	0	4

Hornbeam	1·1283	.... 0·1254
Beech	0·58432	.... 0·14572
Fir	0·34133	.... ——
Vine branches........	3·379	.... 0·55†
Common nettle	10·67186	.... 2·5033
Common thistle	4·04265	.... 0·53734
Fern	4·00781	.... 0·6259
Cow thistle	10·5	.... 1·96603
Great river rush	3·85395	.... 0·72234
Feathered rush	4·33593	.... 0·50811
Stalks of turkey wheat .	8·86	.... 1·75†
Wormwood....	9·744	.... 7·3
Fumitory	21·9	.... 7·9†
Trifolium pratense	——	.... 0·078†
Vetches	——	.... 2·75†
Beans with their stalks .	——	.... 2·0 †

Pounds.	Vegetables.	Ashes. lbs.	oz.	dr.	Salts. oz.	dr.
150	Roots of black hellebore, which dried came to 50 lbs...............................	6	0	0	1	0
150	Roots of white hellebore, fresh, which dried came to 50 lbs.........................	2	0	0	4	0
96	Roots dried and burnt of fresh esula......	3	0	0	2	0
30	Roots of liquorice	2	0	0	1	4
20	Pellitory	1	0	0	0	6
100	Green endive	2	0	0	2	0
90	Green bindweed	1	0	0	2	0
2000	Leaves of laurel	33	0	4	0	0
500	Leaves of laurel	6	0	0	10	0
1000	Water melons well ripe, the seeds being taken	25	0	1	9	0
2400	Cucumbers.............................	18	0	0	0	0
300	Wood of ivy............................	9	0	0	0	0
50	Scorzonera dried	8	0	0	0	0
300	Pine apples, the nuts taken out	3	0	0	0	0
150	Mugwort dried..........................	8	0	0	0	0
130	Leaves of cyprus	6	0	0	0	·0
10	Peel of pomegranates dried..............	0	8	0	0	0
2	Sassafras	0	0	0	0	0
12	Lignum sanctum	2	6	0	0	0
4	Yellow sanders.........................	0	1	4	0	0
4	Black pepper	0	2	4	0	0
30	Ginger	1	7	0	0	0
12	Turbith	1	0	0	0	0
	Wood of fir	3	0	0	3	0
	Scopæ	16	0	1	4	0
	Scopæ.................................	16	0	1	0	0

In general, three times as much ashes are obtained from shrubs, and five times as much from herbs, as from trees. Equal weights of the branches of trees produce more ashes than the trunk, and the leaves more than the branches. Herbs arrived at maturity produce more ashes than at any other time. Green vegetables produce more ashes than dry.*

The salt which is obtained from plants does not consist wholly of potash, there are other salts mixed with it; these usually are sulphate of potash, muriate of potash, sulphate of lime, phosphate of lime, &c.; but these bear, in general, but a small proportion to the potash. The ashes consist of potash, mixed with earths.

Some judgment may be formed of the quantity of potash which a plant contains, from the quantity of ashes which it yields: but the foregoing table is sufficient to show us, that were we to trust to that we should often be misled.

2. Soda is found in almost all the plants which grow in the sea, and in many of those which grow on the shore. In general, the quantity of soda which plants contain bears a much greater proportion to their weight than the potash does which is found in inland vegetables. One-hundred parts of the *salsola soda*, for instance, yield 19·921 of ashes; and these contain 1·992 parts of soda; some of which, however, is combined with muriatic acid.† The plants from which the greater part of the soda, or *barilha* as it is called, which is imported from Spain, is extracted, are the *salsola sativa* and *vermiculata*.

Soda.

III. EARTHS.

The only earths hitherto found in plants are the three following; *lime, magnesia, alumina.*

1. Lime is usually the most abundant of the earths of plants, and the most generally diffused over the vegetable kingdom. Indeed it is a very uncommon thing to find a plant entirely destitute of lime: salsola soda is almost the only one in which we know for certain that this earth does not exist.‡

2. Magnesia does not exist so generally in the vegetable

Lime.

Magnesia.

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* Ann. de Chim. xix. 174.   † Vauquelin, ibid. xviii. 77.
‡ Vauquelin, Ann. de Chim. xviii. 76.

Book IV. kingdom as the two preceding earths. It has been found, however, in considerable quantities in several sea plants, especially fuci; * but the salsola soda contains a greater proportion of magnesia than any plant hitherto examined. Mr. Vauquelin found that 100 parts of it contained 17·929 of that earth.†

Alumina.   3. Alumina has only been found in very small quantities in plants.

The following table will show the quantity of these four earths which exist in several vegetables.

100 parts of Oak contain of earths	1·03 ‡
Beech	0·453 §
Fir	0·003 §
Turkey wheat	7·11 §
Sunflower	3·72 §
Vine branches	2·85 §
Box	2·674 §
Willow	2·515 §
Elm	1·96 §
Aspin	1·146 §
Fern	3·221 ‖
Wormwood	2·444 **
Fumitory	14·000 **

This table shows us that the quantity of earth is greater in herbs than in trees.

Bergman found all the four earths in every kind of grain which he analysed.††

Vauquelin found that 100 parts of oat grain left 3·1591 of residuum. This residuum is composed of

Silica	60·7
Phosphate of lime ..	39·3
	100·0 ‡‡

When the whole of the *avena sativa*, however, stalk and seed together, is burnt, it leaves a residuum composed of

* Vauquelin, Ann. de Chim. xviii. 86, and ix. 94.   † Ibid. p. 78.
‡ Watson.   § Kirwan, Irish Trans. iii. 35.
‖ Home.   ** Wiegleb.   †† Opusc. v. 94.
‡‡ Ann. de Chim. xxix. 17.

5

Silica 55
Phosphate of lime ... 15
Potash 20
Carbonate of lime ... 5
                      ——
                      95 and a little oxide of iron.*

This shows us that the stalk contains several substances not to be found in the grain.

The following table exhibits the quantity of earths and metallic oxides in grains, obtained by Schræder from 32 ounces of the seeds of the following kinds of corn; wheat (*triticum hybernum*), rye (*secale cereale*), barley (*hordeum vulgare*), oats (*avena sativa*), and likewise from the same quantity of rye straw.†

	Wheat.	Rye.	Barley.	Oats.	Rye Straw.
Silica	13·2	15·6	66·7	144·2	152
Carbonate of lime	12·6	13·4	24·8	33·75	46·2
Carbonate of magnesia	13·4	14·2	25·3	33·9	28·2
Alumina	0·6	1·4	4·2	4·5	3·2
Oxide of manganese ..	5·0	3·2	6·7	6·95	6·8
Oxide of iron	2·5	0·9	3·8	4·5	2·4
	47·3	48·7	131·5	227·8	238·8

Earths in corn.

Saussure junior, in his *Chemical Researches on Vegetation*, a work published in 1804, has given us the most copious table of the earthy and saline constituents of vegetables which has yet appeared. This table is the more valuable, as it was constructed entirely from his own experiments. For that reason I shall insert it in this place:

* Ann. de Chim. xxix. 19.   † Gehlen's Jour. iii. 525.

Book IV.

Saussure's table.

		TABLE OF INCINERATIONS.			Constit. of 100 parts of ashes.					
	Names of Plants.	Ashes from 1000 parts of the plant green.	Ditto, dry.	Water from 1000 parts of the plant, green.	Soluble Salts.	Earthy Phosphates.	Earthy Carbonates.	Silica.	Metallic Oxides.	Loss.
1	Leaves of oak (*quercus robur*), May 10.	13	53	745	47	24	0·12	3	0·64	25·24
2	Ditto, Sept. 27.	24	55	549	17	18·25	23	14·5	1·75	25·5
3	Wood of a young oak, May 10.		4		26	28·5	12·25	0·12	1	32·58
4	Bark of ditto.		60		7	4·5	63·25	0·25	1·75	22·75
5	Perfect wood of oak.		2		38·6	4·5	32	2	2·25	29·65
6	Alburnum of ditto.		4		32	24	11	7·5	2	23·5
7	Bark of ditto.		60		7	3	66	1·5	2	21·5
8	Cortical layers of ditto.		73		7	3·75	65	0·5	1	12·75
9	Extract of wood of ditto.		61		51					
10	Soil from wood of ditto.		41		24	10·5	10	32	14	8·5
11	Extract from ditto.		111		66					
12	Leaves of poplar (*populus nigra*), May 26.	23	66	652	36	13	29	5	1·25	15·75
13	Ditto, Sept. 12.	41	93	565	26	7	36	11·5	1·5	18
14	Wood of ditto, Sept. 12.		8	26		16·75	27	3·3	1·5	24·5
15	Bark of ditto.		72		6	5·3	60	4	1·5	23·2
16	Leaves of hazel (*corylus avellana*), May 1.		61		26	23·3	22	2·5	1·5	24·7

Table continued.

	Names of Plants.	TABLE OF INCINERATIONS.			Constit. of 100 parts of the ashes.					
		Ashes from 1000 parts of the plant, green.	Ditto, dry.	Water from 1000 parts of the plant, green.	Soluble Salts.	Earthy Phosphates.	Earthy Carbonates.	Silica.	Metallic Oxides.	Loss.
17	Ditto, washed in cold water.		57		8·2	19·5	44·1	4	2	22·2
18	Leaves of ditto, June 22.	28	62	655	22·7	14	29	11·3	1·5	21·5
19	Ditto, Sept. 20.	31	70	557	11	12	36	22	2	17
20	Wood of ditto, May 1.		5		24·5	35	8	0·25	0·12	32·2
21	Bark of ditto.		62		12·5	5·5	54	0·25	1·75	26
22	Perfect wood of mulberry (morus nigra), November.		7		21	2·25	56	0·12	0·25	20·38
23	Alburnum of ditto.		13		26	27·25	24	1	0·25	21·5
24	Bark of ditto.		89		7	8·5	45	15·25	1·12	23·13
25	Cortical layers of ditto.		88		10	16·5	48	0·12	1	24·38
26	Perfect wood of hornbeam (carpinus betulus), Nov.	4	6	346	22	23	26	0·12	2·25	26·63
27	Alburnum of ditto,	4	7	390	18	36	15	1	1	29
28	Bark of ditto.	88	134	346	4·5	4·5	59	1·5	0·12	30·38
29	Wood of horse-chesnut (æsculus hyppocastanum), May 10.		35		9·5					
30	Leaves of ditto, May 10.	16	72	782	50					

Table continued.

Book IV.

	Names of Plants.	Ashes from 1000 parts of the plant, green.	Ditto, dry.	Water from 1000 parts of the plant, green.	Soluble Salts.	Earthy Phosphates.	Earthy Carbonates.	Silica.	Metallic Oxides.	Loss.
	TABLE OF INCINERATIONS.				**Constit. of 100 parts of the ashes.**					
31	Ditto, July 23.	29	84	652	24					
32	Ditto, Sept. 27.	31	86	636	13·5					
33	Flowers of ditto, May 10.	9	71	873	50					
34	Fruit of ditto, October 5.	12	34	647	82	12	0	0·5	0·25	5·25
35	Plants of pease (*pisum sativum*), in flower.		95		49·8	17·25	6	2·3	1	24·65
36	Ditto, ripe.		81		34·25	22	14	11	2·5	17·25
37	Plants of vetches (*vicia faba*), before flowering, May 23.	16	150	895	55·5	14·5	3·5	1·5	0·5	24·50
38	Ditto, in flower, June 23.	20	122	876	55·5	13·5	4·12	1·5	0·5	24·38
39	Ditto, ripe, July 23.		66		50	17·75	4	1·75	0·5	26
40	Ditto, seeds separated.		115		42	5·75	36	1·75	1	12·9
41	Seeds of ditto.		33		69·28	27·92	0	0	0·5	2·3
42	Ditto, in flower, raised in distilled water.		39		60·1	30	0	0	0·5	9·4
43	*Solydago vulgaris*, before flowering, May 1.		92		67·5	10·75	1·25	1·5	0·75	18·25
44	Ditto, just in flower, July 15.		57		59	8·5	9·25	1·5	0·75	21

Table continued.

	Names of Plants.	Ashes from 1000 parts of the plant, green.	Ditto, dry.	Water from 1000 parts of the plant, green.	Soluble Salts.	Earthy Phosphates.	Earthy Carbonates.	Silica.	Metallic Oxides.	Loss.
	TABLE OF INCINERATIONS.				Constit. of 1000 parts of the ashes.					
45	Ditto, Seeds ripe, Sept. 20.		50		48	11	17·25	3·5	1·5	18·75
46	Plants of turnsol (*helianthus annuus*), a month before flowering, June 23.		147		63	6·7	11·56	1·5	0·12	16·67
47	Ditto in flower, July 23.	13	137	877	61	6	12·5	1·5	0·12	18·78
48	Ditto, bearing ripe seeds, Sept. 20.	23	93	753	51·5	22·5	4	3·75	0·5	17·75
49	Wheat (*triticum sativum*), in flower.				43·25	12·75	0·25	32	0·5	12·25
50	Ditto, seeds ripe.				11	15	0 25	54	1	18·75
51	Ditto, a month before flowering.		79		60	11·5	0·25	12·5	0·25	15·5
52	Ditto, in flower, June 14.	16	54	699	41	10·75	0·25	26	0·5	21·5
53	Ditto, seeds ripe.		33		10	11·75	0·25	51	0·75	23
54	Straw of wheat.		43		22·5	6·2	1	61·5	1	7·8
55	Seeds of ditto.		13		47·16	44·5	0	0·5	0·25	7·6
56	Bran.		52		44·16	46·5	0	0·5	0·25	8·6
57	Plants of maize (*zea mays*), a month before flowering, June 23.		122		69	5·75	0·25	7·5	0·25	17·25

Table continued.

Book IV.

	Names of Plants.	Ashes from 1000 parts of the plant, green.	Ditto, dry.	Water from 1000 parts of the plant, green.	Soluble Salts.	Earthy Phosphates.	Earthy Carbonates.	Silica.	Metallic Oxides.	Loss.
	TABLE OF INCINERATIONS.				Consist. of 100 parts of the ashes.					
58	Ditto, in flower, July 23.		81		69	6	0·25	7·5	0·25	17
59	Ditto, seeds ripe.		46							
60	Stalks of ditto.		84		72·45	5	1	18	0·5	3·05
61	Spikes of ditto.		16							
62	Seeds of ditto.		10		62	36	0	1	0·12	0·88
63	Chaff of barley (*hordeum vulgare*).		42		20	7·75	12·5	57	0·5	2·25
64	Seeds of ditto.		18		29	32·5	0	35·5	0·25	2·8
65	Ditto.				22	22	0	21	0·12	29·88
66	Oats.		31		1	24	0	60	0·25	14·75
67	Leaves of *rhododendron ferrugineum*, raised on Jura, a limestone hill, June 20.		30		23	14	43·25	0·75	3·25	15·63
68	Ditto, raised on Breven, a granite hill, June 27.		25		21·1	16·75	16·75	2	5·57	31·53
69	Branches of ditto, June 20.		8		22·5	10	39	0·5	5·4	22·48
70	Spikes of ditto, June 27.		8		24	11·5	29	1	11	24·5

Table continued.

Chap. I.

	TABLE OF INCINERATIONS.				Constit. of 100 parts of the ashes.					
	Names of Plants.	Ashes from 1000 parts of the plant, green.	Ditto, dry.	Water from 1000 parts of the plant, green.	Soluble Salts.	Earthy Phosphates.	Earthy Carbonates.	Silica.	Metallic Oxides.	Loss.
71	Leaves of fir (*pinus abies*), raised on Jura, June 20.		29		16	12·27	43·5	2·5	1·6	24·13
72	Ditto, raised on Breven, June 27.		29		15	12	29	19	5·5	19·5
73	Branches of pine, June 20.		15		15					
74	Blaeberry (*vaccinium myrtillus*), raised on Jura, Aug. 29.		26		17	18	42	0·5	3·12	19·38
75	Ditto, raised on Breven, Aug. 20.		22		24	22	22	5	9·5	17·5
76	Soil from *rhododendron ferrugineum* of Nos. 67 and 69.		65		0·5	6	29	28	18	15·5
77	Extract from soil of ditto.		140		53	17·25	21·5	3·25	3	21·88
78	Soil of *rhododendron ferrugineum*, raised on a siliceous earth of Nos. 68 and 70.		620							
79	Extract from the preceding soil.		142		24	13	17	14	10	21·88

For some other tables of a similar nature, I refer the reader to Dr. John's tabellen der pflanzen analysen, p. 63.

IV. METALS.

Several metallic substances have also been found in the ashes of vegetables, but their quantity is exceedingly small; so small, indeed, that without very delicate experiments their presence cannot even be detected.

The metals hitherto discovered are iron, which is by far the most common, manganese, and, if we believe some chemists, gold.

1. Iron has been found in many plants; the ashes of salsola contain a considerable quantity of it.   From the experiments of Mr. Grimshaw, it appears that six ounces of cotton cloth, unbleached, contain about four grains of iron; and six ounces of linen in the same state about three grains; but it is likely, as Mr. Grimshaw observes, that part of this iron is communicated to the cloth by the weaver's dressing. When it gets acid, and is allowed to remain in iron pans, it must take up a part of the metal.*

2. Scheele first detected manganese in vegetables.† Proust found it in the ashes of the pine, calendula, vine, green oak, and fig-tree.‡

3. With respect to the minute portion of gold extracted from the ashes of plants by Kunkel, Sage, &c. it is probable that it proceeded rather from the lead which they employed in their processes than from the ashes.

SECT. XXXVII.

OF VEGETABLE PRINCIPLES IN GENERAL.

In the preceding sections a pretty full account has been given of the different vegetable principles hitherto examined by chemists.   They amount to no fewer than 35 genera. They consist of substances which owe their formation to the processes of vegetation.   It is of them, of course, that

* Phil. Mag. xvi. 33.   † Opusc. i. 106.   ‡ Phil. Mag. v. 99.

vegetables are formed; they are the substances which come into view when vegetables are analysed. It is necessary therefore to be well acquainted with their essential characters, that we may know the marks by which they are to be recognized. These unfortunately are sometimes ambiguous; so that a good deal of skill and experience are necessary before we can distinguish them readily. Some of them indeed are so imperfectly known, that we are in possession of no good characteristic marks. The following table contains a general view of the most striking properties of the different genera.

1. *Sugar.*—Crystallizes. Soluble in water and alcohol. Taste sweet. Soluble in nitric acid, and yields oxalic acid.

2. *Sarcocoll.*—Does not crystallize. Soluble in water and alcohol. Taste bitter sweet. Soluble in nitric acid, and yields oxalic acid.

3. *Gum.*—Does not crystallize. Taste insipid. Soluble in water, and forms mucilage. Insoluble in alcohol. Precipitated by silicated potash. Soluble in nitric acid, and forms saclactic and oxalic acids.

4. *Mucus.*—Does not crystallize. Taste insipid. Soluble in water, and forms mucilage. Insoluble in alcohol. Not precipitated by silicated potash. Precipitated by alcohol from water in a fibrous form without rendering the liquid opaque.

5. *Ulmin.*—Does not crystallize. Taste insipid. Sparingly soluble in water and alcohol, and does not form mucilage. Very soluble in liquid carbonate of potash. Precipitated by acids and sulphate of iron.

6. *Nicotin.*—Volatile, and when drawn into the nose excites sneezing. Precipitated by tincture of nutgalls.

7. *Extractive.*—Soluble in water and alcohol, insoluble in ether. Precipitated by chlorine, muriate of tin, and muriate of alumina; but not by gelatine. Dyes fawn.

8. *Morphia.*—Soluble in water and alcohol. Crystallizes. Converts vegetable blues to green. Forms neutral salts with acids.

9. *Asparagin.*—Crystallizes. Taste cooling and nauseous. Soluble in hot water. Insoluble in alcohol, soluble in nitric acid, and converted into bitter principle or artificial tannin.

10. *Cerasin.* Insoluble in water and alcohol. When

Book IV. put into water it swells up into a transparent jelly, which may be employed to paste paper. Soluble in water acidulated with nitric acid. Without taste or smell.

11. *Inulin.* A white powder. Insoluble in cold water. Soluble in boiling water; but precipitates unaltered after the solution cools. Insoluble in alcohol. Soluble in nitric acid, and yields oxalic acid.

12. *Starch.*—A white powder. Taste insipid. Insoluble in cold water. Soluble in hot. Solution opaque and glutinous. Precipitated by infusion of nutgalls; precipitate redissolved by a heat of 120°. Insoluble in alcohol. Soluble in dilute nitric acid, and precipitated by alcohol. Yields with nitric acid oxalic acid and a waxy matter.

13. *Indigo.*—A blue powder. Taste insipid. Insoluble in water, alcohol, ether. Soluble in sulphuric acid. Soluble in nitric acid, and converted into bitter principle and artificial tannin. Volatilized by heat in a purple smoke.

14. *Gluten.*—Forms a ductile elastic mass with water. Partially soluble in water; precipitated by infusion of nutgalls and chlorine. Soluble in acetic acid and muriatic acid. Insoluble in alcohol. By fermentation becomes viscid and adhesive, and then assumes the properties of cheese. Soluble in nitric acid, and yields oxalic acid.

15. *Pollenin.*—Insoluble in water, alcohol, ether, oils, and petroleum. Forms a brown coloured solution in caustic alkalies. Burns rapidly when thrown into the flame of a candle. Colour yellow. Not altered by exposure to the air. Destitute of taste and smell.

16. *Fibrin.*—Tasteless. Insoluble in water and alcohol. Soluble in diluted alkalies and in nitric acid. Soon putrifies.

17. *Fixed oils.*—No smell. Insoluble in water, alcohol. Form soaps with alkalies. Coagulated by earthy and metallic salts.

18. *Wax.*—Insoluble in water. Soluble in alcohol, ether, oils. Forms soaps with alkalies. Fusible.

19. *Volatile oil.*—Strong smell. Insoluble in water; soluble in alcohol. Liquid. Volatile. Oily. By nitric acid inflamed, and converted into resinous substances.

20. *Camphor.*—Strong odour. Crystallizes. Insoluble in water; soluble in alcohol, oils, acids; insoluble in alkalies. Burns with a clear flame, and volatilizes before melting.

3

21. *Bird-lime.*—Viscid. Taste insipid. Insoluble in water. Partially soluble in alcohol. Very soluble in ether; solution green.

22. *Resins.*—Solid. Melt when heated. Insoluble in water. Soluble in alcohol, ether, and alkalies. Soluble in acetic acid. By nitric acid converted into artificial tannin.

23. *Guaiacum.*—Possesses the characters of resins, but dissolves in nitric acid, and yields oxalic acid and no tannin.

24. *Balsams.*—Possess the characters of the resins, but have a strong smell; when heated, benzoic acid sublimes. It sublimes also when they are dissolved in sulphuric acid. By nitric acid converted into artificial tannin.

25. *Caoutchouc.*—Very elastic. Insoluble in water and alcohol. When steeped in ether, reduced to a pulp which adheres to every thing. Fusible and remains liquid. Very combustible.

26. *Gum resins.*—Form milky solutions with water, transparent with alcohol. Soluble in alkalies. With nitric acid converted into tannin. Strong smell, brittle, opaque, infusible.

27. *Cotton.*—Composed of fibres. Tasteless. Very combustible. Insoluble in water, alcohol, and ether. Soluble in alkalies. Yields oxalic acid to nitric acid.

28. *Suber.*—Burns bright and swells. Converted by nitric acid into suberic acid and wax. Partially soluble in water and alcohol.

29. *Wood.*—Composed of fibres. Tasteless. Insoluble in water and alcohol. Soluble in weak alkaline ley. Precipitated by acids. Leaves much charcoal when distilled in a red heat. Soluble in nitric acid, and yields oxalic acid.

30. *Medullin.*—Insoluble in water, alcohol, ether, and oils. Destitute of taste and smell. Structure porous. Soluble in nitric acid, and forms oxalic acid, but no suberic acid. When distilled it yields ammonia, and leaves a charcoal having a metallic lustre.

31. *Fungin.*—Insoluble in water, alcohol, and ether. Partially soluble in a strong boiling alkaline ley Soluble in hot muriatic acid, and forming a gelatinous matter. When distilled it yields ammonia.

But these are not the only substances which occur in the vegetable kingdom. It cannot be doubted that there are

several others easily recognized by their peculiar properties in certain vegetable bodies; though chemists have not yet succeeded in obtaining them in a separate state, and in ascertaining their characters with precision. It was this deficiency of precise information that induced me to omit them; for nothing can be more hazardous than to swell the list of vegetable constituents, by introducing supposed substances from vague analogies and imperfect experiments.

Acrid principle.   There are many vegetable substances remarkable for a peculiar acrid property. Most of the *ranunculi*, the *polygonum hydropiper*, *mustard*, &c. are well known instances. In some of these, the acridity disappears on drying, while in others, as *mustard*, it remains. In some, as the ranunculi, the acrid portion is taken up by water; while in mustard water dissolves only a very small part, and acquires the taste of garlic. This acrid property certainly depends upon the presence of some principle or principles with which we are unacquainted.

We are equally ignorant of the nature of the peculiar liquid to which the leaves of the common nettle owe their property of irritating the skin. We do not know the substance which gives the alliaceous tribe their peculiar taste and smell; a substance amazingly penetrating, but which is destroyed or dissipated by the heat of boiling water. We know little of the poisonous juices with which many vegetables are filled. Indeed the only vegetable poison with which we can say we are acquainted is *prussic acid*. These are but a small number of instances, but abundance of others will occur to every reader. Indeed whole regions of the vegetable kingdom remain still unexplored. Much curious information may be expected from the analysis of the *fungi*, and other kindred plants; from the analyses of the *algæ*, and of the *lichens*.

Vegetable analysis imperfect.   Indeed the state of the chemical analysis of vegetables is still very imperfect. No general rules have yet been laid down; no successful method has yet been ascertained. In every particular case the analyst must follow his own judgment, and be guided by his own experience. Thus every one is obliged, in some measure, to invent a method for himself, and to create the whole as it were anew. Thus much time is wasted before the chemist is upon a level with his predecessors: and every one striking, as it were, from

the same point, the progress is much slower than it other-
wise would be.

The older chemists confined their analysis entirely to destructive distillation. By this process they obtained nearly the same products from every vegetable. For every plant when distilled yields water, oil, acid, and carbureted hydrogen and carbonic acid gas; while a residuum of charcoal remains in the retort. For the first introduction of solvents we are indebted to the apothecaries. The experi- ments of Boerhaave and Neumann were doubtless of value; but it was Rouelle who first made the great step in vegetable analysis, by pointing out the uses of various solvents to separate the different constituents of vegetables from each other. He was the first that attempted a precise description of the vegetable principles, and that gave marks by which their presence might be ascertained. The next great step was made by Scheele, who detected the different acids of vegetables, ascertained their properties, and pointed out the method of separating them from those vegetable substances into which they enter as constituents. The experiments of some of the German chemists, especially of Hermbstadt, added considerably to the discoveries of Rouelle and Scheele, and made us better acquainted with some of the constituents of vegetables. But of all the modern chemists none is entitled to greater praise than Vauquelin. His analyses have been numerous, and his discoveries important. He has introduced into the subject that precision which distinguishes all his researches, and his method has been followed by all the other French chemists. Fourcroy has been often associated with Vauquelin, and his analysis of the quinquina, which he published alone, is entitled to considerable praise. Proust has turned his attention to the same subject, and has favoured the world with very instructive papers. Till lately the analysis of vegetable substances was almost entirely overlooked by British chemists; but the fineness of the field has now begun to attract their attention. Experiments of great importance have been published by Davy, Chenevix, &c. and above all by Hatchett, to whom vegetable chemistry lies under deep obligations; and we may expect still more important information from the zeal and skill of those enlightened philosophers. A few years will probably change the appear-

ance of this branch of chemistry almost entirely, and bring it nearer to the state which the chemistry of minerals has already acquired.

Thus we have examined all the substances which have been hitherto examined from vegetables. By analysing each of them, or by exposing them repeatedly to destructive distillation, combustion, &c. we come at last to those bodies which we are at present obliged to consider as simple, because they have not yet been decompounded, and of which accordingly we must suppose that vegetables are ultimately composed. These amount to 15, namely,

Substances
found in
plants.

1. Oxygen.
2. Sulphur.
3. Phosphorus.
4. Carbon.
5. Hydrogen.
6. Azote.
7. Muriatic acid.
8. Silica.
9. Iron.
10. Manganese.
11. Potash.
12. Soda.
13. Lime.
14. Magnesia.
15. Alumina.

But of these substances there are twelve which compose but a very small proportion indeed of vegetables. Almost the whole of vegetable substances are composed of four ingredients, namely,

Carbon.   Oxygen.
Hydrogen.   Azote.

Of these the last, namely azote, forms but a small proportion even of those vegetable substances of which it is a constituent part, while into many it does not enter at all: so that, upon the whole, by far the greater part of vegetable substances is composed of carbon, hydrogen, and oxygen. I do not mention caloric and light; concerning the nature of which too little is known to enable us to determine with certainty into what substances they enter.

The substances at present known to chemists, which they have not been hitherto able to decompose, amount (omitting caloric and light) to 49. Fifteen of these exist in plants; the rest belong exclusively to the mineral kingdom: for it is a fact, that no substance (I mean simple substance) has been hitherto found in the animal kingdom which does not exist also in vegetables.

On the contrary, all the simple substances at present known may be found in minerals. This indeed ought not to surprise us, if we recollect that the spoils of animals and vegetables, after they have undergone decomposition, are ultimately confounded with minerals, and consequently arranged under the mineral kingdom. Besides, if vegetables draw their food from the mineral kingdom, it would be absurd to suppose that they contain substances which they could not have procured from minerals.

Only eight of these principles (omitting the acids) have been analysed with sufficient precision to give us an idea of the number of atoms of which they are composed. The following table exhibits the number of atoms of oxygen, carbon, and hydrogen, which enter into the composition of these eight bodies:

	Atoms of		
	Oxygen.	Carbon.	Hydrogen.
Wax	1	20	18	= 39 atoms
Rosin	2	15	13	= 30
Copal	2	19	18	= 39
Woody fibre	4	7	4	= 15
Starch sugar	5	5	5	= 15
Common sugar	5	6	5	= 16
Gum arabic	6	6	6	= 18
Starch	9	10	10	= 29

From this table it appears that the composition of all of them is very complicated. We have no conception at present in what way these atoms are united together. Most probably they are first grouped together in binary or ternary compounds, and a certain number of these primary groups go to the composition of the vegetable principle.

CHAP. II.

OF THE PARTS OF PLANTS.

WE have, in the preceding Chapter, enumerated and described the different substances hitherto detected in plants. But a more difficult task remains for the present Chapter; namely, to explain the composition of each vegetable organ

Book IV. in all the numerous families of plants which constitute the vegetable kingdom. This task, indeed, in the present state of vegetable chemistry, cannot be fulfilled. By far the greater number of plants have never been examined at all; and even of those which, from their medicinal virtues or nutritive qualities, have attracted the attention of chemists, only particular organs have been analysed, while the rest have been neglected as unworthy of notice. Nothing, therefore, either resembling a complete view, or an exact arrangement, is to be looked for in this Chapter. I shall satisfy myself with stating the most important facts hitherto discovered respecting the composition of plants, as far as I am acquainted with them, under the fifteen following heads :

1. Sap.   9. Seeds.
2. Juices.   10. Fruits.
3. Air.   11. Bulbs.
4. Wood and roots.   12. Lichens.
5. Bark.   13. Mushrooms.
6. Leaves.   14. Fuci.
7. Flowers.   15. Diseases.
8. Pollen.

These form the subjects of the following Sections.

SECT. I.

OF THE SAP OF PLANTS.

Definition.   It is the general opinion of physiologists, that plants receive a considerable part of their nourishment by the root; that it enters into them in a liquid state, and passes up in proper vessels towards the leaves. This liquid is distinguished by the name of *sap*. In the spring, when the buds begin to expand themselves into leaves, if we break off the extremity of a branch, or cut into the wood of a tree, this sap flows out, and may be obtained in considerable quantities. It was first examined by Dr. Hales; but chemical analysis had not made sufficient progress in his time to enable him to ascertain its constituents. Deyeux

and Vauquelin have more recently analysed the sap of different trees. To them we are indebted for most of the facts known respecting this liquid.

The sap in all the vegetables hitherto examined is nearly as liquid as water. It always contains an acid, sometimes free, but more commonly combined with lime and potash. Various vegetable principles are also present: of these sugar is the most remarkable, and mucilage. Sometimes albumen and gluten, and sometimes tannin, can be detected. When left to itself, the sap soon effervesces and becomes sour; or even vinous, when the proportion of sugar is considerable.

Hitherto the sap of a few species of trees only has been examined. We are not in possession of any means of collecting the sap of the inferior orders of plants. The expressed juices of a considerable number of vegetables, indeed, have been prepared for medicinal purposes; but these are not sap, but a collection of all the liquid substances which the plant contained. At present, then, it is not possible to present a general view of the properties of sap. The following are the particular species which have been examined.

1. Sap of the Elm, ulmus campestris.

Vauquelin collected three different specimens of the sap of this tree; the first portion towards the end of April, the second in the beginning of May, and the third about the end of May. It had a reddish brown colour; it taste was sweet and mucilaginous; and it scarcely altered the colour of the infusion of litmus. Ammonia, barytes, and lime water throw down a copious yellow-coloured precipitate, which dissolves with effervescence in acids. Oxalic acid and the nitrate ef silver throw down a white precipitate. Diluted sulphuric acid occasions a brisk effervescence, and disengages the odour of acetic acid. Chlorine destroys the colour of the sap, and throws down a brown precipitate. Alcohol produces a flaky precipitate. When evaporated by a gentle heat, a pellicle forms on the surface; brown flakes precipitate, and an earthy matter is deposited on the sides of the vessel. The earthy matter was a mixture of carbonate of lime and vegetable substance. The liquid, after depositing these bodies, and being evaporated to $\frac{9}{10}$ths of its original bulk, contained a considerable portion of acetate of potash.

Book IV.   1039 parts of this sap were composed, according to Vauquelin's analysis, of

Constituents.

Water and volatile matter .... 1027·904
Acetate of potash .... 9·240
Vegetable matter .... 1·060
Carbonate of lime .... 0·796

The vegetable matter was partly extractive and partly mucilaginous.*

Changes of the sap by vegetation.   On analysing the same sap somewhat later in the season, Mr. Vauquelin found the quantity of vegetable matter a little increased, and that of the carbonate of lime and acetate of potash diminished. Still later in the season the vegetable matter was farther increased, and the other two ingredients farther diminished. The carbonate of lime was held in solution by carbonic acid, of which there existed a considerable excess in the sap. It is to this acid gas that the air bubbles, which so often accompany the sap as it issues from the tree, is owing.†

2. Sap of the Beech, fagus sylvatica.

Vauquelin collected two different specimens of this sap; the first in the end of March, the second about the end of April. It had a reddish brown colour, and a taste similar to the infusion of tan. It slightly reddened vegetable blues. Barytes, ammonia, carbonate of potash, and oxalate of ammonia, occasion precipitates in it; chlorine throws down yellow flakes; sulphuric acid blackens it, and disengages the odour of acetic acid; sulphate of iron strikes a black, and glue throws down a copious whitish precipitate. When gently evaporated to dryness, it leaves a brown extract amounting to about $\frac{1}{458}$ of its weight, ductile while hot, but brittle when cold, and having the smell and somewhat of the taste of new baked bread. It absorbs moisture from the atmosphere, and increases in weight about $\frac{1}{7}$th. Lime disengages ammonia, and sulphuric acid acetic acid, from this extract. Alcohol dissolves only a small part of it. This sap contained the following ingredients:

Properties.

Constituents.

Water.
Acetate of lime with excess of acid.

* Ann. de Chim. xxxi. 20.   † See Coulomb, Jour. de Phys. xlix. 392.

Acetate of potash.
Gallic acid.
Tannin.
A mucous and extractive matter.
Acetate of alumina.

It contained, besides, a colouring matter, which may be fixed on cotton and linen by means of alum, and dyes them of a fine solid reddish brown colour.*

3. *Sap of the Hornbeam, carpinus sylvestris.†*

Three specimens of this sap were collected by Vauquelin during the months of March and April. It was limpid, Properties. and its colour was whitish; its taste slightly sweet, and its smell analogous to that of whey. Barytes throws down from it a copious white precipitate, soluble in muriatic acid. Carbonate of potash likewise throws down a precipitate, soluble in acids with effervescence. Sulphuric acid deepens the colour, and evolves the odour of vinegar. Oxalic acid throws down a copious precipitate, and nitrate of silver gives the solution a fine red colour. 3918 parts, when distilled, left an extract of a reddish yellow colour, amounting to 8·279 parts. It had a sharp taste, and attracted humidity from the air.

When the extract is digested in alcohol, about the half of it dissolves. This portion consists of extractive, a saccharine matter, and acetate of potash. The residue, which is soluble in water, consists of mucilaginous matter, acetate of lime, and a colouring substance.

When this sap was left exposed to the air in an open Action of glass vessel, it became milky, disengaged carbonic acid, the air. acquired a spirituous smell and taste, and its acidity increased. After some weeks this odour was dissipated, and carbonic acid was no longer extricated. Its acidity continued still to increase, white flakes fell to the bottom, and the liquid became transparent. After 50 days the acidity was found diminished, a mucous pellicle formed on the surface, which became at last blackish brown, and the liquid had only a mouldy taste. In a close bottle the sap

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* Ann. de Chim. xxxi. 26.

† I presume the carpinus betulus is meant.

never became transparent; and when the bottle was opened after three months, the air which it contained was found converted into azote and carbonic acid. The liquid had a very strong taste of vinegar.*

4. *Sap of the Birch, betulus alba.*

Properties. The sap of this tree is colourless; it has a sweet taste; reddens vegetable blues. Neither ammonia, alcohol, nor chlorine, produce any change upon it. Barytes and lime throw down a precipitate which dissolves in muriatic acid. Hydrosulphurets, sulphate of iron, and glue, produce no effect. Oxalic acid throws down a white precipitate. Sulphuric acid disengages the odour of vinegar. Nitrate of silver strikes a red colour. When evaporated to about ¼th, it lets fall a reddish brown powder insoluble in water. When 3918 parts of the sap were evaporated to dryness, they left 34 parts of brown extract. This had an agreeable taste, attracted moisture from the atmosphere, Fermented. and was almost completely soluble in alcohol. When this extract is dissolved in water and mixed with yest, it ferments, and the fermented liquor yields a considerable proportion of alcohol; it yields also a considerable portion of vinegar. Vauquelin did not succeed in his attempts to obtain crystallized sugar from this sap; but he ascertained that it contained a portion of extractive which dyes wool of a brownish yellow colour. Acetate of lime and of alumina were also present, and probably also acetate of potash.†

5. *Sap of the Yoke Elm.*

Properties. This sap has a bitter taste. When evaporated to dryness it leaves a brown extract, in which crystals of nitrate of potash are gradually formed. This extract was scarcely soluble in alcohol. It gave traces of the presence of acetate of potash and acetate of lime.‡

6. *Sap of the Vine, vitis vinifera.*

This sap was examined by Dr. Prout. It had the whitish appearance of common river water. Its taste was sweetish but not rough. It did not alter litmus paper, nor

* Ann. de Chim. xxxi. 31.   † Ibid. p. 36.   ‡ Ibid. p. 38.

did its specific gravity differ from that of pure water. Potash and ammonia gave it a fine red colour, and threw down red flocks readily dissolved by acetic acid. It was slightly precipitated by oxalate of ammonia, ferrocyanate of potash, nitrate of silver, and subacetate of lead. Two thousand three hundred parts of it when evaporated left only one part of residuum, half of which was carbonate of lime and the remainder a peculiar vegetable matter, which was insoluble in alcohol. The sap had contained both carbonic acetic acids, and likewise an alkali.*

7. *Sap of the common maple, acer compestre.*

The sap of this tree was examined by Professor Scherer, of Vienna. It has a milky aspect, a sweetish taste, and its specific gravity varies. It does not alter litmus or turmeric paper. It is precipitated by oxalate of potash, nitrate of silver, and barytes water; but not by muriate of barytes. When boiled it lets fall gluten in flocks. It yields when evaporated a salt with basis of lime possessing peculiar properties. The acid is destroyed by heat, and according to Scherer differs from every other vegetable acid. He therefore distinguishes it by the name of *aceric* acid. The ace- Aceric acid. rate of lime is white, slightly translucent; has a weak acidulous taste, and is not altered by exposure to the atmosphere. One thousand parts of cold water dissolve 9 parts, and 1000 parts of boiling water 17 parts of this salt.†

SECT. II.

OF THE PECULIAR JUICES.

THE sap passes from the roots in peculiar vessels to the leaves, where it is altered by a process similar to that of digestion in animals, and formed into all the liquid substances requisite for the purposes of the plant. These liquids flow from the leaves towards the root in appropriate vessels, and have received the name of the *peculiar juices* of vegetables. They differ very considerably from Nature. each other in different plants. They have all a certain

* Annals of Philosophy, v. 109.
† Schweigger's Jour. iv. 362.

Book IV. degree of consistency, and always contain much more vegetable matter than the sap. In the present state of vegetable chemistry, an accurate detail of their properties cannot be attempted. Indeed it is often difficult to procure them from any plants unmixed with the sap. They sometimes exude spontaneously, and may always be procured in smaller or greater quantity by incisions through the bark of the plants containing them. The following are the species of peculiar juices which have been hitherto attended to.

Milky
juices.   1. *Milky Juices.*—Many plants, when wounded, emit a considerable quantity of a milky liquid, which may, in most cases at least, be considered as one of the peculiar juices of the vegetable from which it flows. The nature of this juice is extremely various.

The root of the *campanula rotundifolia* yields a milky juice, of a peculiar, and not unpleasant smell and taste. Children in some parts of Scotland collect the plant for the sake of this juice, which they suck with avidity. Its chemical properties have not been examined.

Euphorbia.   The different species of *euphorbia* yield a milky juice, which has a hot taste analogous to that of pepper, but more acrid, and which continues for a long time in the mouth. When chlorine was poured into this juice, a very copious white precipitate fell down. This powder, when washed and dried, had the appearance of fine starch, and was not altered by keeping. It was neither affected by water nor alkalies. Alcohol, assisted by heat, dissolved two-thirds of it; which were precipitated by water, and had all the properties of resin. The remaining third part possessed the properties of the *woody fibre.* Mr. Chaptal tried the same experiment on the juices of a great number of other plants, and he constantly found that chlorine precipitated from them *woody fibre.* *

Poppy.   The different species of the poppy (*papaver*) and lettuce (*lacuta*) yield a milky juice, which possesses narcotic qualities, and is distinguished by a peculiar taste and smell. These juices have been more examined than the preceding. They are of a very complex nature, containing a great variety of constituents. Gum and resin, and extractive,

* Ann. de Chim. xxi. 285.

are the most prominent of these; and if the experiments of Sertürner concerning the peculiar narcotic principle which he detected in opium, and which have been detailed in the preceding Chapter, be confirmed, we must consider that principle as constituting an essential ingredient in these juices.

The milky juice which exudes from the *jatropha elastica*, Caoutch-the *hevæa caoutchouc*, the *artocarpus integrifolia*, the *urceola* ouc. *elastica*, and from several other plants, gradually becomes inspissated when exposed to the air, and constitutes caoutchouc. This juice has been hitherto examined only by Fourcroy. Though kept in close vessels, the caoutchouc for the most part gradually separates, and forms a white solid elastic mass. The juice, however, still continues milky. When evaporated in the open air, a pellicle of caoutchouc gradually forms on the surface, and when this is removed another succeeds. Fourcroy ascribes this formation to the absorption of oxygen from the atmosphere. Besides the caoutchouc, Fourcroy obtained from the juice transparent prismatic crystals, which had a sweet taste, and which he considered as saccharine matter approaching to the nature of an acid.*

The juice of the papaw tree possesses properties which Papaw. distinguish it from most others. According to the analyses of Vauquelin, detailed in the preceding Chapter, its constituents resemble very closely the constituents of blood.

Besides the milky juices enumerated above, there are many others. Almost all the gum resins indeed are originally in that state; but as no chemical analysis of these juices has yet been made, it is needless to dwell upon them. †

2. *Mucilaginous Juices.*—The peculiar juices of many Mucilagi-plants are not milky, and some not distinguished by any nous juices. strong taste or smell. In these mucilage seems to be the predominating matter. Under this head may be reckoned the juices of most of the mucilaginous plants enumerated in the fifth Section of the preceding Chapter.

The substance called *cambium*, too, if we may be al- Cambium.

* Ann de Chim. xi. 225.
† The reader may consult a dissertation on the milky juices of plants by Carradori. See Gehlen's Jour. vi. 630.

Book IV. lowed to consider it as a peculiar juice, since it is obviously different from the sap, is entirely mucilaginous. It makes its appearance, according to Mirbel, in all those parts of vegetables where new matter is to be formed, and seems necessary for all such formations, either as the matter employed in their formation, or as furnishing a proper bed for them to be formed in. It does not appear to be confined in vessels like the other juices.*

Turpentine. 3. Some juices are intermediate between volatile oils and resins. These may be distinguished by the name of *turpentines*. Common turpentine, balsam of copaiva, and probably also opobalsamum, belong to this class. These juices are originally limpid and transparent, have a strong smell and taste, and gradually acquire consistency by exposure to the air, probably by absorbing oxygen.

Resins. 4. Other juices obtained by excision possess at first the properties of resins, or at least acquire them before they are brought into this country. Such, for example, are tacamahac and mastich, and most of the resinous bodies described in Section XXV. of the preceding Chapter.

Balsams. 5. Others are entitled to the name of *balsam*, according to the strict meaning of the word; as balsam of tolu, of Peru, styrax, and benzoin.

Tannin. 6. Some peculiar juices are composed almost entirely of tannin, or at least are characterised by containing a super-abundance of that substance. Such probably are the juices of oak, sumach, and of most vegetables that yield abundance of the tanning principle. In some cases, it would seem that these juices exude spontaneously; though in general they are obtained by artificial means.

Sugar. 7. Some vegetables possess juices characterized by the great quantity of sugar which they contain. Such, for example, are the sugar-cane, the carrot, and the various species of beet. For it is surely more reasonable to consider the saccharine matter in these plants as belonging to the peculiar juices, than as confined to the sap.

Saline matter. 8. Finally, the peculiar juices of some plants are characterized by containing a considerable portion of saline matter. Thus the various species of sorrel contain a notable quantity of superoxalate of potash, and several of the

* Mirbel, Ann. de Mus. d'Hist. Nat. No. xl. p. 294.

sedums malate of lime. In short, the peculiar juices of plants are nearly as numerous as the vegetable principles themselves; and when the fungi, algæ, lichens, and several other of the numerous inferior tribes of vegetables have been once examined, it cannot be doubted that the number will greatly increase.

Braconnot has lately examined the juices of a number of plants, in order to ascertain the peculiar acids which they contained. The following is a short abstract of the results which he obtained.*

The expressed juice of the *aconytum lycortonum* evaporated to dryness and incinerated leaves about 0·01 of carbonate of potash. This juice contains a considerable proportion of citric acid, partly combined with potash and partly with lime. Perhaps also malic and acetic acids are present in the juice of this plant.

The juice of the *delphinum elatum*, the *ranunculus aconitifolius*, the *thalictrum flavum*, the *clematis recta* and *viticella*, likewise contains a quantity of citric acid like the preceding juice.

The juice of the *salvia sclarea* contains benzoic acid probably combined with potash.

The juice of the *ruta graveolens* contains malic acid combined with potash and with lime.

The juice of the *eupatorium cannabinum* contains an acid which appears to be the malic mixed with some phosphoric.

The juice of the *nicotiana rustica* and *tabacum* contains malic acid combined with potash and lime.

The juice of the *mirabilis jalapa* contains nitric acid, muriatic acid, malic acid, and a little sulphuric acid chiefly combined with potash.

The *spinacia oleracea* contains oxalates of lime, and of potash, malate and phosphate of potash.

The *tropæolum majus* contains phosphoric acid, nitric acid, and malic acid united to lime and to potash.

The *ricinus communis* contains malic acid doubtless combined with potash.

The *phytolacca decandra* contains an uncommon proportion of potash, and an acid which possesses the properties of the oxalic.

* Ann. de Chim. lxv. 277.

SECT. III.

OF THE GASES IN PLANTS.

In many plants the stem is hollow and filled with air.
In others, as the onion, the leaves are filled with air.   Air
is lodged in the pod of the pea, in the leaves of some
species of fuci.   In short, there is hardly a plant that does
not possess some part more or less hollow, and of course
filled with air.   Now it is a question of some curiosity to
determine what species of gas thus fills up the hollow parts
of plants.   Is it common air? or is it a secretion by the
plant itself?   On the latter supposition it may be hydrogen
gas, azotic gas, carbonic acid gas, or any other gas what-
ever.

A few experiments were made by Dr. Priestley on the
air in the sea-weed.   He found it sometimes the same as
common air; in other cases it contained a greater propor-
tion of oxygen, in others a greater proportion of azote.
The air within the leaves of onions and in the bladder of
senna he found the same as common air.   Air pressed from
the stalks of the common *flag* contained a greater propor-
tion of azote than common air.*

The air in two or three plants examined by Dr. Darwin
was the same as common air.   Hubert found the air from
the arundo bambos worse than common air.

M. Bidault de Villiers examined the air in a considerable
number of plants.   That in the leaves of the onion was
the same as common air.   The same observation applies to
the air in the petals of the *melo peppo* in the capsules of
the *colutea arborescens*, the pods of the *pisum sativum*, the
capsules and vesicles of the *staphylea pinnata*, and *nigella
damascena*, the stems of the *borago officinalis, conium macu-
latum, sonchus oleraceus*.   In some cases he found the air
in the leaves of onions extinguish a candle; it must of
course have contained a considerable excess of azote.†

From these few observations it seems to follow, that the
air contained in plants is common air, frequently unaltered;
but sometimes deprived of a portion of its oxygen.   In
Dr. Priestley's experiment it would appear that a redun-

* Priestley, iii. 279.   † Ann. de Chim. lxxxviii. 89.

dancy of oxygen was present. But this experiment would
require repetition before it could be considered as authen-
ticated.

SECT. IV.

OF THE WOOD AND ROOTS.

I. THE roots of a great variety of plants are employed in
medicine and the arts; but few of them have been hitherto
subjected to chemical examination. The substances found
in them are various; and indeed, as the peculiar juices of
the roots are always included in such examinations, it is
clear that almost all the vegetable principles will be found
in them.

The process usually followed in examing these substances,
is first to separate every thing soluble in cold water, then
to boil the root in water. Alcohol is applied next; and
afterwards different acids or alkalies, according to the
nature of the substances suspected to be present. The
roots of the following plants have been subjected to chemi-
cal examination:

Helleborus hyemalis.	Rubia tinctorum.	List.
Brionia alba.	Curcuma longa.	
Calaguala.	Valeriana officinalis.	
Ho-ang-lien.	Cochlearea armorica.	
Cephælis, or calicocca.	Glycyrrhiza glabra.	
ipecacuanha.	Inula helenium.	
Convolvulus jalappa.	Acorus calamus.	
Gentiana lutea.	Andropogon schænanthus.	
Rheum palmatum.		

1. *Helleborus hyemalis.*—The root of this plant is tube- Helleborus
rous, has a yellowish-white colour, and is covered with a hyemalis.
black skin. At first it has no taste; but in a short time a
strong acridity becomes sensible in the mouth and throat.
Vauquelin has subjected it to a chemical examination,
chiefly in order to ascertain the nature of the bitter
and acrid principle which it contains. This principle he Contains a
found to be an oil of a peculiar nature, possessing pro- poisonous
oil.

Book IV. perties intermediate between the fixed and volatile oils. He obtained it by digesting the root in alcohol, and then distilling off the alcohol in an alembic. The oil gradually separated and concreted on cooling. Its taste was extremely acrid, and it had a yellowish-brown colour. When dissolved in weak alcohol, it precipitates the sulphates of iron of a fine purplish-red colour, which becomes green by means of alkalies. This oil is extremely poisonous, and, according to Vauquelin, exists in many plants, and is the cause of their poisonous qualities.

When the root is digested in water, and the liquid passed through a cloth, it is obtained opaque and milky, and gradually deposits a white powder which possesses the properties of starch. The liquid, by evaporation, deposits a brownish matter, which forms successive pellicles on the surface. This substance possesses the properties of extractive. Besides these substances, Vauquelin detected a substance analogous to gluten, some sugar, and a portion of woody fibre.[*]

Brionia alba.

2. *Brionia alba.*—This root has been used in medicine, and was known to contain a considerable portion of starch, and a bitter principle soluble in water and alcohol. Vauquelin lately examined it. By maceration in water, and subsequent pressure in a linen-cloth, the starch was separated and obtained in a state of purity. The bitter substance was soluble both in alcohol and water, and appeared

Constituents.

to possess the properties of pure bitter principle. The root was found likewise to contain a considerable portion of gum; a substance which is precipitated by infusion of galls, and which Vauquelin denominates *vegeto-animal matter*, some woody fibre, a small portion of sugar, and a quantity of supermalate of lime and phosphate of lime.[†]

Calaguala.

3. *Calaguala root.*—This is a root brought from America for medicinal purposes, which has acquired considerable celebrity on the continent. The plant from which it is obtained is not known; but from the observations of Vauquelin is supposed to be a species of *polypodium*. It has a brown colour, is partly covered with scales like the roots of fern, and is very hard and difficult to reduce to powder.

* Ann. de Mus. d'Hist. Nat. No. xliii. 82.   † Ibid. 88.

Vauquelin, who has subjected it to analysis, found it a very
complex substance, and separated from it no fewer than
the following substances:

Woody fibre.	Colouring matter.	Constitu-
Gum.	Malic acid ?	ents.
Resin.	Muriate of potash.	
Sugar.	Lime.	
Starch.	Silica.	

Alcohol dissolves the resin and sugar. By evaporating
the solution to dryness, and treating the residue with water,
the sugar is separated and the resin left. This resin has
a reddish-brown colour, and a bitter and acrid taste. It
dissolves in alkalies, communicating a brown colour and
a bitter taste, and is again separated by acids. Vauquelin
suspects that this principle is the constituent of the root,
both of this plant and of the other filices which possess
vermifuge properties. Water dissolved the gum and the
muriate of potash, which were obtained by evaporation.
Diluted nitric acid dissolved the starch and the colouring
matter, and let fall the former when mixed with four times
its bulk of alcohol. The woody fibre remained, which
when incinerated left carbonate of lime, muriate of potash,
and a little silica. As the decoction reddened vegetable
blues, it is possible that the lime was in combination with
malic acid.*

4. *Ho-ang-lien.*—This is a bitter tasted root, brought
from China, and used on the continent as a medicine. It
has been slightly examined by Bouillon La Grange. From
his experiments, it seems to owe its properties chiefly to
the bitter principle, of which it contains a considerable
portion. It contains also a resinous matter, taken up by
alcohol and thrown down by water. This substance when
dry has a brown colour, melts when heated, and burns,
emitting an aromatic odour.†

5. *Ipecacuan.*—This is the root of a plant which grows
spontaneously in Brazil, and probably in other parts of
South America. It was first correctly described and
figured by Dr. Brotero, under the name of *callicocca ipeca-
cuanha.*‡ The root is about the thickness of a quill, un-

* Vauquelin, Ann. de Chim. lv. 22.   † Ibid. p. 40.
‡ Linean Trans. vi. 137.

Book IV. equal and knotty, and varies considerably in its colour. When pounded it forms the mildest and safest emetic in the whole Materia Medica. Though probably employed in America from time immemorial, it was not introduced into Europe till the time of Lewis XIV, when one Grenier, a French merchant, brought 150lbs. of it from Spain; with which trials were made at the Hotel Dieu. Helvetius first made known its use in dysentery, for which he was rewarded by Lewis XIV. with 1000*l*. sterling.*

Properties.   This substance has been recently analysed by M. M. Majendie and Pelletier. The following are the constituents which they obtained :

$$
\begin{array}{ll}
\text{Oil} & 2 \\
\text{Emetin} & 16 \\
\text{Wax} & 6 \\
\text{Gum} & 10 \\
\text{Starch} & 42 \\
\text{Wood} & 20 \\
\text{Loss} & 4 \\
\hline
& 100\dagger
\end{array}
$$

Jalap.   6. *Jalap.*—This very active carthartic is the root of the *convolvulus jalappa*, a plant which is a native of Xalapa, a province of New Spain.‡ It is brought to Europe in thin slices, which are hard, of a brown colour, exhibiting resinous streaks and circles, easily inflammable, of scarcely any smell, and a weak acrid taste. From the few experiments detailed by Neumann, it appears to contain a resin, to which its active properties are ascribed, and likewise a portion of extractive and of mucilaginous matter. It has been analysed by Mr. Henry, who found its constituents resin, extractive, starch, and woody fibre.§ According to him, the proportions of these different substances, contained in 500 parts of the three varieties of jalap which occur in commerce, are the following :

	Resin.	Extract.	Starch.	Woody Fibre.
Jalap leger	60	75	95	270
—— sain	48	140	102	210
—— piqué	72	125	103	200

* Neumann's Chem. p.357.   † Ann. de Chim. et Phys. iv. 180.
‡ Hence the term *Jalap*. Neumann's Chem. p. 352.
§ Ann. de Chim. lxxii. 275.

7. *Rhubarb.*—This is the root of the *rheum palmatum,* and perhaps also of some other species of rheum, brought chiefly from the northern parts of China by the way of Russia, though of late it has been cultivated also in Britain. The root is large, of an oblong or roundish shape; of a dark-brown colour externally, with black and reddish streaks; internally it is reddish-yellow, and when fresh contains a juice of the same colour. No accurate chemical analysis of rhubarb has yet been made; but from the experiments of Neumann, it appears that nearly one half of it is soluble in water, and that alcohol scarcely takes up any thing from the residue. From the properties of the watery extract, enumerated by that laborious chemist, we may infer, with some probability, that it consists chiefly of the extractive and bitter principle, and that it contains some tannin. A small quantity of greenish-yellow resinous matter seems also to be present.* Scheele separated from the root about $\frac{1}{6}$th of its weight of oxalate of lime.† But this salt is not taken up by the water.

8. *Gentian.*—This is the root of the *gentiana lutea,* a plant which grows spontaneously in the mountainous parts of France, Switzerland, Hungary, &c. It is it said to have been named after Gentius, a king of Illyria, who is supposed to have first discovered its virtues. The root is externally brown; internally yellow, with a spongy pith in the middle. Its taste is intensely bitter. From the experiments of Neumann, we may conclude that the soluble parts of it consist chiefly of bitter principle, mucilaginous matter, resin, and extractive. The first seems to be the most copious and most active ingredient, and the one to which it owes its medicinal properties.

9. *Madder.*—This is the root of the *rubia tinctorum,* a plant cultivated in Zealand, &c. for the dyers. The root is the useful part, forming one of the most valuable of the red dyes. It is about the thickness of a goose quill, somewhat transparent, of a reddish colour, and a strong smell. The colouring matter of madder is the only part of this root that is valued. Mr. Watt has published a dissertation on

* Neumann's Chem. p. 360.
† Crell's Annals. i. 34. Eng. Trans.

it; to which we owe almost every thing that we know respecting its chemical nature.

It appears that there are two distinct colouring matters in madder: a red, which is extracted readily by cold water; and a brown, which requires a boiling heat to separate it in any quantity. Hence the reason that dyers are cautious not to raise the infusion of madder to a boiling temperature till towards the end of their process. Both of these colouring matters appear to possess the properties of extractive. They are soluble in water and alcohol; and when the solution is evaporated, pellicles successively form on the surface. These gradually subside, and form a reddish-brown matter, only imperfectly soluble in water. When alum liquor is poured into the infusion of madder, a deep brownish-red flaky precipitate falls, and the liquid assumes a brownish-yellow colour; and alkaline carbonates and lime water throw down a blood-red lake, differing in the shade of its colour according to the proportion of alum employed. Acetate of lead throws down a brown-coloured precipitate.

When carbonate of magnesia is mixed with infusion of madder, the liquid assumes a bright blood-red colour; and by evaporation an extract is obtained, which readily dissolves in water, and when spread upon paper becomes yellow in a few days, if exposed to the sun.

Water, holding a little alkali in solution, forms with madder a dark brownish-red solution; but if the water be mixed with a little acid, the infusion is yellowish.*

From the late observations of Merimé, it appears probable that a third colouring matter is present in madder; that it is more soluble than the red; and that it may be separated by steeping the madder a certain time in water, and then precipitating the solution with an alkali. After this a much finer red lake may be obtained from madder.†

10. *Turmeric.*—This is the root of the *curcuma longa*, a plant which grows in the East Indies. It has a fine yellow colour, a slight smell, and an aromatic bitter taste. To water it gives its own yellow colour, and the infusion is

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* See Watt, Ann. de Chim. iv. 104.
† Berthollet, Elemens de l'Art de la Teinture, ii. 120.

rendered brown by alkalies. To alcohol it gives a red colour, which stains hot marble of a durable colour.* The constituents of this root are but imperfectly known. From the experiments of Neumann, we learn that it contains a little volatile oil; that water dissolves nearly one-third of the root, but that a very small portion only is soluble in alcohol.† It forms the chief ingredient in *curry powder*.

11. *Valerian*.—Trommsdorf has examined the root of the *valeriana officinalis*. It loses three-fourths of its weight by drying. Distilled with water it yields a volatile oil, very liquid, and of a greenish-white colour. Its odour is strong and camphoric; its specific gravity, at the temperature of 77°, is 0·9340; its taste is aromatic and camphoric without being acrid. When exposed to the light it becomes yellowish. Nitric acid converts it into a resinous substance, or, if it be used in a sufficient dose, into oxalic acid. The expressed juice of the roots of this plant is muddy, and has a strong odour. It lets fall a portion of starch. It contains a peculiar substance approaching the nature of extractive, soluble in water, but insoluble in ether, and in pure alcohol. It is precipitated from water by the salts of lead, silver, mercury, and antimony. This juice contains also a portion of gum. The roots deprived of this juice yield a portion of black-coloured resin, but consist chiefly of woody fibre.‡

12. *Horse radish*.—Einhoff has examined the root of this vegetable, the *cochlearea armorica*, and found that its acridity is owing to the presence of a small quantity of volatile oil, which he obtained by distilling the mashed roots in a water bath. A liquid came over which was at first milky, but gradually deposited a little of the volatile oil in question. This oil had a pale yellow colour, and the consistence of the oil of canella. It odour was that of horse radish excessively strong. Its taste was at first sweetish; but it left an acrid impression, and excited inflammation in those parts of the tongue and lips to which it was applied. It is heavier than water, with which it forms a milky liquid by agitation. It dissolves readily in alcohol. It is volatilized at the tempe-

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* Lewis, Neumann's Chem. p. 384.   † Ibid. p. 388.
‡ Ann. de Chim. lxx. 95.

Book IV. rature of 60°. The liquid obtained from the roots of the
horse radish by distillation yielded traces of sulphur.*

Liquorice.   13. *Liquorice.*—The *glycyrhiza glabra*, or liquorice, is a
native of the south of Europe, but is cultivated in considerable
quantities in England for the sake of the root, from which
is extracted the black substance well known under the
name of *liquorice*, or *black sugar*. This root was subjected
to analysis by M. Robiquet, who obtained the following
substances from it :

(1.) Starch, first observed in it by M. Lautour.

(2.) Gluten, which is separated by boiling.

(3.) Liquorice sugar, a substance which approaches sar-
cocoll in its properties. It is soluble in alcohol and water;
but insoluble in cold water. It has a sweet taste, does not
yield alcohol by fermentation, nor is it converted into oxalic
acid by the action of nitric acid.

(4.) Phosphates and malates of lime, and magnesia.

(5.) A brown thick resinous oil, which gives an acrid
character to the decoction of liquorice.

(6.) A substance similar in its properties to asparagin;
but crystallizing in octahedrons.

(7.) Woody fibre.†

Elicam-   14. *Elicampane.*—The roots of the *inula helenium* or *ele-*
pane.   *campane* were examined by Rose, who extracted from them
the peculiar vegetable principle called *inulin*. M. Funke
afterwards subjected them to a new analysis, and obtained
the following substances :

A crystallizable volatile oil.

Inulin.

Extractive.

Acetic acid.

A crystallizable resin.

Gluten.

A fibrous matter (woody fibre ?)‡

Sweet flag.   15. *Sweet flag.*—The roots of the *acorus calamus*, or
sweet flags, have been subjected to analysis by Trommsdorf.
According to him 64 ounces of this root are composed of
the following ingredients :

* Ann. de Chim. lxx. 185.   † Ibid. lxxii. 145.
‡ Ibid. lxxvi. 98.

	oz.	dr.	gr.	Chap. II.
Volatile oil	0	0	13·33	
Inulin	1	0	1	
Extractive with some muriate of potash	2	1	10	
Gum with some phosphate of potash	3	4	0	
A viscid resin	1	4	0	
Woody fibre	13	6	0	
Water	42	0	35·67	
	64	0	0*	

16. *Andropogon schœnantus.*—The root of this plant from the isle of France was examined by M. Vauquelin. It was found to contain, 1. A resin similar to that of myrrh. 2. A bitter colouring matter soluble in water. 3. An acid. 4. Oxalate of lime. 5. Abundance of oxide of iron. 6. Much woody fibre. †

Many other roots have been employed either in medicine or the arts; but as they have not yet been subjected to chemical analysis, I think it unnecessary to enumerate them here.

II. The *wood* of different trees differs materially in hardness, strength, durability, and beauty. But from the experiments of Count Rumford, there is reason to believe that the mere woody fibres of all plants are nearly the same, and that the differences are owing almost entirely to the various proportions of liquids and empty spaces with which the woody fibres are intermixed. He found the specific gravity of the wood of different trees as follows:

Poplar .... 1·4854
Lime .... 1·4846
Birch .... 1·4848
Fir .... 1·4621
Maple .... 1·4599
Beech .... 1·5284
Elm .... 1·5186
Oak .... 1·5344

A cubic inch of oak and poplar consisted respectively of the following proportions of wood, sap, and air:

* Ann. de Chim. lxxxi. 332.   † Ibid. lxxii. 302.

Q 2

	Wood.		Sap.		Air.
Oak	0·39353	..	0·36122	..	0·24525
Poplar	0·24289	..	0·21880	..	0·53831

He found likewise that the same tree in winter contains more sap than in summer; and that in summer it contains more air than in winter.*

Out of the great number of woods known and employed in the arts, I shall mention only the following.

Logwood.

1. *Logwood.*—This is the wood of the *hæmatoxylon campechianum*, a low prickly tree, which grows abundantly about Campeachy, in the bay of Honduras. It comes to Europe in large logs, cleared from the bark, and is very hard, compact, heavy, and of a red colour. It has a sweetish astringent taste, but no perceptible smell. It is very much used by dyers, especially in dyeing black, to which indeed it is in some degree essential. For the facts known respecting its properties, we are chiefly indebted to Dr. Lewis.† Several of its constituents have lately been ascertained by Chevreul. ‡

Properties.

Logwood gives out its colouring matter both to water and alcohol; but to neither with much facility. The liquors assume a fine red colour with a shade of purple. The infusion becomes gradually deeper, and at last almost black. To cloth, previously boiled in alum and tartar, it gives a very beautiful, but perishable violet colour. Alkalies deepen the colour of the infusion; acids change it to yellow. With sulphuric, nitric, muriatic, and acetic acids, slight reddish-brown precipitates fall. Alum throws down a copious violet precipitate. Sulphate of iron strikes a dark bluish-black like ink, and throws down slowly a precipitate of the same colour. Sulphate of copper throws down a copious brownish-black precipitate, and acetate of lead an equally copious reddish-black precipitate; and muriate of tin throws down instantly a copious purple lake, while the liquid becomes transparent and colourless. §
Chevreul has shown that this wood contains a volatile oil, tannin, a yellow colouring matter, and acetates of lime and

† Nicholson's Jour. xxxiv. 319.   † Neumann's Chem. p. 385.
‡ Ann de Chim. lxvi. 254; and lxxxi. 128.
§ Berthollet, Elemens de l'Art de la Teinture, ii. 344.

of potash.* But the most important of its constituents is the substance to which Chevreul has given the name of hematin, and which has been described in the preceding Chapter.

2. *Brazil wood.*—This is the wood of the *cœsalpinia crista*, a tree which grows in Brazil, and likewise in other countries, where it is cultivated for the dyer. The tree is very large, and the wood very hard and heavy. Its colour is at first whitish, but it becomes red by exposure to the air. Water in which it is boiled acquires a fine red colour; while the wood itself, by repeated decoctions, becomes black. After water has ceased to act, alkaline leys still deprive it of a considerable quantity of colouring matter. Alcohol likewise takes up the colouring matter of Brazil wood, and acquires a deeper colour than water.

From the decoction in water, sulphuric and muriatic acids throw down a scanty red precipitate, while the liquid becomes yellow. An additional dose of acid restores the red colour again. Nitric acid changes it to yellow, and then to orange. Oxalic acid throws down an orange red precipitate. The alkalies change the colour to purple, and throw down a scanty precipitate. Alum precipitates slowly a copious reddish lake, and muriate of tin an abundant rose-coloured powder, while the liquid becomes nearly colourless. Sulphate of iron strikes a black with a tint of violet, and throws down a precipitate of the same colour. Acetate of lead throws down a fine dark red precipitate.† An elaborate set of experiments on Brazil wood has lately been published by Chevreul. The following are the results which he obtained :

The decoction of yellow Brazil wood is yellow. When distilled it yields water containing a portion of acetic acid, and a volatile oil having the odour and taste of pepper. As the liquid is concentrated by evaporation, a viscid matter is perceptible, of a brown colour, which is a compound of tannin and the colouring matter. The liquid retains a portion of the same substances. It contains also traces of ammonia, and of lime probably combined with acetic acid. Chevreul suspects also the presence of sugar and of

* Ann. de Chim. lxvi. 254.
† Berthollet, Elemens de l'Art de la Teinture, ii. 229.

gallic acid; both of which he detected in the extract of Brazil wood of commerce. All his attempts to separate the colouring matter from the tannin, and obtain it in a separate state, failed. The acids change it from yellow to red in the infusions containing it. Alkalies and alkaline earths make it pass to violet. Alumina strikes a carmine, protoxide of tin a violet, and peroxide of tin a red colour. Several neutral salts, as sulphate of soda, &c. when added in considerable quantity, change the colour to red. Sulphureted hydrogen gas combines with it, and destroys the colour; but it appears again, and the sulphureted hydrogen is separated. It has a stronger affinity for alkalies than litmus: and accordingly it renders litmus paper red, by depriving it of the alkali with which it is in combination.*

Red saunders.

3. *Red saunders.*—This is the wood of the *pterocarpus santalinus*, a large tree which grows on the Coromandel coast, and in other parts of India. The wood is at first light-red, but becomes very dark by exposure to the air. It is very compact and ponderous, and has no smell, and very little taste. This wood is chiefly used for colouring drugs, and has not yet been subjected to chemical examination. The colouring matter is of a resinous nature, and probably similar to that of dragon's blood. It is taken up by alcohol, but not by water. The alcoholic tincture is a fine red, but becomes yellow when diluted with a large quantity of spirits.† By this property of yielding no colouring matter to water, we can easily distinguish red saunders from Brazil wood; a distinction first pointed out by Dr. Lewis. ‡

Fustic.

4. *Fustic.*—This is the wood of the *morus tinctoria*, a large tree which grows in the West India islands. It is used in dyeing yellow, and is very rich in colouring matter. It is neither very hard nor heavy; its colour is yellow with orange veins. It gives a deep orange colour to water. The decoction gives a precipitate with glue, but still retains its colour. Acids throw down a slight greenish-yellow precipitate, which is re-dissolved by alkalies. These give the decoction a dark red colour, and gradually separate a yellowish matter. Alum throws down a scanty yellow preci-

* Ann. de Chim. lxvi. 225.   † Neumann's Chim. p. 337.
‡ Ibid p. 336.

pitate; sulphate of iron, a precipitate at first yellow, but
which becomes brown; sulphate of copper, a yellowish-brown
precipitate; acetate of lead, an orange yellow precipitate;
and muriate of tin, a very copious fine yellow precipitate. *

5. *Sumach.*—This is the shoots of the *rhus coriaria*, a
shrub which grows in the countries bordering on the Le-
vant. They are cut down yearly, dried, and ground in a
mill. Like the preceding substances, it is used in dyeing,
and chiefly as a mordant, on account of the tannin which
it contains. It gives to water a greenish-yellow colour,
which soon becomes brown by exposure to the air. It has
not yet been subjected to a regular chemical analysis. The
tannin appears to be the principal ingredient; and, accord-
ing to Proust, it differs in its properties from the tannin
contained in other plants. Bartholdi published a set of
experiments on the decoction of this plant. According to
him, it contains a great variety of saline matters; nitrate
of potash, muriate of soda, sulphate of lime, gallate of
magnesia, carbonate of lime, &c. But these experiments
stand in need of repetition.†

Chap. II.

Sumach.

SECT. V.

OF BARKS.

THE bark is the outermost part of vegetables. It covers
the whole plant from the extremity of the roots to the ex-
tremity of the branches. It is usually of a green colour:
if a branch of a tree be cut across, the bark is easily dis-
tinguished from the rest of the branch by this colour. If
we inspect such a horizontal section with attention, we
shall perceive that the bark itself is composed of three dis-
tinct bodies, which, with a little care, may be separated
from each other. The outermost of these bodies is called
the *epidermis*, the middlemost is called the *parenchyma*, and
the innermost, or that next the wood, is called the *cortical
layers*.

Bark.

Consists of
three sub-
stances.

* Berthollet, Elemens de l'Art de la Teinture, ii. 259.
† Ann. de Chim. xii. 305.

The *epidermis* is a thin transparent membrane, which covers all the outside of the bark. It is pretty tough. When inspected with a microscope, it appears to be composed of a number of slender fibres crossing each other, and forming a kind of net-work. It seems even to consist of different thin retiform membranes, adhering closely together. This, at least, is the case with the epidermis of the birch, which Mr. Duhamel separated into six layers. The epidermis, when rubbed off, is reproduced. In old trees it cracks and decays, and new epidermes are successively formed. This is the reason that the trunks of many old trees have a rough surface.

The *parenchyma* lies immediately below the epidermis; it is of a deep green colour, very tender, and succulent. When viewed with a microscope, it seems to be composed of fibres which cross each other in every direction, like the fibres which compose a hat. Both in it and the epidermis there are numberless interstices, which have been compared to so many small bladders.

The *cortical layers* form the innermost part of the bark, or that which is next to the wood. They consist of several thin membranes, lying the one above the other; and their number appears to increase with the age of the plant. Each of these layers is composed of longitudinal fibres, which separate and approach each other alternately, so as to form a kind of network. The meshes of this network correspond in each of the layers; and they become smaller and smaller in every layer as it approaches the wood. These meshes are filled with a green-coloured cellular substance, which has been compared by anatomists to a number of bladders adhering together, and communicating with each other.

Fourcroy supposes that the epidermis is the same in its nature in all trees, and that it possesses constantly the properties of suber; but this opinion is not likely to be verified. The cortical layers seem, at least in many cases, to have a similar fibrous basis; a basis possessing essentially the properties of flax, which is itself merely the cortical layers of the *linum usitatissimum*. The matter of the parenchyma, and the juices which exist in barks, vary extremely, and probably occasion most of the differences between them. Some, as oak bark, are characterized by their

astringency, and contain tannin; others, as cinnamon, are aromatic, and contain an essential oil; others are bitter, as Jesuits' bark; some are chiefly mucilaginous, others resinous, &c. But in the present state of the subject, an enumeration of the different kinds of barks is not to be expected. I shall therefore, as in the preceding Sections, satisfy myself with detailing the properties of those barks that have been subjected to examination. The following are the most remarkable of these:

1. *Bark of the cinchona floribunda*, or *quinquina of St. Domingo.*—This bark has been analysed with great address by Fourcroy. His analysis still constitutes one of the completest which has hitherto been made on any of the substances belonging to the vegetable kingdom.

Quinquina of St. Domingo.

This bark is in rolled pieces, six or seven inches long, and three or four lines in thickness. Its colour is greyish-green externally, but within it exhibits different shades of green, purple, white, brown, &c. Its taste is bitter and disagreeable; its odour strong and unpleasant.

It gives out nearly half its weight to water, provided it be boiled in a sufficient quantity of that liquid. The residue possesses the properties of woody fibre. When burnt it leaves a coal, which contains the following saline constituents. The quantities are those obtained from a pound, or 9216 grains of the bark.

Carbonate of potash .... 10 grains.
Sulphate of potash 12
Muriate of potash 38
Phosphate of lime 20
Carbonate of lime 420
Silica 4

Earthy residue.

The decoction of the bark has a reddish-brown colour, and an extremely bitter taste. It deposits on cooling a blackish substance, soft and tenacious, which does not dissolve in cold water, though it is soluble in hot water and in alcohol. More of this substance precipitates as the liquor is evaporated. When the inspissated juice, freed from this precipitate, is mixed with alcohol, a quantity of gummy matter separates. When the black matter which precipitates as the decoction cools is treated with hot alcohol, the greatest part of it is dissolved; but a fine red

Matter soluble.

powder remains mixed with some mucilage, which is easily separated by water. When the alcoholic solution is exposed to the air, it deposits light-yellowish crystals of a saline nature. When mixed with water, white flakes are thrown down, which possess the properties of gluten; but the greatest part remains in solution. Thus the soluble part of the bark may be separated into five distinct substances; namely, *gum, gluten,* a *red powder,* a *saline matter,* and a *brownish bitter substance,* retained in solution by the diluted alcohol. The last is by far the most abundant. To it the peculiar qualities of the decoction of this bark are to be ascribed. The following are the quantities obtained by Fourcroy from 9216 grains of the bark:

Gum .... 648 grains.
Gluten 84
Red powder 144
Saline crystals 72
Brownish matter ..4076
———
Total 5024

Properties. The gummy matter and gluten possessed very nearly the properties of these substances, as described in the last Chapter of this work. The red powder is insoluble in water and alcohol, but dissolves readily in alkalies. When distilled it yields much oil and ammonia, and little water. According to Fourcroy, it is *extractive* saturated with oxygen. The nature of the saline matter was not determined in a satisfactory manner. The brownish matter which remained dissolved in the diluted alcohol, being by far the most abundant and important ingredient, was examined with particular care. From the experiments of Fourcroy, it appears to approach nearest to *extractive* in its properties.

Its colour is reddish-brown, and its taste very bitter. When dry it appears black, is very brittle, and breaks with a vitreous fracture. It is insoluble in cold water, but dissolves very readily in that liquid when heated, precipitating, however, in part, as the water cools. But if one part of it be dissolved in 24 parts of hot water, no portion of it precipitates. If lime water be dropped into this solution, it throws down a reddish powder, redissolved by the addi-

tion of a sufficient quantity of water. Muriatic acid pre-
cipitates nothing from this solution. The brown matter dis-
solves readily in alcohol, if it be previously reduced to
powder. When distilled it gives out carbonic acid and
inflammable air, water impregnated with pyromucous acid,
and a quantity of oil. The watery portion contains like-
wise ammonia. The charry residue is very bulky, ten
times as much so as the original matter.

When chlorine gas is passed through this extractive
substance dissolved in water, it becomes immediately
reddish, and then a precipitate of the same colour gra-
dually falls. This precipitate possesses exactly the pro-
perties of the *red powder* obtained from the decoction of
the bark; a proof that this red powder is merely the brown
extractive altered in its properties by the absorption of
oxygen. If the current of chlorine gas be continued,
the whole liquor gradually loses its colour, and the preci-
pitate also becomes a pale yellow. If it be separated in
this state by filtration, it assumes the appearance of gam-
boge. Alcohol dissolves it, but not a mixture of alcohol
and water.*

2. *Bark of cinchona officinalis.*—This tree grows in Peruvian
Quito; it is confined to the high grounds, and when strip- bark.
ped of its bark soon dies. There are three different kinds
of *bark* to be found in commerce, but whether they be all
obtained from the same trees is not known; the contrary
is probable. The following are the most remarkable of
these varieties.

Red Peruvian bark.—This bark is usually in large pieces, 1. Red.
and is reducible to powder with more ease than the pre-
ceding. Its powder is reddish-brown, and has a slightly
bitter taste, with a good deal of astringency. We are
indebted to Fourcroy likewise for the analysis of this bark.

Water in which the powdered bark is macerated, ac-
quires the property of reddening vegetable blues, and con-
tains a portion of citric acid, some muriate of ammonia,
and muriate of lime. When 576 parts of the bark are
boiled repeatedly in water till that liquid ceases to have any
action on it, the water acquires a reddish orange colour,
and when evaporated to dryness leaves a residue which

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* Fourcroy, Ann. de Chim. viii. 120.

Book IV. amounts to 38 parts. This contains a small portion of the acid and salts just mentioned, but consists chiefly of a matter which possesses nearly the properties of extractive. When the residual bark is treated with a sufficient quantity of alcohol, that liquid takes up 24 parts of a substance which has a red colour, and appears intermediate between resin and extractive. The residue of the bark possesses the properties of woody fibre. When burnt it leaves twelve parts of a grey ash, consisting of

Carbonate of potash	1·9
Muriate of potash	0·6
Sulphate of potash......	0·5
Carbonate of lime	9·0
	12·0

Such is the result of Fourcroy's analysis.* Subsequent experiments have detected a portion of resin and of bitter principle. The presence of tannin in small quantity was indicated by the property which the decoction showed of striking a black with sulphate of iron. The bitter principle seems to belong to the second species, or that which was first observed in coffee.

2. Yellow.   *Yellow Peruvian bark.*—This species of bark, first brought into use in this country about the year 1790, has not yet been subjected to a rigorous analysis; but its constituents do not appear, from the trials which have been made, to differ much from those of the red species. M. Dechamps, has published a method of extracting from it a considerable quantity of an undescribed salt with base of lime, which Vauquelin has shown to be kinate of lime. It is white, and crystallizes in plates. The process consists in macerating the bark in a sufficient quantity of cold water, in concentrating the liquid, and setting it aside to spontaneous evaporation. The crystals gradually separate, and are purified by repeated crystallizations. The quantity procured amounts to about seven parts for every hundred of bark employed.*

3. Pale.   *Pale Peruvian bark.*—This is the common variety of the bark. It has not yet been subjected to a correct chemical analysis. Its taste is astringent and bitter, and very dis-

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* Ann. de Chim. viii. 174.   † Ann. de Chim. xlviii. 65.

agreeable. It is supposed to contain bitter principle, tannin, extractive, and resin. Besides these, it contains a principle first pointed out by Seguin, and upon which Dr. Duncan junior published some experiments.* It is distinguished by the property of precipitating infusion of galls; but as this property is common to a considerable number of substances, it is not sufficient alone to characterize it.

3. *Bark of cinchona Carribæa.*—This bark was first made known by Dr. Wright, who published a botanical description of the tree, with a figure, in the Philosophical Transtions;† and an account of the medicinal properties of the bark in the London Medical Journal for 1787.‡ A description of a tree to which the same name is given, together with a chemical analysis of the bark, was published in the Journal de Physique for 1790 § by M. Vavasseur; but it is not quite certain that the plants are the same.

4. Vauquelin has examined all the different species of cinchona, or Peruvian bark, which he could procure, in order to determine, if possible, how far they differ from each other, and what the constituents are that act as febrifuge. ||

They may be divided into three sets:

I. The infusions of the first set precipitate the infusion of nutgalls, but not that of glue.

II. The infusions of the second set precipitate glue, but but not the infusions of nutgalls.

III. The infusions of the third set precipitate at once glue, nutgalls, and tartar emetic.

The following table exhibits the effects of the different reagents upon all the barks tried. As Vauquelin has not given the botanical name in all cases, it is difficult, notwithstanding his descriptions, to ascertain the real names of the different species tried. Indeed, there is reason to believe that the same species occur in different parts of the table under different names:

* Nicholson's Jour. vii. 226.   † Vol. lxvii. p. 504.
‡ Vol. viii. 239.   § Vol. xxxvii. p. 241.
|| Ann. de Chim. lix. 113.

Barks.	Precipitate by glue.	Precipitate by tannin.	Ditto by tartar emetic
Yellow bark	White.		Copious.
Quinquina of Sta Fé .	Reddish.	Copious.	0
Grey quinquina ...	White.	Ditto.	White.
Quinquina gris canelle	Brown.	0	0
Red quinquina	Red.	0	Yellowish white.
Grey quinquina, . ..	White.	Yellow.	Ditto.
Quinquina gris plate	0		0
Cinchona pubescens .	0	Yellow.	Yellowish white.
Cinchona officinalis. .	0	Ditto.	0
Cinchona magnifolia	Copious.	0	0
Quinquina pitton vrai	0	Copious.	Copious.

Barks brought from Peru by Humboldt.

Quinquina of Loxa ..	Copious.	Copious.	Copious.
Quin. white of Sta Fé	0	0	0
Quin. yellow of S. Fé	0	Copious.	Copious.
Quin. red of Sta Fé ..	Copious.	0	0
Q. yellow of Cuença	0	0	0
Quinquina, ordinary .	Copious.	Copious.	Copious.
Infusions of nutgalls. .	Copious.		Yellow white.
Oak bark.	Ditto.		0
Cherry-tree bark	0	0	0

All the barks strike a green with iron, and the most of them precipitate it of that colour.

The substance in these barks which precipitates tannin has a brown colour and a bitter taste; it is less soluble in water than in alcohol. It precipitates tartar emetic, but not glue. It has some resemblance in its properties to the resins, though it gives out ammonia when distilled.

Croton.   5. *Bark of croton eleutheria.*—This bark constitutes the eleutheria and cascarilla of the shops. It is usually in rolled pieces, and has some resemblance to Peruvian bark. It has an aromatic smell, and an agreeable bitter taste. When burnt it emits an aromatic odour resembling that of musk. For the only chemical analysis of this bark hitherto published we are indebted to Professor Trommsdorf; 4696 parts of it yielded him the following products.*

* Ann. de Chim. xxii. 219.

Mucilage and bitter principle	864 parts
Resin	688
Volatile oil	72
Water	48
Woody fibres	3024
	4696

6. *Bark of the white willow (salix alba).*—The bark of White willow. this tree, which is common enough in Scotland, is remarkable for its astringent taste, and has been often used in intermittents by the common people. It has lately been proposed by Bouillon La Grange as an excellent substitute for Peruvian bark; being composed, according to him, of the very same constituents to which that bark owes its medicinal virtues. A very superficial examination, however, may satisfy any one, that the properties of the two are very far from similar.

The decoction of this bark has a dark-reddish colour; and, according to Bouillon La Grange, when repeated decoctions are made with the same portion of bark, the last is always deepest coloured. It is precipitated abundantly by glue, carbonate of potash, and carbonate of ammonia. Lime-water throws down a precipitate, at first blue, and afterwards buff-coloured. Sulphate of iron throws down a very dark-green precipitate. Alcohol separates white flakes. When evaporated to dryness, a reddish brittle substance remains, which has a very bitter taste, and does not attract moisture from the atmosphere.

When alcohol is digested over this bark, it acquires a greenish-yellow colour. The tincture is rendered muddy by water. When evaporated, it leaves a brilliant yellow substance of a very bitter taste, which melts at a moderate heat, and emits an aromatic odour.*

These experiments indicate the presence of tannin, bitter principle, extractive, and gluten, in this bark.

7. *Bark of quercus nigra.*—This tree, to which the name Quercitron. of *quercitron* has been given, grows spontaneously in North America. Dr. Bancroft discovered, about the year 1784, that the inner bark of this tree contains a great quantity of colouring matter; and since that time, it has been very

* Ann. de Chim. liv. 290.

Book IV. generally used by the dyers. To prepare it for them, the epidermis (which contains a brown colouring matter) is shaved off, and then the bark is ground in a mill. It separates partly into stringy filaments, and partly into a fine light powder.

Quercitron bark readily gives out its colouring matter to water heated to the temperature of 100°. At that heat water dissolves about $\frac{1}{12}$th of the bark employed. The infusion has a yellowish-brown colour, and is rendered lighter by acids, and darker by alkalies. Alum occasions a scanty precipitate of a deep-yellow colour; muriate of tin a copious bright-yellow precipitate; sulphate of iron a dark-olive precipitate; and sulphate of copper a precipitate of a yellow colour, inclining to olive.[*] From these experiments it is obvious, that the colouring matter of this bark is a species of extractive. The other ingredients have not been examined.

Horse chesnut.
8. *Bark of the æsculus hippocastanum.*—The bark of this tree, which forms so fine an ornament in parks and avenues, has lately been proposed in Paris as a remedy in intermittents, and a set of observations on it have been published by Mr. Henry.[†] Water or moderately strong spirits are the best solvents of it. Strong alcohol dissolves but little. The watery infusion has a fawn colour and a bitter taste, without astringency. It is precipitated abundantly by gelatine, and sparingly by acids. It precipitates iron green. With nitrate of mercury it forms a copious precipitate. The infusion of nutgalls and tartar emetic produce no effect upon it. From these properties it is obvious that it differs entirely in its constituents from the different species of cinchonæ examined by Vauquelin.

Cinnamon.
9. *Cinnamon.*—This is the inner bark of the *laurus cinnamomum*, a tree which grows chiefly in Ceylon, where it is cultivated for the bark.

This has a reddish-brown colour, and consists of long rolled pieces which break into splinters. It has a very pleasant aromatic smell, and a pungent but agreeable taste. Its properties are owing entirely to the volatile oil which it contains. This oil may be separated by infusing the bark

* Berthollet, Elemens de l'Art de la Teinture, ii. 262.
† Ann. de Chim. lxvii. 205.

in alcohol, and then separating the alcohol from the oil by distillation. It has a whitish-yellow colour, and an extremely pungent taste and smell. The quantity yielded by cinnamon is very small. From 16 ounces of bark, Neumann obtained only two scruples and a half of oil. When water is distilled off this bark, it comes over milky, from the accompanying oil, which it retains with great obstinacy; very little separating till the mixture has stood a very considerable time.*

SECT. VI.

OF LEAVES.

THE leaves of plants bear a greater resemblance to each other than any of the parts already treated of. They are covered only with an epidermis; the cortical layers of the bark being wanting. Below the epidermis is a pulpy matter, usually green, which contains a resinous substance and a portion of gluten. Below this is the fibrous matter, or rather the vessels which form the outline of the leaf. Alcohol extracts the green colouring matter of leaves, and so do oils but not water. It is remarkable, that even those leaves which are not green still give a green tincture to alcohol. The green colour soon fades when exposed to air, either in solution, or separated by evaporation.† Many leaves give a yellow colour to cloth, which may be fixed by means of alum. Hence the much greater number of yellow dyes than of any other colour. The leaves of woad (*reseda luteola*) are those which give the finest yellow, and they are much employed by the dyers on that account.

No extensive series of chemical experiments having hitherto been made upon leaves in general, I must satisfy myself with noticing the few specimens which have been examined by chemists. The following are the most remarkable of these.

1. *Senna.*—This drug, much used in medicine as a mild purgative, is composed of the leaves of *cassia senna*, a small shrub which grows chiefly in Egypt, from which country it

Properties.

Senna.

* Neumann's Chemistry, p. 402.   † Lewis, Neumann's Chem. p. 434.
VOL. IV.   R

Book IV. is imported into Europe. It has been chemically examined by Bouillon La Grange.

The leaves are lanceolate, of a yellowish-green colour; an aromatic and somewhat disagreeable odour, and a bitter taste. Steeped in water, senna communicates to that liquid its peculiar smell and taste, and a reddish-brown colour. The strong mineral acids, oxalic acid, and the alkaline carbonates, throw down a precipitate; so do barytes water, and the nitrates of mercury, silver, and lead. The infusion of galls strikes a yellowish-buff colour, and throws down a slight precipitate. Alcohol throws down a precipitate, which, if we believe Bouillon La Grange, is composed of about 5 parts of carbonate of lime and 1 part of silica.* The residual liquor contains extractive, with some salts, whose bases are potash and magnesia.

When the infusion is exposed to the air, a substance precipitates from it. A precipitate is obtained also by chlorine. This precipitate is of a lemon-yellow colour, insoluble in water, has a bitter taste, dissolves in alcohol and alkalies, and, in short, possesses the characters of resin.

The chief matter taken up from senna by water is a peculiar extractive, which is converted into a species of resin by the absorption of oxygen; to this substance the qualities of senna are owing. If we believe Bouillon La Grange, its activity depends upon its absorbing oxygen.

A hundred parts of water boiled on senna are sufficient to deprive it of all the soluble matter which water is capable of extracting. Alkali separates from the residue a portion of matter similar to the extractive, altered by exposure to the air. The leaves are now green, and give out a green matter to alcohol. This substance is insoluble in water and alkalies, and is whitened by chlorine, and rendered less soluble in alcohol. These properties indicate a peculiar substance. 244·6 parts of senna yield to these different menstrua 79·6 parts, or rather more than $\frac{1}{3}$d of soluble matter. When the watery infusion of senna is evaporated

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* I do not clearly understand this part of the analysis. The precipitate is stated to be partly soluble in water and alcohol, and yet to be obtained by alcohol. These characters surely do not apply to carbonate of lime and silica.

3

to dryness, and the residue burnt, it yields potash, sulphate of potash, carbonate of lime, magnesia, and silica.*

2. *Wormwood.*—This is the leaves, and likewise the stalks and flower-tops of the *artemisia absynthium*, a plant which grows wild in many parts of Britain. Wormwood has a strong smell, rather disagreeable, and an intensely bitter taste. Its smell is owing to a volatile oil which it contains. It contains, besides, a considerable portion of bitter principle. No late analysis of wormwood has been made. The last is that of Kunsmuller,† who obtained, by water, from 12 parts of wormwood, the following products :

Resin	0·48
Muriate of potash	0·12
Vegetable acid	0·50
Ditto combined with potash ..	2·14
	3·24

The residue, after the action of water, being burnt, left an ash, which, from 12 ounces of wormwood, contained the following substances :

Muriate of potash ..	3 grains
Sulphate of potash .	1
Carbonate of lime .	59
Alumina	5
Sulphate of lime ..	5
Silica	4
Oxide of iron	3

3. *Tobacco.*—This substance is formed from the leaves of the *nicotiana tabacum*, a plant which is a native of Virginia, where it is cultivated very extensively for the purposes of commerce. Its name was given it from Tabaco, a province of Mexico, where it was first observed, and whence it was originally brought to Europe.‡

Tobacco, when properly cured, has a yellowish-green colour, a strong and rather unpleasant smell, and a very acrid taste. When burnt it emits a strong odour, which to many is peculiarly grateful. When swallowed, it acts very violently upon the system; and when taken in sufficient

* Ann. de Chim. xxvi. 3. † Ibid. vi. 35.
‡ For a detailed account of the culture and management of tobacco, see Tatham's Essay on its culture and commerce, published in 1800.

Book IV. quantity, proves fatal. Vauquelin subjected the leaves of different species of *nicotiana*, particularly the *latifolia*, to analysis. The expressed juice contained the following substances:

A considerable quantity of vegetable albumen or gluten.

Supermalate of lime.

Acetic acid.

A notable quantity of nitrate and muriate of potash.

A red matter soluble in alcohol and water which swells considerably when heated.

Muriate of ammonia.

Nicotin.

Green fecula composed chiefly of gluten, green resin, and woody fibre.*

Asparagus. 4. *Asparagus.*—This plant has been analysed by Robiquet. I place the result here rather than any where else, because the whole plant was employed, and the leaves constitute the principal part of it.

M. Robiquet reduced the asparagus to the state of a pulp, and separated its juice by expression. A feculous matter was separated from this juice by filtration. Boiling alcohol dissolved a portion of this fecula, and left matter which possessed the properties of gluten. As the alcohol cooled, a portion of wax precipitated. The alcohol, by evaporation, left a green acrid matter, intermediate in its properties between resin and volatile oil.

The filtered juice had the appearance of whey, and reddened the infusion of litmus. When heated it deposited flakes, which were considered by Robiquet as albumen. When left for a long time to evaporate in the open air, a quantity of asparagin and of saccharine matter, having the appearance of manna, separated in crystals. The juice was inspissated, and treated with alcohol. A portion dissolved; the residue was dissolved in water.

The alcoholic solution, when treated with sulphuric acid, and distilled, yielded vinegar. When this solution was evaporated to dryness and burnt, the ashes consisted of potash, carbonate of lime, and phosphate of potash and of lime. Hence it was probable that the acetic acid was combined with potash and lime.

* Ann. de Chim. lxxi. 189.

The watery solution reddened vegetable blues. The infusion of nutgalls throws down a precipitate from this solution. The residue contains a peculiar extractive matter and a colouring matter; and doubtless, also, asparagin and sugar.

Such is the result of Robiquet's very ingenious and interesting analysis of this substance.*

5. *Atropa belladona, deadly nightshade.*—The leaves of this plant have been examined by Melandri. He found in them oxalate of magnesia with excess of acid, oxalate of lime, muriate of potash, a soft green-coloured resin, mucus, extractive, and a substance which Melandri called animal extractive, no doubt analogous to gluten or albumen.† The leaves of this plant have been examined likewise by Vauquelin. He obtained from them the following constituents:

(1.) Vegetable albumen, or gluten.

(2.) A bitter nauseous substance, which constitutes the narcotic part of the plant.

(3.) Nitrate, muriate, sulphate, superoxalate, and acetate of potash.‡

6. *Rheum palmatum, rhubarb.*—The leaves of this plant have been lately examined by Bouillon La Grange, who found them to contain a considerable quantity of superoxalate of potash and of malic acid.§

7. *Isatis tinctoria, woad.*—The leaves of this plant have been subjected to analysis by Chevreul. The expressed juice, separated by filtration from the *green fecula,* with which it was mixed, deposited on standing a blue powder, which possessed the properties of *indigo.* When heated, white flocks separated, consisting no doubt of *gluten.* When distilled, the liquid that came over yielded traces of a *volatile oil,* of *ammonia,* and of *sulphur.* When distilled with sulphuric acid, the liquid that came over contained *acetic acid* and *prussic acid.* Evaporated to dryness, and digested in alcohol, it yielded to that liquid a quantity of matter described in the last Chapter of this Work, under the Section entitled *Of Indigo* by the name of *green matter.*

* Ann. de Chim. lv. 152. † Ibid. lxv. 222.
‡ Ibid. lxxii. 53. § Ibid. lxvii. 91.

Book IV. It yielded also a yellow-coloured *extractive*, and the follow-
ing salts; *nitrate of potash*, *muriate of ammonia*, *acetate of
potash*, *muriate of potash*, and pure *acetic acid*. The residue
thus deprived of the substances soluble in alcohol consisted
of *gum*, *yellow extractive*, *supermalate of lime*, *sulphate of
lime*, and a salt which Chevreul considered as *citrate of lime-
and-magnesia*. The green fecula being examined, was
found to consist of *green-coloured resin*, *wax*, *indigo*, *gluten*,
and *woody fibre*. The dry matter of the leaves, from which
the juice had been expressed, yielded *woody fibre*, *green
resin*, *wax*, *indigo*, *nitre*, a *red-coloured matter*, *malate of lime*,
and traces of some other salts.*

Indigofera
anil.
 8. The leaves of the *indigofera anil*, examined by the
same chemist, yielded the same products with the isatis, but
the quantity of indigo obtained was much greater.†

Agatho-
phyllum ra-
vensara.
 9. The leaves of the *agathophyllum ravensara* were found
by Vauquelin to contain an oil similar to the oil of cloves,
gum, and carbonate of lime.‡

Gratiola of-
ficinalis.
 10. *Gratiola officinalis.*—This plant was found by Vau-
quelin to contain, 1. A brown gummy matter, 2. A resin-
ous matter, differing from other resins in being soluble in
hot water; but much more soluble in alcohol than in water,
and having a very bitter taste. It is in this substance that
the purgative quality of the plant resides. 3. A small quan-
tity of animal matter. 4. Common salt in considerable
quantity, and another salt which is probably malate of
potash. It contained likewise oxalate and phosphate of
lime and oxide of iron probably united to phosphoric acid.§

Menianthes
trifoliata.
 11. *Menianthes trifoliata.*—This plant was analysed by
Trommsdorf. The fresh plant consists of 75 parts of
moisture and 25 of solid matter. The expressed juice,
when boiled, lets fall green flocks composed of 75 parts of
vegetable albumen, and 25 of green resin. The liquid con-
tains disengaged malic acid, acetate of potash, and a pecu-
liar matter which is precipitated by tannin, but not coagu-
lated by heat, and which is soluble in alcohol. It contains
likewise a bitter extractive matter, a brown gum, and a
quantity of inulin.‖

* Ann. de Chim. lxviii. 284.   † Ibid. p. 305.
‡ Ibid. lxxiii. 306.   § Ibid. lxxii. 191.   ‖ Ibid. lxxx. 330.

12. *Conium oleracea.*—An elaborate analysis of this plant has been published by Schrader. One thousand grains of it yielded the following constituents:

Extractive	27·3
Gum	35·2
Resin	1·5
Vegetable albumen	3·1
Green fecula	8·0
	75·1 *

13. *Brassica oleracea.*—Schrader obtained from 1000 grains of this plant the following substances:

Extractive	23·4
Gum	28·9
Resin	0·5
Vegetable albumen	2·9
Green fecula	6·3
	62·0 †

SECT. VII.

OF FLOWERS.

THE flowers of vegetables, on account of the great variety and beauty of their colour, attracted at an early period the attention of dyers and painters; but, upon trial, few have been found capable of yielding serviceable materials for either of these artists. The blue-coloured flowers, in general, Blue flow- readily give out their colour to water; though there are ers. some from which water gains only a reddish or purplish hue. Scarcely any give a blue colour to alcohol: some give a red colour to that liquid, and some no colour whatever.‡ The expressed juice of most of these flowers is blue. This colour is changed into red by all acids, and into green by all alkalies and alkaline earths.

The nature of the colouring matter of these flowers is

* Schweigger's Jour. v. 19. † Ibid.
‡ Lewis, Neumann's Chem. p. 430.

Book IV. still unknown.   But whatever it be, it is of a very perish-able nature; for the flowers cannot be dried without losing their colour almost entirely. The more rapidly they are dried, and the more completely the air is excluded, the more of their colour they retain : but even after that, they mostly lose it altogether, and become white or yellow. The expressed juice gradually becomes purple, and soon fades altogether. Even when reddened by acids, these juices soon become purple, and at last colourless. The green colour induced by alkalies gradually changes to a yellow, which has some permanence.*

Red.   The colour of the red flowers, in general, is scarcely more permanent than the blue. They all give out a red colour to water. The pale-red and purple flowers scarcely tinge alcohol; resembling in this respect the blue flowers, to which indeed, in point of colouring matter, they seem to approach very nearly. The flowers, which have a full red colour, give a deep-red tincture to alcohol; the pale-red are tinged green by alkalies, and their red heightened by acids, like the blue flowers; but this is not the case with the full red flowers.†

Yellow.   The colour of the yellow flowers, whether pale or deep, is much more durable. They, in general, dry very well, and give out their colouring matter both to water and alco-hol. When wool or silk is previously impregnated with alum and tartar, it receives a durable yellow colour when boiled with yellow flowers. Some of them, indeed, appear to be used by dyers for this purpose. Neither acids nor alkalies destroy the yellow colour of flowers, though both alter its shade; the acids rendering it paler, and the alkalies deeper. Alum likewise heightens the colour, though not so much as alkalies.‡

White.   Even white flowers are by no means destitute of colouring matter. Many of them strike a green with alkalies, though acids do not turn them red. Some of them seem to contain the same colouring matter as yellow flowers. Thus the petals of the *convolvulus sepium*, though white, give a deep-yellow or orange colour to water, which is rendered paler by acids, and heightened by alkalies and alum. The

* Lewis, Neumann's Chem. p. 431.   † Ibid.   Ibid.

vapours of sulphurous acid do not alter white flowers,
though they destroy the colour of all others.*

For these curious observations on the colours of flowers, we are indebted to Dr. Lewis. Most of them contain a peculiar volatile oil, to which they owe their smell. Their other constituents remain still unknown, as few of them have been subjected to chemical analysis. The following are the species which have hitherto attracted the attention of chemists or artists:

1. *Flowers of the carthamus tinctorius.*—This is an annual plant, cultivated chiefly in Egypt for the sake of the flowers. The petals are originally of a fine red, but lose much of their colour on drying. It is from this substance that the *rouge*, or red pigment, employed by the ladies, is extracted. When the flowers have come to maturity, they are pulled, their juice expressed, the residue washed repeatedly with salt water, and exposed upon mats to dry. Care is taken to cover them from the action of the sun during the day, and to expose them to the action of the evening dews, in order to prevent them from drying too fast. In this state they are brought to Europe under the name of *safflower*, and the colouring matter is extracted from them by different artists. The process has been kept secret.

Beckmann published a very elaborate set of experiments on the flowers of the carthamus, in 1774.† Little addition was made to our knowledge of this substance after that period, till 1804, when Dufour published an excellent analysis of it;‡ and his observations have been since confirmed by those of Marchais.§

The flowers of the carthamus contain two colouring mat- ters: a yellow, which is soluble in water, and has hitherto been applied to no use; and a red, which is employed by the dyers, &c. and which constitutes the pigment called *rouge*. The yellow-colouring matter dissolves readily in water; but it is very difficult by that means to separate the whole of it. The method followed by Dufour was to put the carthamus in a linen cloth, and knead it continually between the fingers, while a streamlet of water dropped

* Lewis, Neumenn's Chem. p. 432.
† In the Gottingen Transactions for that year.
‡ Ann. de Chim. xlviii. 283.   § Ibid. l. 73.

upon it.   By continuing this process, and then steeping it in water, it assumed a fine red colour.   The liquid which passed, after being filtered to separate some portion of the carthamus, and some impurities with which it was mixed, had a yellow colour.   When heated to about 145°, a number of flakes formed in it, consisting of albumen, or rather of gluten.   These were separated by filtration, and the liquid evaporated to dryness.   The extract obtained had a yellow colour and a strong taste.   Water dissolved the whole of this extract, except a portion of brown matter, which possesses the properties of resin.   The watery solution gives a red colour to vegetable blues, and is precipitated abundantly by infusion of galls, but not by glue. Chlorine destroys the yellow colour, and renders it white. When evaporated to dryness, and treated with alcohol, a portion dissolves, and a portion remains undissolved.   The soluble portion is chiefly extractive : the insoluble yellow-colouring matter.

When the residual carthamus is digested for a sufficient time in alcohol, that liquid assumes a brick-red colour. When this alcoholic solution is sufficiently concentrated by evaporation, a matter separates in grains, which has the appearance of honey, and possesses properties analogous to those of wax.   Scarcely any colouring matter could be procured from the alcoholic solution.

Dufour, after various unsuccessful attempts to obtain the red-colouring matter of carthamus in a separate state, at last succeeded by the following process, founded on the strong attraction between the red matter and cotton.   Having deprived the carthamus as much as possible of its yellow-colouring matter, by means of water, he macerated it for an hour in a weak solution of carbonate of soda.   He then decanted off this solution, put into it a quantity of cotton, and then dropped into it lemon-juice, till the liquid acquired a fine cherry-red colour.   After standing 24 hours, the liquid lost its red colour, the whole colouring matter having united with the cotton and dyed it red.   The cotton was taken out, and washed repeatedly in water, to separate any of the yellow-colouring matter which might have adhered.   It was then put into a very diluted solution of carbonate of soda.   This alkali separated the colouring matter from the cotton, dissolved it, and assumed a yellow
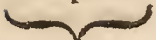
colour. The cotton being removed, and lemon-juice dropped into the solution, a fine rose-coloured powder gradually separated, and at last precipitated. This was the red-colouring matter.

From this process, we see that the red-colouring matter has a stronger attraction for cotton than the yellow, and that by means of cotton the two pigments may be separated. We see, too, that it is insoluble in alkaline carbonates, but precipitated by acids. The alkalies dissolve it also but alter its nature. The solution of it in the alkaline carbonates is yellow. It is insoluble in water. Alcohol dissolves it readily, and assumes a fine rose-red colour. When this tincture is heated, it assumes a shade of orange. It dissolves likewise in ether, but not well. The oils, both fixed and volatile, have no action on it. When distilled it yields very little water, scarcely any gases, a little oil, and a portion of charcoal equal to $\frac{1}{3}$d of its original weight. When this charcoal is burnt, no sensible portion of ashes remains behind. From these properties, for which, as well as for almost all the other facts respecting carthamus, we are indebted to Dufour, it appears that the red-colouring matter of the carthamus differs from every other known vegetable substance.

When the carthamus has been deprived of its colouring matter, the residue consisted chiefly of woody fibre and some earthy matter. The following table exhibits the constituents of 1000 parts of carthamus, according to the experiments of Dufour.

Moisture 62
Sand and small particles of the plant 34
Gluten 55
Yellow colouring matter 268
Extractive 42
Resin 3
Wax........................... 9
Red colouring matter 5
Woody fibre 496
Alumina and magnesia 5
Red oxide of iron 2
Sand.......................... 12
Loss 7
———
1000

If we believe Marchais, a considerable portion of what was considered by Dufour as woody fibre is in reality albumen.

2. *Flowers of the arnica montana.*—These flowers have been employed in medicine, especially in Germany, where their virtues have been much celebrated. They have a yellow colour, a bitter and sharp taste, and a very weak aromatic smell. When macerated in water, the liquid acquires a brown colour and a bitter taste. It reddens the infusion of litmus, does not form a precipitate with glue, and does not alter the solution of tartar emetic. With sulphate of iron it strikes a deep green, which passes into black on drying. The mineral acids occasion brown precipitates, but the alkaline carbonates produce no change in it.*

When the flowers are macerated in alcohol, the liquid acquires a yellow colour. It reddens vegetable blues, strikes a green with sulphate of iron, and becomes milky when mixed with water. When this tincture is distilled, the alcohol which comes over has a bitter taste, but does not alter vegetable-blues; while the liquid which remains in the retort is very acid, precipitates with water, and strikes a green with sulphate of iron. When evaporated to dryness, a bitter acid powder remains, seemingly of a peculiar nature.†

When distilled, the flowers of the arnica yield a yellowish acid liquor, which strikes a black with sulphate of iron. This liquid is covered by a quantity of oil. When these flowers are burnt, the residual ashes contain potash, carbonate of potash, and muriate and sulphate of potash.‡

3. *Saffron.*—This yellow pigment is composed of the pistils of the *crocus sativus.* The flowers of this plant are of a purplish-blue colour, but the upper part of the pistil is of a deep orange, and divided into three fleshy filaments. These are carefully picked out, dried, and pressed into cakes.

Saffron is in long broad filaments of a deep-red colour without any yellow; moderately dry, yet flexible and soft, and difficultly reduced to powder. It has a strong agree-

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* Bouillon La Grange, Ann. de Chim. lv. 38.
† Ibid. lv. 39.   ‡ Ibid.

able smell, affecting the eyes, and drawing tears from them, and a pungent, and somewhat bitter taste.*

Hitherto saffron has not been subjected to a correct chemical analysis. From the experiments of Neumann, it does not appear that any volatile oil can be procured from it by distillation. It is probable, however, that it owes its strong smell to such a principle, though in too small a quantity to be easily obtained separate. The colouring matter of saffron is equally soluble in alcohol and water; and is the substance called polychroite by Vogel.

SECT. VIII.

OF POLLEN.

THE antheræ of most vegetables, at the time that the flower is in perfection, is covered with a considerable quantity of a powdery matter, usually of a yellow colour, which, falling upon the pistil, is supposed to impregnate it. This matter is known by the name of *pollen*. In some plants, especially those in which the male and female flowers are separate, the quantity of it is so great, that it may easily be collected.

The first person who examined this powder was Dr. Lewis; but in his time chemistry had not made sufficient progress to enable him to make a complete analysis. He found that alcohol, in which it is macerated, acquires a bright yellow colour, and that water takes a duller yellow, while the undissolved portion is of a yellowish white colour. The colour of these infusions is heightened by alkalies, and turned *red* by acids. When alkalies are dropped into the reddened solution, a deep yellow colour is restored.†

Fourcroy and Vauquelin have published a detailed analysis of the pollen of the *phœnix dactilifera*, or date tree, which may be considered as furnishing a pretty correct view of the properties of this class of vegetable substances. At least it is probable, that the pollen of different vegeta-

* Neumann, p. 401.   † Neumann's Chem. p. 231.

bles does not differ nearly so much from each other as the other parts of plants.

Pollen of the date tree.

The pollen of this tree is so abundant, that at the season of fructification, it surrounds the plants like thick dust. The specimen examined was brought from Egypt by De-lille. Its colour was sulphur-yellow, its taste was sourish and unpleasant, it reddened the infusion of litmus, and communicated to water a yellow colour, and a sensible degree of acidity. The watery infusion was precipitated by lime water and ammonia, by alcohol, and by some metallic salts.

Action of water and

When pollen was washed in cold water, that liquid acquired a reddish brown colour, a sourish taste and smell, not unlike that of beer. When evaporated, the liquid left a reddish brown matter, which had the consistence and odour of melasses; its taste was acid, but disagreeable.

Alcohol.

Cold alcohol produced no effect upon this matter, but by the assistance of heat it dissolved a portion of it, and assumed a dark colour. The residue had more consistence, and was less coloured. It dissolved with facility in water, allowing at the same time a greyish bulky matter to separate. Thus the matter taken up by the watery infusion from pollen has been divided into three portions.

The alcoholic solution being concentrated by evaporation to the consistence of an extract, had a red colour, the odour of baked apples, and a taste strongly acid, but disagreeable. It presented all the characters of malic acid. The grey matter, which refused to dissolve in water, possessed the properties of phosphate of lime.

The aqueous solution was ascertained to consist chiefly of phosphate of magnesia, malic acid, and an animal matter, which formed a copious precipitate with the infusion of nutgalls.

Insoluble parts.

The pollen, thus deprived of its soluble matter, being exposed on filtering paper to the open air for a week, instead of drying assumed the form of a paste, and ran rapidly to putrifaction, emitting an odour similar to that of old cheese. When dried, this matter, became semitransparent, and of a consistence resembling that of glue. Before being dried it mixed readily with water, and exhibited the characters of soap. The fixed alkalies showed the presence of ammonia in it. When distilled there came over a

watery liquid, which gradually became coloured as the dis- tillation advanced : some time after there came over a red coloured oil and carbonate of ammonia, partly in crystals, and partly in solution. The liquid also contained a portion of the oil in the state of a soap. The charcoal left was voluminous, and difficult of incineration. When burnt it left a considerable portion of phosphate of lime.

The pollen is partly soluble in muriatic acid. The nitric acid reduces it to a paste, azotic gas is disengaged, and afterwards, on the application of heat, nitrous gas and carbonic acid. A yellowish oil separated and swam upon the surface, and alkalies separated earthy phosphates and oxalates. When the liquid was evaporated to dryness, it left a yellowish-red matter, extremely bitter, tenacious, and adhesive, and perfectly soluble in water. This matter, from the description of it, must have been a species of artificial tannin. Thus it appears, that by the action of nitric acid, the portion of the pollen which is insoluble in water is converted into oil and artificial tannin. The oily matter became solid on cooling, and possessed almost exactly the properties of tallow treated with nitric acid.

Strong alkaline leys dissolve the pollen, and assume with it the properties of soap, while ammonia is disengaged.

When the pollen, mixed with water, is set aside to ferment, it disengages the odour of new cheese, and assumes the form of a tenacious mass. Its taste is extremely sharp: it contains abundance of ammonia, partly united to oil, and partly to malic acid. From all these phenomena, there is reason to believe that the insoluble part of the pollen approaches vegetable gluten in its properties; or rather, that it is intermediate between gluten and albumen.

Such are the properties and constituents of the pollen of the date tree, as far as they have been ascertained by Fourcroy and Vauquelin.* We may conclude from them, that it approaches very much to the nature of animal matter.

Professor Link has examined the pollen of the hazel nut. It differs a good deal from that of the date tree just described. He found in it tannin in great abundance, a resin, a good deal of gluten, and a little fibrin.† The pollen of the tulip, which has been carefully analysed by Grothus, is

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* Ann. de Mus. d'Hist. Nat. i. 417.　　† Ann. de Chim. lxii. 292.

also very different from that of the date tree. He could neither detect in it phosphorus nor pollenin. From 26 grains of it he extracted

Pollen of the tulip.

Vegetable albumen .... 20·25
Malate of lime with trace of malate of magnesia 3·5
Malic acid 1
Malate of ammonia ⎫
Colouring matter .. ⎬ .... 1·25
Saltpetre ? .... ⎭

                                        ─────
                                        26·0 *

SECT. IX.

OF SEEDS.

THE seeds of vegetables, constituting one of the most important articles of food, and being the materials from which a variety of useful substances are procured, have been more subjected to chemical experiments than any of the other parts of plants.

Constituents.

They all contain a considerable portion of starch, though this matter differs somewhat in its properties in different seeds. Gluten is likewise a common ingredient, but extremely various both in its quantity and in its appearance. Some seeds contain a saccharine matter, as those of the *lycopodium*; but the quantity is always small, and its properties are hardly ever the same as those of true sugar. Fixed oil is also a common ingredient. In the seeds of the grasses, the proportion of it, if any can be detected, is always small: the same remark applies to the seeds of the papileonaceous plants; but the seeds of the cruciform plants abound in a limpid and nearly insipid oil. In some seeds a volatile oil is present, but this is not common. Some possess a peculiar colouring matter; some possess a portion of bitter principle, as the seeds of the common broom and of the coffee plant.

Saussure junior has shown that wheat, and probably every other kind of corn, yields a quantity of phosphorus, if it be charred in a moderate heat, and the charcoal

* Schweigger's Jour. xi. 281.

be afterwards violently heated in a porcelain retort. He has shown that the phosphorus, in this case, is owing to the decomposition of phosphate of potash, which exists in these seeds, and which is decomposed by the charcoal at a very high temperature. He has shown that phosphate of soda, and even phosphate of lime, may be decomposed in the same way.* Thus the observations of Margraff, and some of the earlier chemists, respecting the phosphorus which may be obtained from the seeds of plants have been verified.

I shall in this section enumerate, in the first place, the properties of those seeds which are known by the name of *corn*, and are used as articles of food; then the seeds of the papilionaceous plants; namely, peas, beans, vetches, &c. which are likewise employed as food. The seeds of the remaining tribes of plants have been hitherto but imperfectly examined; we can only therefore detail the experiments hitherto made, without any attempt at arrangement.

The most important genera of corn are, wheat, rye, oats, barley, rice.

1. Wheat, the *triticum hybernum* (and other species) of Wheat. botanists, has been cultivated from time immemorial in Europe and the northern parts of Africa, and the seeds of it employed as one of the most important articles of food. Indeed wheat flour is the only substance known from which good loaf-bread can be made. The seeds, when ripe, are ground to a fine powder, and by passing this powder through cloth sieves, of various degrees of fineness, it is separated into distinct portions. The fine flour constitutes the greatest portion; and the *bran*, which consists of the outer coat of the seed, and which is the coarsest of all, constitutes the next greatest portion.

. Hitherto the flour of wheat only has been subjected to a Constitu- chemical examination; while the bran, which may vary ents. from one-third to one-fourth, has been neglected. The two most remarkable substances in wheat flour are the *starch*, which constitutes by far the greatest part of it, and the *gluten*, which is the next ingredient in point of quantity. It appears also, from my trials, to contain a small portion of *bitter principle*. Saccharine matter exists in it

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* Ann. de Chim. lxv. 189.

Book IV. also, though in a very small proportion. Mucilage is
mentioned as a constituent by Fourcroy and Vauquelin;
and from their experiments, also, it appears that phosphate
of lime is present, but that they did not detect any phos-
phate of potash.*

Water in which wheat flour has been macerated for six
hours, has an opal colour, and becomes transparent very
slowly. Its taste is sweetish, it has the odour of unripe
grain, and does not alter vegetable blues. The infusion
of nutgalls, chlorine, and other acids, occasion a pre-
cipitate in it. It becomes very rapidly sour. When
heated, yellowish flakes are separated. When concen-
trated by evaporation, its taste becomes more perceptibly
sweet. When inspissated sufficiently, it assumes a golden
yellow colour; has a sweet taste, but is, at the same time,
acid and acrid; yellowish flakes separate, and a crust of
posphate of lime coats the capsule in which the evaporation
is performed. Alcohol coagulates it, and throws down a
substance which possesses the properties of gluten. Hence
it is evident, that the water owes its properties to the gluten
which it holds in solution,† and probably also to a little
bitter principle. It contained also some sugar and muci-
lage, and phosphate of lime.

Rye.   2. Rye is the seed of the *secale cereale*, a plant cultivated
in the northern parts of Europe, in considerable quantity,
as an article of food. Bread made of it is much denser than
wheaten bread, and has a brownish colour, and a peculiar
sweetish taste, which to most persons is rather agreeable.
We are indebted to Einhof for an elaborate analysis of rye-
meal. He published the result of his experiments in the
summer of 1805.‡

Soluble   A determinate portion of rye-meal was formed into a
part;   paste, washed in pure water till that liquid ceased to ac-
quire any colour, or take up any thing. The liquid, after
filtration, had a yellowish colour, an insipid taste, and a
smell like that of new whey. It slightly reddened litmus
paper, and was rendered muddy by carbonate of potash,
sulphate of silver, and infusion of galls. When raised to

* Ann. de Mus. d'Hist. Nat. No. xxxvii. p. 3.
† Fourcroy and Vauquelin, ibid.   ‡ Gehlen's Jour. v. 131.

the boiling temperature, it became muddy, and a number of white flakes separated. These, when collected and edulcorated, had the appearance of curd. They dissolved in alkaline leys, were insoluble in alcohol, and possessed the properties of *vegetable albumen*. When the liquid was concentrated by evaporation, it deposited a small additional portion of albumen. This being separated, the liquid was evaporated to the consistence of honey, and digested in alcohol repeatedly till nothing more was taken up. The residue was greyish-white and insipid: water dissolved it slowly, and the solution, being evaporated, deposited more flakes of albumen. The residue had the appearance of a solution of gum arabic, and when evaporated to dryness, left behind it a portion of gummy matter.

The alcoholic solution became muddy when mixed with water. The alcohol being drawn off by distillation, there remained in the retort an aqueous solution, of a wine-yellow colour, with large brownish flakes swimming in it. These flakes, when collected, were found to possess the properties of gluten. They formed a glutinous mass with cold water, the bulk of which contracted when the water was made to boil. Boiling alcohol dissolved it; but ether took up only the colouring matter. Alkalies dissolved it, and acids threw it down again from its solution.

The watery solution, thus freed from the gluten, being evaporated, left an extract of a wine-yellow colour. By repeated digestions in alcohol, dilutions with water, and evaporations, it was freed from a portion of gluten, which still adhered to it. Its taste was then sweet, but harsh; its colour wine-yellow; and it was soluble in water, alcohol, and ether. It was considered as the saccharine matter of rye.

The rye-meal, thus freed from the matters soluble in Insoluble. water, was mixed with a great quantity of water, and by repeatedly agitating the liquid, and decanting it off after standing some time, it was separated into two portions; namely, a greyish-coloured substance, which, being lightest, did not so soon subside, and a white powder which possessed the properties of starch. The grey-coloured substance, by repeated digestions in alcohol and water, was separated into three portions; namely, gluten, starch, and the coats of the rye-seeds. Such are the constituents of rye-meal, according to Einhof. The following are the proportions of

these different substances, detected by this chemist, in the best rye-seeds and rye-meal. 3840 parts of good rye-seeds were composed of

Constituents.

Husk 930
Moisture. 390
Pure meal 2520
                       ─────
                        3840

A hundred parts of good rye-meal contained

Albumen. .... 3·27
Gluten, not dried .... 9·48
Mucilage ....11·09
Starch ....61·09
Saccharine matter. .... 3·27
Husk..................... 6·38
Loss .... 5·42
                        ─────
                       100·00

But the proportion of these substances must vary extremely according to the soil, the climate, and the age of the rye. The gluten of rye differs in several particulars from that of wheat. It is less tenacious and more soluble. When it was allowed to ferment, Einhof perceived a strong smell of nitric acid, which is peculiar to this species of gluten. The starch of rye bears a striking resemblance to that of wheat. Like this last, it does not form a colourless solution with boiling water, and always precipitates at last, when the solution is left a sufficient time at rest.

Ashes.   Einhof did not examine the ashes of rye; but from the experiments of Schrader, we know that the same quantity, analysed by Einhof, namely 3840, yielded the following fixed substances : *

Silica..................... 3·90
Carbonate of lime .... 3·35
Carbonate of magnesia ...... 3·55
Alumina.................... 0·35
Oxide of manganese. .... 0·80
Oxide of iron.............. 0·22
                        ─────
                        12·17

* Gehlen's Jour. iii. 525.

3. Oats are the seeds of the *avena sativa*, a plant culti-vated in considerable quantities as an article of food. No correct chemical analysis of this seed has yet been made. The husk is uncommonly thick, and constitutes a consider-able portion of the corn. The proportion of starch is like-wise considerable, though it is difficult to free it from another substance with which it is united.

4. Barley is the seed of the *hordeum vulgare*, a plant too well known to require any description. Great crops of it are reared annually, partly as an article of food, and partly as a material from which malt liquors and ardent spirits are drawn. This species of corn has been examined of late with considerable attention by chemists, partly in order to form correct conceptions, if possible, of the nature of the process of fermentation, and partly to ascertain the con-stituents of barley. Fourcroy and Vauquelin published several ingenious remarks and experiments on it in 1806,* and Einhof published a still more elaborate analysis about the commencement of the same year; having examined this grain in different stages of its growth, and after is was fully ripe.†

When unripe barley-corns are triturated with water, the liquid acquires a milky colour. If this process be conti-nued, adding fresh portions of water as long as the liquid passes off muddy, there remains only a green husky matter. When this matter is macerated a sufficient time in cold water, it acquires a greenish-grey colour, and when dry has the appearance of vegetable fibre. The water in which it was macerated, when boiled, deposits a few flakes of albumen, and when evaporated to dryness leaves a small portion of extractive.

The water with which the barley was at first triturated is at first milky, and gradually deposits a white powder; yet it does not become transparent, though allowed to stand a considerable time. When filtered, it passes through transparent, while a slimy substance of a greenish-grey colour remains upon the filter. This substance posseses the properties of gluten. When the solution, now transparent and of a yellowish colour, is boiled, it deposits flakes of albumen. It reddens litmus paper, and is strongly preci-

* Ann. de Mus. d'Hist. Nat. No. xxxvii. p. 5.
† Gehlen's Jour. vi. 62.

pitated by lime-water, nitrate of lead, and sulphate of iron, indicating the presence of phosphoric salts.

The liquid being evaporated to the consistence of a syrup, and the residue treated with alcohol, the solution diluted with water, and the alcohol distilled off, to separate some gluten which still remained, a syrupy matter was obtained, having a sweet taste, which was considered as a saccharine matter of the barley. A portion refused to dissolve in alcohol. This portion was considered as extractive.

The white powder which precipitated from the water in which the barley had been originally triturated possessed the properties of starch.

Such are the constituents of unripe barley, according to the experiments of Einhof. The following are the proportions of each which he obtained from 2880 parts of unripe barley.*

Constitu-
ents.

Green husk, &c.	478
Albumen, with phosphate of lime	13
Gluten	51
Saccharine matter	160
Extractive	76
Starch	420
Volatile matter	1500
Loss	182
	2880

Ripe barley.   When ripe barley is steeped in water a sufficient time, and then cautiously kneaded between the fingers in a cloth, every part of the grain is washed away except the husk, which by this process may be dried and weighed.

When barley meal, previously made into a paste, is treated in the same way, a brownish residuum remains, consisting chiefly of the husk, though it contains also portions of starch and gluten which cannot well be separated. The water in which the meal has been washed gradually deposits a white powder, but does not become transparent though left at rest. It runs very soon into acidity. Indeed, if we believe Fourcroy and Vauquelin, barley often contains an acid; the water in which it has been macerated reddening the infusion of litmus: this acid is the acetic. The colour of this water is reddish-brown. It holds in solution

* Gehlen, vi. 83.

a considerable portion of matter, which, according to Fourcroy and Vauquelin, consists chiefly of gluten, but which Einhof found to be of a more complicated nature, consisting of albumen, or rather gluten, mucilage, and saccharine matter. It contains in solution likewise a notable portion of phosphate of lime.

When barley meal is macerated a sufficient time in alcohol, that liquid acquires a yellow colour, and becomes muddy and more odorous, and by evaporation leaves an oily matter of a yellow colour and an acrid taste, having the consistence of butter. This oil burns like a fat oil, and forms soap with alkalies. It is but imperfectly soluble in alcohol.* This oil escaped the observation of Einhof. I obtained it by a process similar to that afterwards described by Fourcroy and Vauquelin; but its colour was asparagus green, and it did not burn with the same readiness as an oil. It has very much the appearance of olive oil coagulated, but its consistence is less, and its colour is darker. To this oil the peculiar flavour of spirits from raw grain is ascribed at present. If this opinion be well founded, the oil must be dissipated or destroyed by the process of malting.

The following are the proportions of the constituents obtained by Einhof from 3840 parts of barley-corns:

Volatile matter	430
Husk	720
Meal	2690
	3840

From the same quantity of barley-meal he obtained

Volatile matter	360
Albumen	44
Saccharine matter	200
Mucilage	176
Phosphate of lime, with some albumen	9
Gluten	135
Husk, with some gluten and starch	260
Starch, not quite free from gluten	2580
Loss	76
	3840

* Fourcroy and Vauquelin, Ann. de Mus. d'Hist. Nat. No. xxxvii. .3.

Book IV. Besides these substances, Fourcroy and Vauquelin ascertained the presence of phosphates of lime and magnesia, and of silica and iron; and I found in it, besides these substances, phosphate of potash and nitrate of soda. The presence of phosphate of potash was ascertained likewise by Saussure junior.

Rice.   5. Rice, the seeds of the *orysa sativa*, have been analysed by Braconnot. He found in this grain the following constituents:

	Carolina Rice.	Piedmont Rice.
Water	5·00	7·00
Starch	85·07	83·80
Parenchyma	4·80	4·80
Vegeto-animal matter	3·60	3·60
Uncrystallizable sugar	0·29	0·05
Gummy matter approaching starch	0·71	0·10
Oil	0·13	0·25
Phosphate of lime	0·13	0·40
	100·00	100·00

Besides traces of muriate of potash, phosphate of potash, acetic acid, sulphur and lime and potash united to a vegetable alkali.*

Maize.   6. Maize. This is the seed of the *zea mais*, or indian corn. Some experiments on it have been made by Proust. It is converted into charcoal in the usual way, and leaves about ¼th its weight of charcoal. This charcoal is extremely difficult of incineration. It contains some phosphate of potash.†

Having now given an account of the constituents of the various species of corn hitherto subjected to chemical examination, let us proceed to the seeds of the papilionaceous plants. The most remarkable of these are peas, beans, kidney-beans, lupines, lentiles, &c.

Peas.   7. Peas. The seeds of the *pisum sativum* constitute a very common and nutritive article of food. They have been examined in different states by Einhof,‡ who has devoted his chief attention to this peculiar branch of chemical investigation.

* Ann. de Chim. et Phys. iv. 370.   † Nicholson's Jour. xviii. 239.
‡ Gehlen's Jour. vi. 115.

By treating the green plant nearly in a similar manner with barley, he obtained from 3840 parts the following constituents :

Volatile matter	3000
Starch	53
Vegetable fibre	400
Gluten*	70
Albumen	35
Phosphate of lime	4
Saccharine matter	176
Extractive	25
Loss	77
	———
	3840

The green pod or husk of the pea, by a similar treat- ment, yielded, from 3840 parts,†

Volatile matter	3120
Vegetable fibre	344
Starch	90
Green gluten	22
Albumen	$17\frac{1}{4}$
Phosphate of lime	$3\frac{1}{2}$
Saccharine syrup	182
Loss	61
	———
	3840

The peas themselves, when very young, are often filled with a sweet juice, which may be obtained by a slight pressure. Einhof examined this liquid. It has a greenish-yellow colour and a very sweet taste. When exposed to the air, thin cuticles formed on its surface, and white flakes precipitated. It gradually underwent a kind of fermentation and became sour. From 1440 parts of this juice, Einhof obtained, by analysis,‡

Albumen	10
Extractive	13
Saccharine syrup	155

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* In the same state as that from the leaves of plants, and mixed with the green colouring matter.

† Gehlen's Jour. vi. 119.　　　　　　　　‡ Ibid. 120.

This syrup had much the taste of raw sugar, but could not be made to crytallize.

From ripe peas, by macerating them in water, and employing a mode of analysis similar to that used for ascertaining the constituents of barley, Einhof obtained the following products. The quantity employed was 3840 parts.*

Volatile matter	540
Starchy fibrous matter, with the coats of the peas	840
Starch	1265
Animo-vegetable matter	559
Albumen	66
Saccharine matter	81
Mucilage	249
Earthy phosphates	11
Loss	229
	3840

The second of these constituents, entitled *starchy fibrous matter*, was what remained after the peas, reduced to a pulp with water in a mortar, had been washed with water till they ceased to discolour it, or to give out any soluble matter to it. This residue was in part composed of the coats of the peas, and partly of a white fibrous matter without taste or smell. When dried, it became yellowish, and was easily reduced to powder; and the powder formed a paste with water, and dissolved like starch in hot water. It then bore a certain resemblance to starch, and agreed in its properties with the fibrous matter of potatoes.†

The fourth of the preceeding constituents, entitled *animo-vegetable matter*, was obtained in this manner: the milky water in which the peas had been macerated, after depositing the starch, still continued muddy, but neither deposited any thing, nor would pass through the filter; but when diluted with its own bulk of water, it gradually deposited a powder, the whole of which, being collected on a filter, constituted the substance to which Einhof gave the name of *animo-vegetable matter*. It approaches most nearly to gluten; but as it differs in several particulars both

* Gehlen's Jour. vi. 13.   † Ibid. p. 123.

from gluten and from all other vegetable constituents, we must consider it as a peculiar principle.

Its colour was at first white ; it had no taste nor smell, but reddened vegetable blues, even after having been repeatedly washed in cold water. It was glutinous and adhesive, and could be kneaded into a paste. It was insoluble in water, both cold and hot; but when mixed with that liquid it soon putrified; and on being treated with lime, gave out the smell of ammonia. In the pure alkaline leys it dissolves readily, and forms a kind of soap; but the carbonates require heat to produce the solution. Sulphuric acid dissolves it; the solution is light-brown, and when diluted with water, lets fall a white thread-like substance. It dissolves also in muriatic acid and chlorine, and in acetic acid. Nitric acid gives it a lemon-yellow colour. It dissolves also in alcohol, and the solution becomes milky when mixed with water. The tincture of galls throws down a copious white precipitate. Ether and volatile oils have no action on it. When dried it assumes a light-brown colour and the semitransparence of glue, and is easily reduced to powder.* Such are the properties of this substance, as far as they have been ascertained by M. Einhof.†

When 3840 parts of ripe peas were reduced to ashes, the residue weighed 112 parts. From these ashes Einhof extracted phosphoric acid, sulphuric acid, muriatic acid, alumina, silica, carbonate of lime, phosphate of lime, oxide of iron, and phosphate of ammonia and magnesia.‡

8. The seeds of the *vicia faba*, a small bean, becoming blackish when ripe, and used as an article of food, have likewise been examined by Einhof. The analysis was conducted in the same way as his other experiments already described. From 3840 parts of the ripe beans he obtained the following substances :

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* Einhof remarks, that he has seen the gluten of wheat assume this appearance. I have observed the same thing twice. In both cases the wheat was very inferior in quality, and had been the growth of a very rainy season.

† Gehlen's Jour. vi. 124.   ‡ Ibid. p. 132.

Volatile matter	600
Skins	386
Starchy fibrous matter	610
Starch	1312
Vegeto-animal matter	417
Albumen	31
Extractive, soluble in alcohol ..	136
Gummy matter	177
Earthy phosphate	$37\frac{1}{2}$
Loss	$133\frac{1}{2}$
	3840*

Fourcroy and Vauquelin, who made experiments upon this substance likewise, found the ashes which it leaves, when incinerated, to consist of the phosphates of lime, magnesia, potash, and iron, and of uncombined potash. They could detect no sugar in it.†

Kidney beans.

9. Kidney beans, which are the seeds of *phaseolus vulgaris*, have been likewise analysed by Einhof. They are characterized by the great proportion of animo-vegetable matter which they contain. From 3840 parts of these beans Einhof obtained the following substances :

Skins	288
Starchy fibrous matter	425
Starch	1380
Animo-vegetable matter, not quite free from starch	799
Extractive	131
Albumen, with some vegeto-animal matter	52
Mucilage	744
Loss	21
	3840‡

Lentiles.

10. Lentiles. To the same indefatigable chemist we are indebted for the analysis of the seeds of the *ervum lens.* From 3840 parts he obtained the following substances :

* Gehlen's Jour. vi. 136.
† Ann. de Mus. d'Hist. Nat. No. xxxvii, 9.
‡ Gehlen's Jour. vi. 545.

Fibrous matter	720	Chap. II.
Albumen	44	
Earthy phosphates, with a little albumen ..	22	
Extractive, soluble in alcohol	120	
Gummy matter	230	
Starch	1260	
Vegeto-animal matter	1433	
Loss	11	
	3840*	

Here the proportion of animo-vegetable matter is still greater than in the kidney bean.

Lentiles were examined by Fourcroy and Vauquelin but whether the same species as the preceding they do not put it in our power to determine, as they omit the botanical name. The liquid in which the flour of these seeds was macerated was not acid: it had a slight and rather disagreeable taste, and was precipitated copiously by infusion of galls, chlorine, and sulphate of iron. In short, it exhibited nearly the same phenomena as are described by Einhof. When the flour of lentiles is digested in alcohol, the liquid assumes a greenish-yellow colour, and a bitter acrid taste. When distilled it has the odour of vanilla very strongly, but acquires a disagreeable smell when mixed with water. The residue is greenish-yellow, has the appearance of a thick solution of soap, and a green oil swims upon the surface. The pod of the lentiles contains a portion of tannin.†

11. White lupine. To Fourcroy and Vauquelin we are White lu- indebted for the analysis of the seeds of the *lupinus albus*; pine. the farina of which, according to their experiments, differs from that of all the other liguminous plants hitherto tried, as it contains neither starch nor saccharine matter. They found in it a yellowish-green oil of an acrid nature, which approaches the fixed oils in its properties: a vegeto-animal matter, which appears to bear a strong resemblance to gluten: a considerable portion of phosphate of lime and magnesia, and traces of phosphates of potash and of iron.‡

12. Hemp-seeds. These seeds have been subjected Hemp- seeds.

* Gehlen's Jour. vi. 542.
† Ann. de Mus. d'Hist. Nat. No. xxxvii. 10.   ‡ Ibid. p. 12.

Book IV. to a chemical examination by Bucholz. The following are the results which he obtained.

Sixteen parts of hemp-seed yielded by expression rather more than three parts of a yellow-coloured oil. Its taste was mild, and it possessed all the characters of the fixed oils. From the residue he procured, by digestion in water and coagulation by heat, about $3\frac{1}{2}$ parts of albumen, and not quite half a part of fibrous matter. The insoluble coats and husks of the seeds weighed $6\frac{1}{8}$ parts. About one-fourth of a part of a brown coloured resin was obtained by means of alcohol, and about the same quantity of a substance to which Bucholz gives the name of *mucilaginous sugar*, and *soapy extract*, and about $1\frac{1}{2}$ part of *gummy extractive*.*

Coffee.   13. Coffee. This is the seeds of the *coffea arabica*, an evergreen-tree, usually of a small size. It was originally brought from Arabia, and was unknown in Europe till 1650.† The entire fruit has some resemblance to a cherry. Under a pulpy skin it contains an oval kernel, which separates longitudinally into two parts, each covered with a thin coat, and marked longitudinally with a furrow on the flat side, where they are joined. The ripe fruit is dried in the sun, and heavy rollers passed over it, by which the seeds are parted and the coats broken. They are afterwards separated by winnowing.

Many experiments have been made by chemists to ascertain the constituents and qualities of coffee; Neumann, Geoffroy, Dufour, Kruger, Westfield, &c. published successively the result of their trials on it. The latest analyses are those of Hermann ‡ and Cadet. § They neither agree well with each other, nor with those of preceding writers. It is probable that these differences ought to be ascribed partly to the different mode of analysis followed, and partly to variations in the berries examined.

Infusion.   The infusion of coffee in boiling water is of a yellowish-green colour; but the decoction, by continuing the boiling, becomes brown. It becomes turbid on cooling. The alkalies render it more brown. It strikes a black with sulphate of iron, but does not precipitate with glue. Chlorine nearly destroys the colour; but if an alkali be added the

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* Gehlen's Jour. vi. 615.   † Neumann's Chemistry, p. 378.
‡ Crell's Annals, 1800, ii. 108.   § Ann. de Chim. lviii. 266.

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liquid becomes red. Cadet obtained a decoction with coffee which produced no effect upon vegetable blues; but other chemists describe it as changing them to red, and Hermann obtained with alcohol a solution which produced the same effect.

When water was distilled from coffee, what came over had an aromatic odour, and a few drops of a substance similar to myrtle wax swam on the surface of it; the residual liquid became milky when mixed with alcohol, and let fall a substance possessing the properties of gum.

When alcohol is digested on coffee, it acquires some colour. The solution when mixed with water becomes milky, and lets fall a whitish resinous matter. The residue being evaporated to dryness leaves a substance composed partly of extractive, and partly of the bitter principle discovered by Chenevix. From these experiments, chiefly made by Cadet, we see that coffee contains an aromatic principle, a little oil, gallic acid, mucilage, extractive, and bitter principle. It contains also, according to Cadet, sulphate of alumina, lime, muriate of potash, and a little albumen, which separates from the decoction in the form of scum. The result of Cadet's experiments was nearly as follows. Sixty-four parts of coffee yielded

Gum .... 8·0
Resin............................ 1·0
Extract and bitter principle ..... 1·0
Gallic acid .... 3·5
Albumen .... 0·14
Fibrous insoluble matter .... 43·5
Loss .... 6·86

64·00

Hermann obtained from 1920 parts of Levant and Martinique coffee the following proportions respectively:

	Levant.	Martinique.
Resin	74	68
Extractive	320	310
Gum	130	144
Fibrous matter.	1335	1386
Loss	61	12
	1920	1920

When coffee is roasted, a portion of tannin is formed in it by the action of the heat. It appears also that a new substance, having a peculiar agreeable smell, is developed; but the nature of this new principle has not yet been ascertained. It is developed also by roasting barley, beans, and a great variety of other vegetables, which are on that account occasionally employed as substitutes for coffee.

Roasted coffee.

An elaborate analysis of coffee has been published by Payssé. He examined with particular care the bitter principle of coffee, first pointed out by Chenevix, and has endeavoured to show that it is in reality a peculiar acid, to which he has given the name of *coffic acid*. It reddens vegetable blues, but in other respects does not seem better entitled to the name of acid than *tannin*. He detected in coffee, besides this substance, a quantity of albumen, resin, and extractive. It contains a great proportion of matter insoluble in water. Its ashes yield muriate of potash and carbonate of lime. Payssé could not succeed in ascertaining the presence of tannin in roasted coffee. When coffee is distilled it yields, according to him, an acidulous water, a thick brown oil, and carbonate of ammonia. Very little gaseous matter was obtained.*

Coco.
14. Coco. This is the fruit of the *cocos nucifera*, one of the most valuable vegetable productions of India. A detailed account of the management and products of this tree has been published by Le Goux de Flaix;† but we are still unacquainted both with the constituents and chemical properties of the nuts. The outer coat is fibrous, and formed by the natives into excellent cordage. The kernel contains a considerable proportion of fixed oil, used by the Indians for lamps.‡

Almonds.
15. Almonds. This is the fruit of the *amygdalus communis*, used both as an article of food and in medicine. There are two kinds, the *bitter* and *sweet*. The latter consists chiefly of fixed oil and starch, or albumen; chemists have not yet ascertained correctly which. Bitter almonds, besides these two substances, probably contain also a portion of bitter principle. Prussic acid is likewise a consti-

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* Ann. de Chim. lix. 196.
† Phil. Mag. xx. 316; and xxi. 77 and 110.
‡ See Tennant's Indian Recreations, ii. 282.

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tuent of them; but hitherto almonds have not been sub-
jected to a regular chemical analysis.

16. Nutmeg. This is the seed of the *myristica moschata*,
a tree which is cultivated in the Asiatic islands. The co-
vering of the nut is known by the name of *mace*. The
nutmeg varies in size and figure; it is furrowed on the out-
side, and greyish brown internally. Those that want white
streaks are the best. From the experiments of Neumann,
we learn that this substance contains two species of oil; a
volatile oil, to which it owes its peculiar smell and taste,
and which in his trials amounted to about $\frac{1}{32}$d part of the
nut; and a solid fixed oil resembling wax, and amounting
to about $\frac{1}{3}$d of the nutmeg. He detected also a quantity
of gum; * and it is probable, from the appearance of the
kernel, that it contains likewise starch. By expression, the
solid oil is separated, and mixed with the volatile oil. In
that state it is sold under the name of *oil of mace*.

17. Pepper. This is the seed of the *piper nigrum*, a
shrub cultivated in India for the sake of its berries. Its
outer coat is of a dark brown colour; when deprived of it,
the berry is known by the name of *white pepper*.

Pepper, when macerated in cold water, does not lose its
shrivelled appearance. The infusion acquires a brown
colour, reddens vegetable blues, and has both the taste and
odour of pepper. If we repeat the maceration a number
of times, the liquid still continues to acquire a colour, but
it ceases to have the smell and flavour of pepper. White
pepper does not communicate any colour to water. Hence
the colouring matter must reside in the outer coat. It pos-
sesses most of the properties of extractive. When pepper
is macerated in alcohol, the liquid acquires a light yellow-
ish green colour. When distilled, it leaves a green co-
loured matter, partly resinous, and partly oily. This oil
is the source of the odour and taste of pepper. Its taste is
extremely hot, and its smell, when dissolved in alcohol,
and diluted with water, extremely pleasant. It possesses
nearly the properties of volatile oil. When water is boiled
for some time with ground pepper, it acquires the property
of forming, with the infusion of nutgalls, a precipitate,
which dissolves again when the liquid is heated to 120°.

* Neumann's Chem. p. 404.

Book IV. Hence it contains a portion of starch. These three sub-
stances, starch, oil, and extractive, are the most remarkable
of the constituents of pepper.*

Anatto.   18. Anatto. This pigment is obtained from the seeds
of the *bixa orellana*, a tree cultivated in Guiana and other
parts of the West Indies. When ripe, the capsules are
gathered, and the seeds being separated, are pounded,
steeped in water for weeks or months, then subjected to the
press; and the colouring matter thus obtained is suffered
to subside, collected, and dried. A shorter process has
been lately proposed by Leblond. The colouring matter,
which is confined to the surface of the seed, is separated
by maceration and washing, and then thrown down from
the water by an acid.† Anatto is usually in hard cakes,
brown without, and red within. It dissolves much more
easily in alcohol than in water. Weak alkaline leys dis-
solve it likewise with facility. The decoction of anatto has
a peculiar smell and a disagreeable taste. Its colour is
reddish yellow; alkalies render it orange yellow; and from
this mixture the acids throw down an orange-coloured
precipitate.‡ The chemical nature of this colouring matter
has not been ascertained, though it appears to be inter-
mediate between extractive and resin.

Phytolacca   19. Berries of the *phytolacca decandra*. These berries
berries.   give a beautiful purple colour to water, of a very fugitive
nature. A few drops of lime water change it to yellow;
and this yellow liquid is the most delicate test of acids hi-
therto observed. The smallest quantity of acid restores
its purple colour. Braconnot, to whom we are indebted
for these observations, has shown, that it is at least four
times as delicate as the infusion of litmus. Unfortunately
it alters its nature in a few hours, and then loses its delicacy
as a reactive. It can only be used when recently pre-
pared.§

Club moss.   20. The seeds of the *lycopodium clavatum*, or common
club moss, have been long remarkable for their combusti-
bility. They are extremely small; and when blown into
the flame of a candle they take fire, with a small explo-

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* See Nicholson's Jour. ii. 7.   † Ann. de Chim. xlvii. 113.
‡ Berthollet, Elemens de l'Art de la Teinture, ii. 268.
§ Ann. de Chim. lxii. 81.

sion, and are used in theatres to imitate the appear- ance of lightning. They have been subjected to chemical analysis by Bucholz. From 1000 parts of the seeds he obtained 60 parts of a fixed oil, soluble in alcohol like castor oil; 30 parts of sugar; 15 of a mucilaginous extract. There remained a matter insoluble in water, alcohol, ether, oil of turpentine, and alkaline leys. But when boiled with the last of these agents, ammonia was disengaged, and a kind of extract formed. When 2000 grains of this substance were distilled, they yielded 290 ounce measures of gas, which was a mixture of carbureted hydrogen and carbonic acid; 1080 grains of a brownish oil, containing ammonia; 330 grains of a watery liquid, holding acetate of ammonia in solution. The residue in the retort, amounting to 310 parts, had very much the appearance of anthracolite. When the insoluble part of the seeds was boiled in nitric acid, a portion of oil soluble in alcohol was likewise formed.*

21. To Braconnot we are indebted for an elaborate Husk of analysis of the outer husks of the common nuts which are nuts. frequently employed in France as a dye stuff, probably as a substitute for nut galls. He obtained from the fresh husks of nuts the following substances.†

Starch.	Citric acid.
An acrid and bitter substance.	Phosphate of lime.
Malic acid.	Oxalate of lime.
Tannin.	Potash.

SECT. X.

OF FRUITS.

THE fruits of vegetables are equally various with the seeds. But few of them have been hitherto subjected to chemical analysis. They almost all contain an acid; and Constitu- this acid is usually the tartaric, the oxalic, the citric, or ents. the malic, or a mixture of two or more of them. Hardly any other, except perhaps the acetic, has hitherto been

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* Gehlen's Jour. vi. 593.   † Ann. de Chim. lxxiv. 303.

Book IV. found in fruits. They usually contain likewise a portion of gummy matter, sometimes starch; and the fleshy fruits contain also a fibrous matter, not yet accurately examined. The colouring matters of fruits, especially the red, dissolve readily both in water and alcohol; but very speedily decay when exposed dry to the action of the sun and weather. Hence they cannot be used as dyes.

A list of the acids contained in a considerable number of fruits has been given already in a former part of this work. As very few vegetable fruits have hitherto been analysed, little can be added to what was given there. The only analyses, indeed, hitherto published, are those of tamarinds, grapes, and cucumber.

Tamarinds.   1. *Tamarinds.*—This substance consists chiefly of a pulpy matter which fills the pods of the *tamarindus indica*, and covers the seeds. It is brought to Europe preserved in sugar. We are indebted to Vauquelin for an analysis of this substance, published however at a very early period of his chemical career. By treating the pulp of tamarinds, such as they are sold by the apothecaries, first with cold water, and afterwards with hot, he separated the following substances : *

Supertartrate of potash	300
Gum	432
Sugar	1152
Jelly	576
Citric acid	864
Tartaric acid	144
Malic acid	40
Feculent matter	2880
Water	3364

9752

Grapes.   2. *Grapes.*—Though grapes have been repeatedly examined by chemists, we are not yet in possession of an accurate chemical analysis of their constituents. It has been ascertained, however, that they contain supertartrate of potash, tartaric acid, citric and malic acids.† They con-

* Ann. de Chim. v. 92.
† Bouillon, Jour. de Phys. xxix. 3. Parmentier, Ann. de Chim. liii. 119.

tain also abundance of sugar, a portion of mucilage and jelly, some albumen and colouring matter, and, according to Proust, a portion of gluten.

3. *Cucumber.*—This is the fruit of the *cucurbita citrullus*, and is well known as an article of food. It was subjected to analysis by Dr. John, who found 600 parts of it composed of the following ingredients:

Water	582·8
Substance similar to fungin	3·2
Soluble vegetable albumen	0·8
Resin	0·25
Extractive with sugar	9·95

Mucus .... ⎫	
Phosphate of lime .. ⎪	
Phosphate of potash ⎪	
Phosphoric acid .... ⎪	
Ammoniacal salt . .. ⎬	3·0
A malate .... ⎪	
Sulphate of potash .. ⎪	
Muriate of potash .. ⎪	
Phosphate of iron .. ⎭	

600·0*

Pears, apples, lemons, oranges, &c. have not yet been subjected to chemical examination. The few facts which have been ascertained respecting them are detailed in a different part of this work.
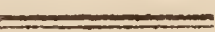
SECT. XI.

OF BULBS.

By *bulbs* are understood tubercles connected with the roots of vegetables, very analogous to the *buds*, and containing the embryo of a future plant. The *potatoe* is a well known example of a bulb.

Bulbs vary considerably in their constituents and properties, as well as the other parts of plants; but they bear,

* Schweigger's Jour. ix. 34.

upon the whole, a considerable resemblance to the seeds of those grasses which are cultivated under the name of *corn ;* at least starch constitutes a notable portion of most of the bulbs hitherto examined. Hence several of them are employed as articles of food. Few of them hitherto have been subjected to a chemical analysis. I can only therefore specify the following :

Potatoes.   1. *Potatoes* are the bulbs of the *solanum tuberosum,* an American plant, first brought to this country by Sir Walter Raleigh, and now cultivated in every part of Europe, and in Britain constituting one of the most important articles of food. The plant and the bulb are too well known to require description.

Potatoes have been repeatedly subjected to chemical examination. Parmentier published an elaborate dissertation on their culture, uses, and properties, about the year 1776, which contributed considerably to promote the cultivation of them on the continent. Dr. Pearson contributed to the Board of Agriculture a valuable essay on potatoes, containing a set of chemical experiments on them, performed with his usual skill and ingenuity ; and Einhof has published a very elaborate analysis of the root in the fourth volume of Gehlen's Journal.

The variety of potatoe which chiefly occupied the attention of Einhof, was that which has a red skin and flesh-coloured juice. When dried by a moderate heat, till they ceased to lose any weight, potatoes were reduced to $\frac{1}{4}$th of their original weight.[*]

The analysis of this root was conducted by Einhof pretty much in the same manner as his analysis of barley and rye. A determinate quantity of potatoes was reduced with water to a pulp, and then washed on a searce till the liquid ceased to come off milky, or to hold any thing in solution. What remained on the cloth was the fibrous matter of the potatoe; but it differed essentially from the fibrous matter of most plants. With boiling water it formed a paste similar to that made by means of starch, and when dry it assumed a semitransparent appearance. This matter, when triturated in a mortar, and again washed with water, yielded a considerable portion of starch. The residue,

* Gehlen's Jour. iv. 457.

which was of a light-grey colour, being triturated a second time, formed a powder which bore a considerable resemblance to starch, both in its appearance and properties.

The liquid with which the potatoe was washed was at first milky, but deposited, on standing, a heavy white powder, which was *starch*. When filtered it had a carmine-red colour, and reddened vegetable blues. When boiled a flaky precipitate separated, partly white and partly red. This precipitate possessed the properties of albumen. The residue, evaporated to the consistence of an extract, had a brownish colour, was insoluble in alcohol and ether, soluble in water, and, according to Einhof, was a mucilaginous matter. The following were the proportions of these various substances obtained from 100 parts of potatoes :

Starch	15
Fibrous starchy matter	7
Albumen.........................	1·4
Mucilage, in the state of a thick syrup ..	4

27·4

Constitu-ents.

To ascertain the nature of the acid which exists in potatoes, Einhof separated the juice of potatoes by a gentle pressure. He had first frozen and then thawed them, to facilitate the separation. Lime-water was added in excess to this liquid, and the precipitate was digested in diluted sulphuric acid, to separate the lime from the acid. Thus Contain obtained, it was found to be a mixture of tartaric and tartaric and phosphoric acids.* The sap, thus deprived of its acid, phophoric acids. contained an excess of lime in combination with the mucilage. Einhof found, that this lime became gradually saturated with carbonic acid, even though the sap was kept in close vessels; and that in process of time, if a sufficient quantity of lime were present, the mucilage acquired a sweet taste; and when treated with alcohol, a portion dissolved, which yielded crystals of sugar. This he considered as a conversion of the mucilage into sugar.

From 1820 parts of dried potatoes, Einhof obtained 96 Ashes.

* Though Einhof obtained phosphoric acid by the method described in the text, it does not follow that it existed in the potatoes in an uncombined state. It might have been in combination with lime, and held in solution in the potatoe juice by means of the tartaric acid.

Book IV. parts of a greyish-white ash. Of these, 64 parts were soluble in water. They consisted chiefly of carbonate of potash; but contained likewise $10\frac{1}{4}$ parts of phosphoric acid, $3\frac{1}{2}$ of sulphuric acid, and two of muriatic. The insoluble 35 parts consisted of earths and oxides. From 20 parts of it he obtained

2·5 silica.
6·0 lime.
4·0 alumina.
7·0 magnesia, with some manganese or oxide of iron.
_____
19·5

Einhof examined different kinds of potatoes. He found the same ingredients in all, but the proportions varied considerably. It is not necessary to state the results of his experiments, because the same variations doubtless occur even in the same kind of potatoe.

But as it may be useful to know the quantity of starch furnished by different varieties of potatoe, the following table, drawn up from the experiments of Mr. William Skrimshire, junior, is subjoined. Five pounds avoirdupois of fresh potatoes were used, and the starch was separated by grating the potatoe, and pouring water upon it placed upon a searce.*

Substances.	Captain Hart.		Rough Red.		White Kidney.		Moulton White.		Yorkshire Kidney.		Hundred Eyes.		Purple Red.		Ox Noble.	
	lb.	oz.	lb.	oz.	lb.	oz.	lb.	oz.	lb.	oz.	lb.	oz	lb.	oz.	lb.	oz.
Fine starch. ...	0	9	0	$7\frac{1}{4}$	0	0	0	9	0	$8\frac{3}{4}$	0	$8\frac{1}{4}$	0	8	0	$6\frac{1}{2}$
Ditto, slightly coloured...	0	3	0	$3\frac{1}{4}$	0	$9\frac{1}{2}$	0	$2\frac{3}{4}$	0	$2\frac{1}{2}$	0	$0\frac{3}{4}$	0	$0\frac{1}{2}$	0	$1\frac{3}{4}$
Pulp dried.....	0	6	0	$6\frac{1}{2}$	0	$3\frac{3}{4}$	0	$5\frac{3}{4}$	0	$6\frac{1}{2}$	0	$6\frac{3}{4}$	0	5	0	8
Water, mucus. and extractive....	3	14	3	15	4	$2\frac{3}{4}$	3	$14\frac{1}{2}$	3	$14\frac{1}{4}$	4	$0\frac{1}{4}$	4	$2\frac{1}{2}$	3	$15\frac{3}{4}$
Total.....	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0

* Nicholson's Jour. xxi. 71.

When potatoes are exposed to the action of frost, it is Chap. II. well known that they become soft, and acquire a sweet Action of taste. This taste is succeeded by a sour taste, owing to frost on po- the rapid evolution of acetic acid, and the root soon passes tatoes. to putrifaction. From the experiments of Einhof, we learn that the sugar is formed at the expense of the mucilage; for the other ingredients were found, in potatoes sweetened by frost, in the usual proportions. He considers this sweetening process as connected with the vegetative powers of the root.

When potatoes are boiled, they lose from 1 to 1½ per Boiling. cent. of their weight. The juice, which may be separated from them, is sweet-tasted. The meal is insoluble even in boiling water, though potatoe starch forms a transparent solution with hot water. Thus it appears, that by boiling, the albumen, fibrous matter, and starch combine together, and form an insoluble compound.*

From these experiments, it appears that potatoes differ essentially from wheat and barley by containing no gluten. They approach, in some measure, to the nature of rye.

2. *Garlic.*—This is the bulbous part of the root of the Garlic. *allium sativum,* and is well known, and remarkable for its strong smell and peculiar taste. It was much celebrated by the ancients, both as an article of food and as a medicine. It has been repeatedly examined by chemists. The analysis of Neumann, considering the state of the art of examining vegetables at that time, must be considered as very exact.†
Cadet has subjected it to a chemical examination ‡

When dried, it loses nearly two-thirds of its weight; but this proportion is doubtless subject to considerable variation. The expressed juice of garlic is of a thick consistence like mucilage, and slightly reddens vegetable blues. When diluted with water, and filtered, it yields flakes of albumen when boiled. The residue consists chiefly of mucilage, of which garlic yields a very great proportion, and of extractive. This last is somewhat acrid in its nature. When garlic is distilled with water, it yields a portion of yellow coloured volatile oil, at first lighter than water, but gradually becoming heavier as the distillation advances.

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* Gehlen's Jour. iv. 485.   † Neumann's Chem. p. 481.
‡ Ann. de Chim. lix. 106.

Book IV. To this oil garlic owes its most remarkable properties. Its
taste is very acrid, and its smell strong.   When applied to
the skin, it produces an irritation not inferior to cantha-
rides, and, like that drug, might be employed to blister the
skin.   When triturated with oxide of iron, it immediately
strikes with it a black colour; but it has no effect upon any
other metallic oxide.

Contains an
acrid oil.

When garlic is treated with alcohol, the liquid assumes
a reddish-yellow colour, and leaves, when evaporated, a
brown extract, very acrid, which attracts moisture from
the air.

Other con-
stituents.

When garlic is distilled, it yields first a liquid slightly
coloured, and having a very acrid taste; then a thick
brown oil, and abundance of inflammable air and carbonic
acid.   The liquid in the receiver emits the smell of am-
monia when mixed with lime.   When 40,320 parts of
garlic were incinerated, they left 4896 parts of ashes, or
about $\frac{1}{8}$th of the original weight.   From 172 parts of these
ashes Cadet obtained the following substances :

Potash	33
Sulphate of potash with some muriate	58
Alumina	2
Phosphate of lime	15·6
Oxide of iron	1·5
Magnesia	9
Lime	14
Silica	8
	141·1

From 1406 parts of fresh garlic he obtained

Mucilage	520
Albumen	37
Fibrous matter	48
Water, by estimate	801
	1406

Onion.

3. *Onion.*—This is the bulbous root of the *allium cepa.*
A few experiments on it had been made by Neumann and
Cadet.   But Fourcroy and Vauquelin have published a
very curious and accurate analysis of it.   When reduced
to a pulp, and subjected to the press, it yields a viscid

juice, somewhat opaque, at first colourless, but becoming gradually red in consequence of the oil which it contains. It has a strong smell, and reddens vegetable blues. It is precipitated by acetate of lead, lime water, oxalic acid, nitrate of silver, and potash. When distilled it yields a milky liquid, slightly acid, on the surface of which swim some drops of oil. It contains a little sulphur dissolved in the oil; for chlorine gives it the property of precipitating nitrate of barytes, and when distilled in a copper vessel some sulphuret of copper is formed. The portion of juice not distilled deposits a fawn-coloured sediment, having a strong oniony odour. Alcohol deprives this sediment of oil and of sulphur; the residue seems to possess properties analogous to those of gluten. The liquid, from which this precipitate has separated, contains phosphoric acid, sulphur, and gluten.

When onion juice is kept at a temperature between 60° and 70° it emits no gas, but it changes its colour successively to red and yellow, and lets fall a fawn-coloured sediment. It is now converted into vinegar still retaining the oniony odour; a proof that the volatile matter remains undecomposed. This vinegar contains in it a good deal of manna, which readily crystallizes in needles. On examining recent onion juice no manna could be found in it, merely a considerable quantity of uncrystallizable sugar. This sugar, in a heat between 60° and 70°, is gradually decomposed, and converted into acetic acid and manna. The fawn-coloured matter, which precipitated during this acetification, consisted of gluten, oil, and sulphur.

Onion juice is capable of undergoing the vinous fermentation. When eight ounces troy were mixed with 122 cubic inches of water, and somewhat less than one ounce of barm, they underwent a brisk fermentation, and yielded by distillation about 2·35 ounces troy of strong alcohol. By Lavoisier's experiments 3·7 ounces of sugar would have yielded the same quantity of alcohol.

Besides the preceding constituents, Fourcroy and Vauquelin found in onion juice mucilage, phosphate of lime, and citrate of lime.*

4. *Squills.*—This is the bulbous root of the *scilla mari-*

* Ann. de Chim. lxv. 161.

tima, and is employed in medicine as a diuretic, and to excite nausea and vomiting. It has been subjected to a chemical examination by Vogel, and was found by him to owe its peculiar properties to a species of bitter principle which he distinguished by the name of *scillitin*, which has been described in the preceding chapter. From dried squills he extracted the following substances : *

<div style="text-align:center">

Gum 6
Scillitin 35
Tannin 24
Citrate of lime . .
Sugar . . . .
Woody fibre . . . 30

</div>

SECT. XII.

OF LICHENS.

History. THE lichens are a class of plants which differ almost in every respect from other vegetables. Many of them have not the smallest appearance of plants, but form hard crusts, which cover rocks, wood, trees, &c.; others have the form of leaves or of branches, but nothing resembling flowers is visible. It was to Tournefort and Micheli that botany is indebted for first fixing the word *lichen*, formerly vague and ill defined, to a peculiar set of plants. Afterwards Linnæus placed them among the algæ, and described 81 species. Since that time a great variety of botanical writers have devoted considerable attention to them, particularly in ascertaining and describing their parts of fructification, and the various changes which they undergo in the different periods of their vegetation ; but few only have attempted to analyse them, or to point out the useful purposes to which they may be applied. Willemet has given us a historical account of 41 species of lichens, and detailed their medical and economical uses with considerable accuracy. Amoreux, in a dissertation on the subject, has given us still more copi-

* Ann. de Chim. lxxxiv. 147.

ous details, and has published likewise a brief chemical analysis of some of the most remarkable lichens. Hoffmann, who had previously distinguished himself by his botanical arrangement of the lichens, published an account of their chemical and economical properties in 1787, and has given us the chemical analysis of several, made by Georgi with considerable care. Westring turned his attention particularly to the uses of the lichens in dyeing; and, in seven dissertations, published successively in the Stockholm Transactions from 1792 to 1797, has examined almost all the lichens of the north, and described the colours which each of them is capable of yielding, and the manner of obtaining it. It is to these writers, and to Georgi, that we are indebted for the few facts known respecting the composition and chemical properties of the lichens.

The lichens are found in all countries and climates, and are very numerous; considerably more than two hundred species have been described by botanists as natives of Britain.

From the experiments of Georgi, professor of chemistry Some lichens conin Petersburgh, we learn that the lichen farinaceus, glau- tain gum. cus, and physodes, form with water a mucilage which yields, when evaporated, a gum as transparent and tasteless as gum arabic. Lichen pulmonarius yields likewise a gum, but its taste is somewhat bitter. The gum yielded by these lichens amounted to $\frac{1}{8}$th of their weight. When treated with alcohol, the liquid acquires a green colour and a bitter taste.* Amoreux, who repeated these experiments, obtained from the lichen pulmonarius a reddish gum, much less transparent than gum arabic. This lichen gave a yellow colour to alcohol. Probably he had examined a different species from that tried by Georgi, or if not, the lichens must have been of very different ages.

Amoreux found, that when the lichen prunastri was steeped in water, its branches became transparent like animal membrane, and adhered strongly to paper. In this state it is insipid, but as friable as celery. He obtained abundance of gum from the lichen islandicus, and from all the broad-leaved lichens tried. He succeeded in extract-

* See the experiments of Georgi, as quoted by Amoreux, in his Researches et Experiences sur les divers Lichens, p. 94.

Book IV. ing gum from the lichen fraxineus, caninus, and caperatus. This last gave a lemon-yellow colour to ammonia.*

Some may be used as food.   Georgi found, that when the lichen physodes, hirtus, farinaceus, and pulmonarius, were boiled in water, they yielded a yellowish mucilage nearly insipid, and that the lichens thus treated might be eaten with salt. They all yielded a portion of resin to alcohol, but it did not give a taste to the water in which they were boiled. When incinerated, these lichens yielded a little potash, lime, and silica, but no sulphuric or muriatic salt. When distilled, they yielded an acidulous water, and a yellow or blackish oil which sunk in water.

Such are the imperfect experiments hitherto made on the constituents of a few of the lichens. One of them, however, the *lichen islandicus*, has been subjected to a rigorous and curious analysis by Berzelius. He obtained from 100 parts of this lichen the following constituents:

Syrup	3·6
Bitartrate of potash with some tartrate of lime and phosphate of lime	1·9
Bitter principle.....................	3
Green wax	1·6
Gum	3·7
Extractive colouring matter	7·0
Starch	44·6
Starchy insoluble matter	36·6
	101·6†

Berzelius afterwards examined the lichen plicatus, lichen barbatus, lichen fastigiatus, and the lichen fraxineus. He found them all characterized by the presence of a species of starch which possesses several peculiar properties.‡

I shall now mention such of the lichens as are most remarkable for the colouring matters which they yield.

Archil.   1. *Lichen roccella.*—This lichen, which grows abundantly in the Canary islands, but which is found also on the south coast of England and France, yields the dye stuff called

* See the experiments of Georgi, as quoted by Amoreux in his Researches et Experiences sur les divers Lichens, p. 95.
† Ann. de Chim. xc. 277.   ‡ Afhandlingar, iii. 381.

archil. If we believe Tournefort, this dye stuff was known to the ancients, and was employed to produce the colour known among them by the name of *purple of amorgos.* Be that as it may, the colouring property of the lichen roccella was accidentally discovered by a Florentine merchant in 1300, who observed that urine gave it a fine violet colour. Since that time it has been an article of commerce, and was long prepared in Florence. The lichen, reduced to powder, is put into a vat with urine and quicklime, and regularly stirred, fresh urine and lime being added till it has acquired the destined colour. Other substances were likewise added; but it has been shown that these only are essential. Hellot ascertained, that by treating lichens with lime and ammonia, their colouring matter, if they have any, will be developed; and Westring has simplified the process by substituting sal-ammoniac for ammonia.

Archil thus prepared is used occasionally to brighten other colours, but the colour which it yields is far from fixed. It is employed to tinge the alcohol used in thermometers. Nollet observed that this tincture became colourless when kept excluded from the air, but that it recovered its colour again when air was admitted. The nature of the colouring matter of archil has not yet been ascertained by chemists.

2. *Lichen parellus.*—From this lichen, which grows abundantly in the mountains of Auvergne, and other parts of France, and which is common also in Britain, the pigment called *archil of Auvergne* is prepared. The process is pretty much the same as that by which the lichen roccella is prepared, and the pigment is distinguished by the same name, and applied to the same use, but is not considered as so valuable. It is obvious that the colouring matter of each is analogous.

3. *Lichen pertusus.*—Treated with lime and sal-ammoniac, it yielded a brown colouring matter to Westring.

4. *Lichen ventosus.*—This lichen dyed wool of a brown colour, which resisted the action of alkalies.

5. *Lichen hæmatoma* yielded a wax-yellow colour.

6. *Lichen corralinus.*—This lichen was found by Westring to abound in colouring matter. By simple infusion in water with a little common salt, it dyed wool-yellow. Without addition, it gives a deep brown of considerable

s

permanence.   It yielded the same colour when treated with sal-ammoniac and lime.

7. *Lichen pseudo-corralinus* yielded a fine orange, which was brightened by muriate of cobalt.

8. *Lichen tartareus* yielded a fine brown.

9. *Lichen centrifugus*, with fixed alkalies, yielded a fine wax-yellow ; with water, a brown ; with common salt and nitre, an orange.

10. *Lichen saxatilis.*—This lichen, with soda, yields a yellow ; with lime and sal-ammoniac, a nankeen ; and with muriate of soda and nitre, an orange.

11. *Lichen physodes*, by the same reagents, yields various shades of yellow and brown ; *lichen juniperinus*, yellow and brown ; *lichen tenellus*, yellow, olive, and reddish-brown ; *lichen furfuraceus*, yellow and brown.   The same colours were obtained from a considerable number of leafy lichens.

Lichen croceus, with lime and sal-ammoniac, gave out a red colour.   Westring obtained several colours from other lichens ; and by mixing several of them together, he varied the shade, and produced a new set of colours, differing both in their intensity and fixity.   But for the particulars of his numerous experiments, the reader is referred to his dissertations on the subject.*

SECT. XIII.

OF MUSHROOMS.

History.   THE mushrooms are a class of plants proverbial for the rapidity of their growth and their speedy decay.   When they putrify, they give out an extremely unpleasant odour, and appear to approach animal matter much more closely than other vegetable substances.   They have lately attracted the attention of M. Vauquelin, and M. Braconnot, to whom we are indebted for the analysis of no fewer than 17 species of this hitherto neglected tribe of vegetables.

* The first has been translated into French, and printed in vols. xv. and xvii. of the Annales de Chimie.   The others are inserted in Crell's Annals for 1796, 1797, and 1799.

Braconnot has distinguished the insoluble spongy portion which characterizes the mushrooms by the name of *fungin*, and under that name it has been described in the preceding chapter. It approaches woody fibre in its properties; but seems to be sufficiently distinguished from it by various characters particularly by constituting a nourishing article of food, and by being much less soluble in alkaline leys. Braconnot likewise ascertained the existence of two new acids in mushrooms. One of these has been described in a former part of this work under the name of *boletic acid.* The other, which appears to constitute a very general ingredient in mushrooms, he has on that account distinguished by the name of *fungic acid.**

Fungic acid was extracted from the *boletus juglandis* in sufficient quantity to examine its properties. He found it also in the *merulius cantharellus, boletus pseudo-ignarius, peziza nigra,* and the *phallus impudicus.* Braconnot obtained it from the boletus juglandis by the following process. The juice of that mushroom was pressed out, boiled, and filtered, in order to separate the vegetable albumen. The filtered liquid was evaporated to the consistence of an extract, and digested repeatedly with alcohol. The undissolved portion was dissolved in water, and the solution mixed with acetate of lead. A copious precipitate fell, consisting chiefly of *fungate of lead.* This precipitate was decomposed in a gentle heat by means of dilute sulphuric acid. The fungic acid thus disengaged was saturated with ammonia, and the fungate of ammonia purified by repeated solutions and crystallizations. It was then dissolved in water, the fungic acid was precipitated by means of acetate of lead, and the fungate of lead, after being carefully washed, was decomposed by means of diluted sulphuric acid. Fungic acid thus obtained possesses the following properties.

It is colourless, has a very sour taste, does not crystallize, and deliquesces if it be evaporated to dryness and exposed to the air.

* This name is unhappy, because according to the received principle of naming acids it indicates that the acid so named is a compound of *fungin* and *oxygen;* an opinion so far from being established that it has not even been advanced.

With potash and soda it forms uncrystallizable salts, very soluble in water, but insoluble in alkohol.

With ammonia it forms a salt which crystallizes in regular six-sided prisms.

With lime a salt not altered by exposure to the air, and soluble at the temperature of 73° in 18 times its weight of water.

With barytes, a salt difficultly crystallizable, and soluble in 15 times its weight of water, at the usual temperature of the atmosphere.

With magnesia, a salt soluble in water and in small granular crystals.

With alumina, an uncrystallizable salt having the appearance of gum.

With oxide of manganese, a salt similar to the fungate of alumina.

With oxide of zinc, a salt moderately soluble in water, which crystallizes readily in parallelopipedons. When exposed to the heat of a candle it burns without frothing and leaves the oxide of zinc pure.

When dropped into acetate of lead it occasions a white precipitate soluble in acetic acid. When dropped into nitrate of silver no precipitate appears; but a precipitate falls when an alkaline fungate is dropped into that salt.*

The following are the different species of mushroom hitherto subjected to analysis.

Agaricus campestris.

1. *Agaricus campestris.*—This agaric, which is a common article of food, was analysed by M. Vauquelin, who found in it the following substances:

(1.) Adipocire. This substance was obtained by boiling in alcohol the matter that remained after the juice of the agaric was pressed out. The alcohol on cooling deposited the adipocire in flocks. It has a brownish-white colour, it has a fatty feel like that of spermaceti, melts when heated, and gives off a white vapour, having the odour of fat.

(2.) An oily or fatty matter.

(3.) Vegetable albumen.

(4.) The sugar of mushrooms.

(5.) An animal matter soluble in water and alcohol.

* Ann. de Chim. lxxxvii. 244.

When heated it gives out the smell of roasting meat. Si- Chap. II. milar to the substance called *osmazome.*

(6.) An animal substance insoluble in alcohol.

(7.) Fungin.

(8). Acetate of potash.*

2. *Agaricus volvaceus.*—This agaric, according to the Agaricus volvaceus. analysis of Braconnot, contains the following constituents:

(1.) Much water.

(2.) Fungin.

(3.) Gelatin.

(4.) Vegetable albumen.

(5.) A great quantity of phosphate of potash.

(6.) Acetate of potash.

(7.) Sugar of mushrooms.

(8.) A fluid brown oil.

(9.) Adipocire.

(10). Wax.

(11.) A very fugaceous deleterious matter.

(12.) An uncombined acid, suspected to be the acetic.

(13.) Benzoic acid.

(14.) Muriate of potash.†

3. *Agaricus acris* or *piperatus.*—This agaricus was exa- Agaricus acris. mined by Dr. Lister in 1672.‡ He obtained from it a milky juice with taste hotter than pepper, not discoloured by exposure to the air, nor by the blade of a knife. It speedily coagulated when kept in a glass vessel; but did not lose its hot taste. Trommsdorf made some experiments on it, and extracted from it a peculiar acrid matter and vegetable albumen. When distilled it yielded a considerable quantity of carbonate of ammonia.§ Braconnot subjected it to an elaborate analysis, and extracted from it the following substances:

Water.

Fungin.

Vegetable albumen.

Gelatin.

Much adipocire.

Acetate of potash.

Sugar of mushrooms.

* Ann. de Chim. lxxxv. 7.   † Ibid. lxxix. 276.
‡ Phil. Trans. vii. 5116.   § Ann. de Chim. xxii. 220.

Book IV.   Phosphate of potash.
                       A peculiar vegetable acid united to potash.
                       An oily matter.
                       A very acrid and fugaceous matter.
                       Muriate of potash.*

Stypticus,   4. *Agraricus stypticus.*—Twenty parts of this agaric ana-
lysed by Braconnot, yielded

Fungin.. 16·7
Resin....⎱
Adipocire.⎰ .... 1·8
Unknown gelatinous substance ..⎫
Combustible acid united to potash. ⎬ 1·5
A fugaceous acrid principle ....⎭

20·0 †

Bulbosus,   5. *Agaricus bulbosus.*—Vauquelin subjected this agaric
to some experiments, and extracted from it the following
substances.
        An animal matter insoluble in alcohol.
        Osmazome.
        A fatty soft matter, of a yellow colour and acrid taste.
        An acid salt, which is not a phosphate.
        The sceleton of the agaric when distilled yielded an acid.‡

Theogalus,   6. *Agaricus theogalus.*—Vauquelin extracted from this
agaric,
        Sugar of mushrooms.
        A fatty matter of a bitter and acrid taste.
        An animal matter insoluble in alcohol.
        Osmazome.
        A salt with a vegetable acid. §

Muscarius.   7. *Agaricus muscarius.*—This agaric was examined by
Vauquelin, who extracted from it
        The two animal matters contained in the last agaric.
        A fatty matter.
        Muriate, phosphate, and sulphate of potash.
        The sceleton both of this and the preceding species
yielded an acid when distilled. ‖

Boletus ju-   8. *Boletus juglandis.*—Braconnot subjected this boletus
glandis,

* Ann. de Chim. lxxix. 285.   † Ibid. lxxxvii. 260.
‡ Ibid. lxxxv. 23.   § Ibid. p. 24.   ‖ Ibid.

to an elaborate and ingenious analysis. He found 1260 parts of it composed of the following constituents,

Water	1118·3
Fungin	95·68
Animal matter insoluble in alcohol .	18
Osmazome	12
Vegetable albumen.............	7·2
Fungate of potash	6
Adipocire	1·2
An oily matter	1·12
Sugar of mushrooms	0·5
Phosphate of potash	Trace
	1260·0 *

9. *Boletus viscidus.*—Braconnot found this boletus com- Viscidus, posed almost entirely of an animal mucus, which acquires cohesion when heated, and becomes in part insoluble in water. †

10. *Boletus pseudo-igniarius.*—A large boletus of this Pseudo-ig- species was subjected to an elaborate analysis by Bracon- narius, not, who extracted from it the following substances :

Water.
Fungin.
A sweet-tasted mucilaginous matter.
Boletate of potash.
A yellow fatty matter.
Vegetable albumen.
Phosphate of potash in small quantity.
Acetate of potash.
Fungic acid in a state of combination. ‡

11. *Boletus laricis.*—This plant, in a dry state, is used on Laricis, the continent as a medicine, and sold under the name of *agaric.* It has been examined by Bouillon La Grange. §

It is in pieces, which are white, light, and friable. The outer skin is leathery and dark-coloured. Its taste is at first sweetish, but it leaves a bitter and acrid impression in the mouth. When steeped in water, it communicates a yellowish colour and a sweetish taste to the liquid. The

* Ann. de Chim. lxxxvii. 237.   † Ibid. lxxix. 302.
‡ Ibid. lxxx. 272.   § Ibid. li. 76.

infusion reddens vegetable blues; and holds in solution sulphate of potash, sulphate of lime, and muriate of potash.

When this substance is boiled in water, the liquid acquires a gelatinous form as it cools. Evaporated to dryness, and treated with lime, the odour of ammonia becomes perceptible. Alcohol, boiled upon the boletus, acquires a red colour; and when mixed with water, lets fall a copious precipitate, which exhibits the properties of a resin. This resin has a yellow colour, is brittle, semitransparent, and has a sour and bitter taste. When treated with lime, and the solution afterwards decomposed with muriatic acid, a quantity of benzoic acid is obtained from it. From these experiments it is evident that this substance contains resin, benzoic acid, different salts, some extractive, and some animal matter, to which the gelatinous form of the decoction must be ascribed.

Sulphuric acid dissolves and rapidly chars the boletus. Nitric acid acts with energy; nitrous gas is disengaged, and the boletus becomes brown. By continuing the action of the acid, crystals of oxalic acid are obtained; malic acid is likewise formed, together with some resin, and a substance which approaches the nature of wax in its properties. The fixed alkalies give it a red colour, render it gelatinous, and a great quantity of ammonia is disengaged.*

Boletus ig-
niarius.

12. *Boletus igniarius.*—This boletus is not uncommon in this country on the trunks of trees. A variety of it is used in Germany and some other countries as *tinder*. It is prepared for this purpose by boiling it in a solution of saltpetre, beating it till it becomes sufficiently soft, and then boiling it a second time in the same solution. In 1750 it was recommended by Brossard, a French surgeon, as an excellent styptic; and various trials were made with it, both in France and Britain. It has been subjected to a chemical examination by Bouillon La Grange.†

When boiled in water the liquid acquires a deep brown colour and a slightly astringent taste. It holds in solution sulphate of lime and muriate of potash. When evaporated to dryness, it leaves a brown-coloured extract, which attracts moisture from the atmosphere. This substance, when

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* Bouillon la Grange, Ann. de Chim. li. 76.
† Ann. de Chim. liv. 92.

incinerated, left a white ash, containing a considerable por- tion of potash; and when dissolved in water, exhibited, by reagents, the presence of lime, and of muriatic and sulphuric acids. The residual portion of the boletus, being calcined, was found to contain phosphates of lime and magnesia, and some iron.

Alcohol has scarcely any action on this boletus; but when assisted by heat, it dissolves a small portion of resin. Nitric acid dissolves it readily; malic and oxalic acids are formed, and probably also a portion of bitter principle, while carbonic acid and nitrous gas are disengaged. Alkaline leys dissolve it with difficulty; forming, however, a soapy liquid, and separating a small portion of ammonia. From these experiments, we learn that this boletus differs in many respects from the preceding. It contains much less resin, and a much smaller proportion of animal matter, and yields no traces of benzoic acid. *

13. *Hydnum repandum.*—This hydnum is not uncom- Hydnum mon in the woods. It has a yellow colour. Braconnot repandum. subjected it to analysis, and extracted from it the following substances:

> Water.
> Fungin.
> Gelatin in small quantity.
> Sugar of mushrooms in considerable quantity.
> Much acetate of potash.
> Fungate of potash.
> A little phosphate of potash.
> Another vegetable alkali united to potash.
> An oil.
> Adipocire.
> A very fugaceous acrid matter.
> Muriate of potash.†

14. *Hydnum hibridum.*—This hydnum has a blackish- Hibridum. brown colour, has not an acrid taste, and when distilled yields no ammonia, but leaves a very alcaline ash. Its constituents according to Braconnot are

* Bouillon La Grange, Ann. de Chim. liv. 92.
† Ann. de Chim. lxxix. 291.

Book IV.

Water.	Phosphate of potash.
Fungin	Fungate of potash.
Gelatin.	Adipocire.
Sugar of mushrooms.	A brown oil.
Vegetable albumen.	A colouring matter.
Acetate of potash.	Muriate of potash.*

Merulius cantharel-lus.

15. *Merulius* or *agaricus cantharellus.*—This substance has a yellow colour and an agreeable odour. When taken into the mouth its taste is at first acrid; but soon becomes exceedingly agreeable. It is very much used as an article of food. According to the analysis of Braconnot its constituents are

Water.
Fungin.
Gelatin.
A considerable proportion of sugar of mushrooms.
Acetate of potash.
Phosphate of potash.
Fungate of potash.
Oil.
Adipocire.
An acrid matter destroyed by heat.
An uncombined acid similar to the acetic.†

Phallus im-pudicus.

16. *Phallus impudicus.*—This fungus, well known in consequence of the intolerable odour which it exhales, was found by Braconnot to contain the following constituents:

Water.
Fungin, much animalized.
Albumen.
Animal matter.
Mucus.
Superacetate of potash.
A little superacetate of ammonia.
Adipocire.
An oily matter.
Sugar of mushrooms.
A little phosphate of potash.
A combustible acid united to potash.‡

* Ann. de Chim. lxxix. 297.   † Ibid. p. 300.   ‡ Ibid. lxxx. 291.

17. *Peziza nigra* or *lycoperdon truncatum.*—This fungus
is common upon the bark of oaks soon after they have
been cut down. Its surface has a black colour, while the
fleshy part is gelatinous, semitransparent, and elastic. Four
hundred parts of it analysed by Braconnot yielded the
following constituents:

Water..........................	376·0
Cerasin........................	18·4
Gum...........................	3·6
Fungic acid chiefly free.............	8·0
Sugar of mushrooms..............	0·4
Matter soluble in alcohol very little animalized	0·4
Fatty matter, rendered purple by potash......	4
Potash and lime	Trace
	———
	407·2*

18. *Lycoperdon tuber,* or *tuber cibarium; truffles.*—This Truffles.
is a globular fungus found four or five inches under ground,
in woody places, and is considered as one of the best of
the eatable mushrooms. Bouillon La Grange has subjected
it to a chemical analysis.† It was attempted nearly in the
manner formerly described for ascertaining the constituents
of the different species of corn.

It was grated down small, and then washed with water
upon a searce, till the liquid ceased to carry off any thing.
A blackish fibrous matter remained upon the searce. The
liquid let fall a brown coloured matter when left at rest.
The liquid produced no effect upon vegetable blues. The
brown deposite does not resemble starch in its properties.
Water produces but little effect upon truffles. Warm
water, however, dissolves a portion, which possesses the
characters of albumen.

When the plant was treated with nitric acid, a solution
was accomplished; nitrous gas, carbonic acid, and azotic
gas were disengaged; and the solution, by distillation,
yielded a liquor containing prussic acid. The residual
liquid yielded bitter principle, an oily matter, and small
crystals, which Bouillon La Grange considered as a com-

* Ann. de Chim. lxxxvii. 253.   † Ibid. xlvi. 197.

bination of oxalic acid and bitter principle.   He suspected also the presence of malic acid.

Alcohol dissolves a small portion of brownish bitter matter, which acquires the properties of resin by exposure to the atmosphere.

When truffles are left in the state of a paste with water, they acquire the smell of cheese.   When mixed with sugar and water they undergo fermentation, carbonic acid is disengaged, and alcohol formed.

When distilled, truffles yield an acid liquid, a black oil, carbonate of ammonia, carbonic acid, and carbureted hydrogen.   The charcoal contains magnesia, phosphate of lime, iron, and silica.*

Several experiments have been likewise made upon this plant by Robert and Antoine, which confirm those of Bouillon La Grange.

Mucor septicus.

19. *Reticularia portensis*, or *mucor septicus.*—This singular vegetable substance appears upon the leaves of ivy and beech, but it is most common upon tan in hot houses.   It has no certain size or figure, but has a fine yellow colour and at first resembles cream beat up to froth.   In 24 hours it acquires a thin filmy coat, becomes dry and full of a sooty powder adhering to downy threads.   According to the analysis of Braconnot its constituents are,

Fungin,very much divided.
A notable quantity of carbonate of lime.
Albumen.
An animal matter.
A yellow fatty matter.
Acetate of potash.†

Tremella nostoc.

20. *Tremella nostoc.*—I place this singular vegetable substance here on account of its resemblance to the preceding species.   It has more similarity to an animal than a vegetable body.   Some naturalists indeed are of opinion that it is the spawn of the frog or of some similar animal. Braconnot subjected it to analysis and extracted from 200 parts of it the following ingredients :

* Bouillon La Grange, Ann. de Chim. xlvi. 197.
† Ann. de Chim. lxxx. 283.

Water.......................... 185·0
Cerasin........................ 13·8
Mucus, having a spermatic smell ...... 1·2
Fat .... ⎤
Phosphate of lime .. ⎥
Carbonate of lime .. ⎬ in small quantity.
Muriate of potash .. ⎥
Sulphate of potash .. ⎥
Potash............ ⎦

200·0*

SECT. XIV.

OF FUCI.

FUCI are well known plants that vegetate in the sea, and History. by the combustion of which the impure alkaline body called Kelp is obtained. Great quantities of fuci are burnt for this manufacture on the coasts of Scotland and Ireland. The same substance is made on the coast of Normandy, and is known in France by the name of *varec*. Some of these *fuci* were examined in 1777 by Macquer and Poulletier de la Salle, chiefly in order to determine the different saline substances which they contain, and the result of their experiments was published by Macquer in the second edition of his dictionary.[†] But chemical analysis had at that time made too little progress to enable these gentlemen to determine with accuracy the nature of the different salts which they had to examine and separate. Besides, they did not distinguish between the different species of fuci; but subjected them indiscriminately to the destructive agency of fire.

After the discovery of iodine in kelp the attention of chemists was naturally turned towards the fuci, by means of which kelp is procured. Several of them accordingly were examined in 1814, by Sir H. Davy, who detected traces of iodine in their ashes.[‡] In 1815, an elaborate analysis of six different species of fucus was published by

* Ann. de Chim. lxxxvii. 265. † Under the article *Varec*.
‡ Phil. Trans. 1814, p. 505.

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Book IV. M. Gaultier de Claubry.* During the same year Dr. John, actuated by the same motive, a desire to determine whether iodine could be detected in fuci, made a set of experiments on the fucus vesiculosus, which he likewise published.† Vauquelin had previously made some observations on the saccharine matter contained in different fuci, and had shown that it possessed the characters of manna, and this was fully confirmed by the subsequent experiments of M. Gaultier de Claubry. I shall in this Section give the constituents of the different species of fucus hitherto subjected to analysis.

Fucus saccharinus, 1. *Fucus saccharinus.*—This which is very common on our coasts consists of a single linear eliptic leaf, without any midrib. It has a tawny-green colour, and when full grown is about 5 feet long and 3 inches wide. But it varies prodigiously in size. Gaultier de Claubry analysed this fucus by treating it first with water, then with alcohol. He examined it also by means of sulphuric acid, nitric acid, and potash. Finally he subjected it to combustion and analysed the ashes which remained behind. The constitution of it was found very complicated, as no fewer than 21 ingredients were extracted from it. The following were the substances:

A saccharine matter. Manna.

Mucilage in considerable quantity.

Vegetable albumen.

Green colouring matter.

Oxalate of potash.

Malate of potash.

Sulphate of potash.

Sulphate of soda.

Sulphate of magnesia.

Muriate of potash.

Muriate of soda.

Muriate of magnesia.

Hyposulphite of soda.‡

Carbonate of potash.

Carbonate of soda.

Hydriodate of potash.

Silica.

Subphosphate of lime.

Subphosphate of magnesia.

Oxide of iron probably united with phosphoric acid.

Oxalate of lime.§

Digitatus, 2. *Fucus digitatus.*—This fucus is olive-coloured: it con-

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* Ann. de Chim. xciii. 75 and 113. † Schweigger's Jour. xiii. 464.

‡ I am not acquainted with this salt, nor do I know any method by which it could be formed. Probably the salt obtained by M. Gaultier de Claubry was sulphite of soda.

§ Ann. de Chim. xciii. 83.

sists of a cylindrical stem sometimes as thick as a walking stick and about two feet long. The summit of the stalk suddenly dilates into a plain broad leaf, sometimes about a foot in breadth and a foot and a half in length, and divided almost to the base into sword-shaped, ribless segments, from four to about twelve in number. It is much employed in Scotland as a manure for the land. It was subjected to analysis by Gaultier de Claubry, who found in it the same constituents, as in the preceding species, but in different proportions. The quantity of hydriodate of potash which it contained was much smaller.*

3. *Fucus vesiculosus.*—This very common fucus consists of a dichotomous leaf, the edges of which are entire, and in the disc of which near the edges are immersed a number of air bladders about the size of a hazel nut, the use of which seems to be to cause the leaf to float in the water. From the analysis of Gaultier de Claubry, it appears to contain nearly the same constituents as the preceding species. He did not obtain the mucilaginous matter which the fucus saccharinus yields in such abundance. It contains less malic acid and less iodine than the fucus saccharinus, but its other constituents are the same.† John from 100 parts of this fucus in a dry state obtained the following constituents :

Vesiculo-sus

A brownish-red slimy matter .... ⎫
Flesh-red extract with some sulphate and muriate ⎬ 4
   of soda .... ⎭
A peculiar acid .... —
Resinous fat 2
Sulphate of soda with some common salt .... 3·13
Sulphate of lime with much sulphate of magnesia
   and some phosphate of lime .... 12·87
Trace of oxides of iron and manganese .... —
Membranous matter or albumen of fuci 78
Silica ? ....

———
100·00‡

4. *Fucus serratus.*—This fucus like the preceding is a dichotomous leaf; but its edges are serrated, and it wants

Serratus,

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* Ann. de Chim. xciii. 113.   † Ibid. p. 116.
‡ Schweigger's Jour. xiii. 464.

Book IV. the air bladders which characterize the vesiculosus. When analysed by Gaultier de Claubry, it yielded abundance of mucilage and albumen. Alcohol separated from it a bitter substance of a brownish-red colour; likewise a green matter which precipitated when the alcohol was cooling, and which had a bitter and disagreeable taste. The salts are the same as in the preceding species; but it contains more iodine than fucus digitatus or vesiculosus; it contains likewise a greater quantity of carbonate of soda.*

Siliquosus,   5. *Fucus siliquosus.*—This fucus consists of a waved coriaceous stalk, about four feet long, greatly branched, dark-olive when fresh but quite black when dry. The fructifications have the appearance of little flat pods. When examined by Gaultier de Claubry he obtained abundance of albumen, mucilage having a brownish-red colour, a very bitter substance soluble in alcohol, a substance of a greenish-brown colour, soluble in hot but insoluble in cold alcohol; the same salts as in the preceding species; but very little iodine. When dried it becomes covered with a notable quantity of manna sugar.†

Filum.   6. *Fucus filum.*—This consists of a cylindrical thread from the size of a fiddle string to that of a whip cord, and often twelve feet long. Its colour is olive-green. When dry it becomes nearly black; but by exposure to the air it acquires a yellowish or nearly white colour. When examined by Gaultier de Claubry, he found in it scarcely any sensible quantity of albumen, a good deal of mucilage, a very little green matter soluble in hot alcohol, and precipitating as the liquid cools: The same salts as in the preceding species; but very little iodine.‡

SECT. XV.

OF THE DISEASES OF PLANTS.

Having now given such an account of the parts of plants as the present imperfect state of the vegetable chemistry permitted, it remains for us to point out the new substances

* Ann. de Chim. xciii. 119.   † Ibid. p. 121.   ‡ Ibid. p. 123.

generated in plants by disease, and to describe the proper-
ties of these substances. But though the diseases of plants
are numerous and well marked, and though the effects
which they produce on those vegetables which are employed
as articles of food are often severely felt, yet little progress
has been made, either in ascertaining the nature of these
diseases, or the method of preventing or removing them.
The following are the only observations, strictly chemical,
which can be at present offered:

1. Old trees are frequently affected with a kind of ulcer, Ulcers.
the chief seat of which is under the bark. There the juices
undergo a change, and acquire a certain acridity, which
enables them to corrode and destroy the solid parts of the
plant. We are indebted to Vauquelin for an examination
of the sanies or morbid liquid which flows from the ulcer
in these cases. He collected the matter which he examined
from the elm, which is particularly subject to this disease.*

This liquor is sometimes nearly transparent like water,
and having an acrid and saline taste; sometimes it is slightly
coloured, sometimes blackish or brown. It deposits upon
the sides of the ulcer a soft matter, which is insoluble in
water. The bark over which the transparent sanies passes
becomes white like chalk, acquires an alkaline taste, and
effervesces powerfully with acids. It becomes friable, loses
its fibrous texture, and exhibits the appearance of crystals.
By means of a glass small rhomboids and four-sided prisms
can be distinguished in it. When the liquid is dark-
coloured, the bark assumes a black appearance, and looks
as if covered with a coat of varnish. This black matter is
sometimes in such quantity that it assumes the appearance
of stalactites. It is soluble in water, has an alkaline taste,
effervesces with acids.

The white matter which was deposited on the bark of
the elm round the ulcer, was found composed of

> Vegetable matter .... 60·5
> Carbonate of potash .... 34·2
> Carbonate of lime...... 5·0
> Carbonate of magnesia .. 0·3
> _____
> 100·0

* Ann. de Chim. xxi. 39.

The black shining matter consisted of carbonate of potash, and a peculiar substance which was obviously ulmin.

The destructive tendency of such ulcers in trees is suffi-ciently obvious. Vauquelin has shown, that to produce the quantity of white matter which surrounded the ulcer of the elm, and on which he made his experiments, 500 lbs. weight of the wood of the tree must have been destroyed.*

Blight in wheat, 2. The blight is a disease which attacks the different spe-cies of corn, especially wheat, and in some seasons nearly destroys the crop. It begins first upon the leaves and stem, and at last, attacking the seed, destroys a consider-able part, or even the whole of it, leaving a black matter in its place. Botanists have shown, that this black matter is a species of small fungus, which draws its nourishment from the wheat.† The wheat thus loaded with the black fungus has been lately examined by Fourcroy and Vau-quelin, in order to ascertain how far the experiments of former chemists were precise. The result of their exami-nation has been published in the sixth volume of the An-nales de Museum d'Histoire Naturelle.‡

When the wheat was macerated with alcohol, it gave out a portion of acrid oil, of the consistence of butter, of a deep green colour. Water in which it was steeped acquired acidity, and when saturated with potash let fall an animal matter, mixed with phosphate of ammonia-and-magnesia, and held phosphate of potash in solution: of course, the acid which it contained was the phosphoric. It still re-tained in solution a matter similar to gluten of wheat al-lowed to run into putrifaction. The residue, distilled, yielded water, holding in solution acetic acid and acetate of ammonia, a brown oil, and a quantity of charcoal, amounting to nearly $\frac{1}{4}$th of the original weight. The re-sult of the experiments was, that blighted wheat contained an acrid oil, putrid gluten, charcoal, phosphoric acid, phos-phate of magnesia and ammonia, and phosphate of lime; but no traces of starch could be detected.

In barley. 3. Barley is subject to a similar disease with wheat, and, doubtless, from the same cause. Einhof has subjected

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* Ann. de Chim. xxi. 39.
† See an account of this fungus, with figures of it, and ingenious con-jectures respecting its propagation, by Sir Joseph Banks. Nicholson's Jour. x. 225.   ‡ No. xxxv. p. 332.

this grain, damaged by the rubigo, or blight, to a chemical examination. The result of his trials coincides pretty nearly with the experiments of Fourcroy and Vauquelin on blighted wheat. He could detect no starch in it. The infusion of it in water reddened vegetable blues, and contained an acid, which appeared to be the phosphoric. There was present a peculiar animal matter, differing in its properties from any of the principles of barley, and a quantity of charcoal.*

CHAP. III.

OF VEGETATION.

WE have now seen the different substances which are contained in plants, and of which they are composed; but we have still to examine the manner in which these substances are produced, and to endeavour to trace the different processes which constitute vegetation. But I must warn the reader not to expect complete information in this chapter. The wonders of the vegetable kingdom are still but very imperfectly explored; many of the organs of plants are too minute for our senses; and scarcely a single process can be completely traced.

The multiplicity of operations continually going on in vegetables at the same time, and the variety of different, and even opposite substances, formed out of the same ingredients, and almost at the same place, astonish and confound us. The order, too, and the skill with which every thing is conducted, are no less surprising. No two operations clash; there is no discord, no irregularity, no disturbance; every object is gained, and every thing is ready for its intended purpose. This is too wonderful to escape our observation, and of too much importance not to claim our attention. Many philosophers, accordingly, distinguished equally by their industry and sagacity, have dedicated a great part of their lives to the study of *vegetation*. But hitherto their success has not been equal to their exertions. No person has been able to detect this *Agent*, always so

* Gehlen's Jour. vi. 91.

Book IV. busy, and performing such wonders, or to discover him at his work; nor have philosophers been much more fortunate in their attempts to ascertain the instruments which he employs in his operations. A great variety, however, of curious and interesting facts have been discovered. These I shall attempt in the following sections to collect and arrange, to point out their dependence on each other, and perhaps to deduce such consequences as obviously result from this mutual dependence.

SECT. I.

OF GERMINATION.

Plants produced from seeds. 1. NATURAL historians have proved, by a very complete induction of facts, that all plants arise from seeds. The pretended exceptions have disappeared, one after another, as our knowledge of vegetables increased: and now there remains scarcely a single objection entitled to the smallest regard. The late attempt of Girtanner* to revive the doctrine of equivocal generation, deserves no attention whatever; because his conclusions are absolutely incompatible with the experiments of Mr. Sennebier upon the very substance on which his theory is founded.

Seeds composed of three parts; A seed consists of three parts; namely, the *cotyledons*, the *radicle*, and the *plumula*, which are usually inclosed in a cover.

viz. Cotyledon, If we take a garden bean, we may perceive each of these three parts with great ease; for this seed is of so large a size, that all its organs are exceedingly distinct. When we strip off the external coats of the bean, which are two, and of different degrees of thickness in different parts, we find that it easily divides into two lobes, pretty nearly of the same size and figure. Each of these lobes is called a *cotyledon* (fig. *a*.) The cotyledons of the bean, then, are two in number.
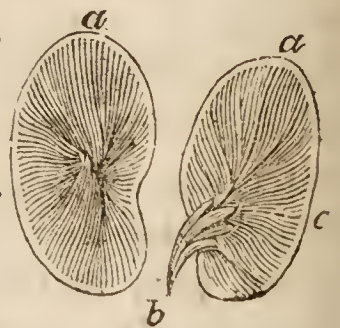
* Ann de Chim. xxxiv. 35.

Near that part of the lobes which is contiguous to what is called the *eye* of the bean, there is a small round white body (*b*), which comes out between the two lobes. This body is called the *radicle*. Chap. III. Radicle,

Attached to the radicle there is another small round body (*c*), which lies between the cotyledons, and wholly within them, so that it cannot be seen till they are separated from each other. This body is called the *plumula*. Plumula.

The appearance and shape of these three parts differ very much in different seeds, but there is no seed which wants them. The figure and size of the seed depend chiefly upon the cotyledons. This is evidently the case with the bean, and it is so with all other seeds. The number of cotyledons is different in different seeds. Some seeds have only one cotyledon, as the seeds of wheat, oats, barley, and the whole tribe of grasses; some have three; others six, as the seeds of the garden cress; but most seeds, like the bean, have two cotyledons.

2. When a seed is placed in a situation favourable to vegetation, it very soon changes its appearance. The radicle is converted into a root, and sinks into the earth, the plumula on the other hand, rises above the earth, and becomes the trunk or stem. When these changes take place, the seed is said to *germinate*: the process itself has been called *germination*. Seeds do not germinate equally and indifferently in all places and seasons. Germination, therefore, is a process which does not depend upon the seed alone: something external must also affect it. Germination

3. It is a well known fact, that seeds will not germinate unless *moisture* have access to them; for seeds, if they are kept perfectly dry, never vegetate at all, and yet their power of vegetating is not destroyed. *Water*, then, is essential to germination. Too much water, however, is no less prejudicial to most seeds than none at all. The seeds of water plants, indeed, germinate and vegetate extremely well in water; but most other seeds, if they are kept in water beyond a certain time, are rotted and destroyed altogether. Requires moisture,

4. It is well known also, that seeds will not germinate, even though supplied with water, provided the temperature be below a certain degree. No seed, for instance, on which the experiment has been tried, can be made to vegetate at Heat,

Book IV. or below the freezing point : yet this degree of cold does not injure the vegetating power of seeds; for many seeds will vegetate as well as ever after having been frozen, or after having been kept in frozen water. We may conclude, then, that a certain degree of heat is necessary for the germination of seeds : and every species of plant seems to have a degree peculiar to itself, at which its seeds begin to germinate ; for every seed has a peculiar season at which it begins to germinate, and this season varies with the temperature of the air. Mr. Adanson found that seeds, when sown at the same time in France and in Senegal, always appeared sooner above ground in the latter country, where the climate is hotter than in France.*

And oxygen gas.   5. Seeds, although supplied with moisture and placed in a proper temperature, will not germinate, provided atmospherical air be completely excluded from them. Mr. Ray found that grains of lettuce did not germinate in the vacuum of an air-pump, but they began to grow as soon as air was admitted to them.† Homberg made a number of experiments on the same subject, which were published in the Memoirs of the French Academy for the year 1693. He found, that the greater number of seeds which he tried refused to vegetate in the vacuum of an air-pump. Some, however, did germinate : but Boyle, Muschenbroek, and Boerhaave, who made experiments on the same subject in succession, proved beyond a doubt that no plant vegetates in the vacuum of an air-pump; and that in those cases in which Homberg's seeds germinated, the vacuum was far from perfect, a quantity of air still remaining in the receiver. It follows, therefore, that no seed will germinate unless atmospherical air, or some air having the same properties, have access to it. It is for this reason that seeds will not germinate at a certain depth below the surface of the earth. Mr. Scheele found that beans would not germinate except oxygen gas were present : Mr. Achard afterwards proved, that oxygen gas is absolutely necessary for the germination of all seeds, and that no seed will germinate in azotic gas, or hydrogen gas, or carbonic acid gas, unless these gases contain a mixture of oxygen gas. These experiments have been confirmed by Mr. Gough, Mr. Cruick-

* Encyc. Method. Physiol. Veget. 124.   † Phil. Trans. No. liii.

shank, and many other philosophers.* It follows, there-
fore, that it is not the whole atmospheric air, but merely
the oxygen gas which it contains, that is necessary for the
germination of seeds.

Nay, Mr. Humboldt has ascertained that seeds vegetate
more rapidly when steeped in chlorine, or when watered
with it; and this substance is well known for the facility
with which it decomposes water and sets at liberty oxygen.
It seems even to augment the vegetative power of seeds.
At Vienna several seeds which had been long kept, and
which had constantly refused to germinate, grew readily
when treated with it.†

6. Light also has considerable influence on the germina-
tion of seeds. Ingenhousz found that seeds always germi-
nate faster in the dark than when exposed to the light.‡
His experiments were repeated by Mr. Sennebier with
equal success. § But the Abbé Bertholin, who distinguished
himself so much by his labours to demonstrate the effect of
electricity on vegetation, objected to the conclusions of
these philosophers, and affirmed that the difference in the
germination of seeds in the shade and in the light was
owing, not to the light itself, but to the difference in the
moisture in the two situations; the moisture evaporating
much faster from the seeds in the light than from those in
the shade; and he affirmed, that when precautions were
taken to keep the seeds equally moist, those in the sun
germinated sooner than those in the shade.‖ But when
Mr. Sennebier repeated his former experiments, and em-
ployed every possible precaution to ensure equality of
moisture in both situations, he constantly found the seeds
in the shade germinate sooner than those in the light.**
We may conclude, therefore, that light is injurious to ger-
mination; and hence one reason for covering seeds with

Impeded by light.

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* Carradori, indeed, has lately attempted to show that seeds will
begin to germinate without oxygen. (Ann. de Chim. xlviii. 188.) But
we learn from the experiments of Saussure, that the water in which the
seeds in these cases are steeped, contains in solution as much oxygen as
is sufficient to enable the seeds just to commence germination, but not to
make any progress (Recherches Chimiques sur la Vegetation, p. 3.)

† Jour. de Phys. xlvii. 63.   ‡ Experiences sur les Vegetaux, ii.
§ Mem. Physico-Chimiques, iii. 41.
‖ Jour. de Phys. 1789, December.
** Encyc. Meth. Physiol. Veget. 126.

the soil in which they are to grow. But from the recent experiments of Saussure, there is reason to believe that light is only injurious in consequence of the heat which it produces; for when the direct rays of the sun were intercepted, though light was admitted, the germination of the seeds was not sensibly retarded.*

7. Thus we have seen that seeds will not germinate unless *moisture, heat,* and *oxygen* be present. Now, in what manner do these substances affect the seed? What are the changes which they produce?

Phenomena of germination.

It was observed before, that all seeds have one or more cotyledons. These cotyledons contain a quantity of farinaceous matter, laid up on purpose to supply the embryo plant with food as soon as it begins to require it. This food, however, must undergo some previous preparation, before it can be applied by the plant to the formation or completion of its organs. It is probable that all the phenomena of germination, which we can perceive, consist in the chemical changes which are produced in that food, and the consequent developement of the organs of the plant.

Carbonic acid emitted.

When a seed is placed in favourable circumstances, it gradually imbibes moisture, and very soon after emits a quantity of carbonic acid gas, even though no oxygen gas be present.† If no oxygen gas be present, the process stops here, and no germination takes place; but if oxygen gas be present, a portion of it is converted into carbonic acid gas. From the experiments of Saussure, it appears, that if seeds be left to germinate in a determinate portion of oxygen gas or common air, the bulk of that gas is not altered; the carbonic acid formed being equal to the oxygen which has disappeared. Hence it follows, that the carbonic acid contains in it exactly the whole oxygen consumed.‡   No

Oxygen of the air diminished.

oxygen, then, is absorbed by the seed; or at least, if it be absorbed, none of it is retained, the whole being thrown out in combination with carbon. The quantity of oxygen thus changed into carbonic acid by the germination of seeds, is in some measure proportional to the weight of the seed; but some seeds require more than others. In the

* Recherches Chimiques sur la Vegetation, p. 23.
† Gough, Manch. Mem. iv. 315.   Cruikshank, Rollo on Diabetes, p. 452.   ‡ Jour. de Phys. xlix. 92.

experiments of Saussure, wheat and barley, weight for weight, consumed less oxygen than peas; while peas consumed less than beans and kidney-beans. The oxygen consumed by wheat and barley amounts to between $\frac{1}{1000}$th and $\frac{1}{2000}$th of their weight; while that consumed by beans, and kidney-beans, may amount to $\frac{1}{100}$th part of their weight.* Similar experiments were made by Dr. Woodhouse.†

It does not appear that any water is decomposed during the process of germination, at least we have no evidence that it is so. Neither hydrogen nor oxygen gas are emitted. It would not be surprising if a portion of water, so far from being decomposed, were actually formed by the union of its constituents previously existing in the grain. When Saussure dried seeds at a certain temperature before germination, and afterwards brought them to the same degree of dryness after germination, he always found that the loss of weight was greater than it ought to have been. Thus 73 peas, which together (when dried at 77°) weighed 200 grains, when left with five times their weight of water in a vessel full of air, and standing over mercury for two days, germinated, and produced $4\frac{1}{2}$ cubic inches of carbonic acid. They were taken out, and dried slowly at the same temperature; during their drying they changed $4\frac{1}{2}$ cubic inches more of oxygen into carbonic acid. Now these nine inches of carbonic acid contain 1·7 grains of carbon. The water in which peas had been placed while germinating, when evaporated to dryness, left 0·75 grains of mucilaginous matter. Thus the peas, by germinating and drying, ought to have lost only 2·45 grains, leaving a residue of 197·55 grains. But their weight was only 189 grains. So that they had lost eight grains more than can be accounted for by the mucilage taken up by the water and carbonic acid formed. We are obliged to suppose this loss owing to water. From Saussure's experiments, this water seems to be formed or set at liberty during the drying of the seeds, for the quantity

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* Recherches, p. 13.

† He tried the seeds of the zea mays, apium petroselinum, lactuca sativa, cucurbita citrulla, phaseolus sativus, sisymbrium sativum, raphanus sativa. They changed oxygen into carbonic acid. Nicholson's Jour. ii. 161.

of it always increased with the slowness of the process of drying.*

Food prepared in the cotyledons,

Several seeds, by germinating, acquire a sweetish taste. Hence it has been supposed, that the mucilage which they contain is converted into saccharine matter. We see that the carbon is diminished by germination; and unless water be formed, the proportion of hydrogen and oxygen must be proportionably augmented. It is obvious from the process of malting, that heat is generated during germination. I have seen the radicles of barley, when kept without turning on the malt-floor, shoot out half an inch in a single night, and the heat rise as high as 100°.

So far seems to be the work of chemistry alone; at least we have no right to conclude that any other agent interferes; since hay, when it happens to imbibe moisture, exhibits nearly the same processes. Carbonic acid gas is evolved, oxygen gas is absorbed, heat is produced so abundantly, that the hay often takes fire: at the same time a quantity of sugar is formed. It is owing to a partial change of the same kind that old hay generally tastes much sweeter than new hay. Now we have no reason to suppose that any agents peculiar to the vegetable kingdom reside in hay; as all vegetation, and all power of vegetating, are evidently destroyed.

And sent into the radicle.

But when the farina in the seeds of vegetables is converted into sugar, a number of vessels make their appearance in the cotyledon. The reader will have a pretty distict notion of their distribution by inspecting the figure. These vessels may indeed be detected in many seeds before germination commences, but they become much more distinct after it has made some progress. Branches from them have been demonstrated by Grew, Malpighi, and Hedwig, passing into the radicle, and distributed through every part of it. These evidently carry the nourishment prepared in the cotyledons to the radicle; for if the cotyledons be cut off, even after the processes above described are completed, germination, as Bonnet
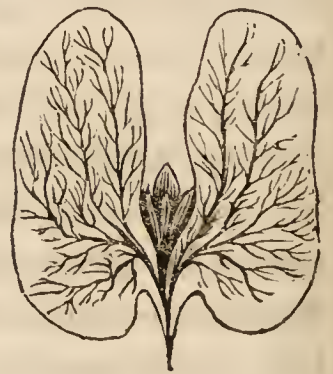
* Saussure, Recherches Chimiques sur la Vegetation, p. 17.

and Sennebier ascertained by experiment, immediately
stops. The food therefore is conveyed from the cotyledons
into the radicle; the radicle increases in size, assumes the Which be-
comes a
form of a *root*, sinks down into the earth, and soon be- root.
comes capable of extracting the nourishment necessary for
the future growth of the plant. Even at this period, after
the radicle has become a perfect root, the plant, as Senne-
bier ascertained by experiment, ceases to vegetate if the
cotyledons be cut off. They are still, then, absolutely ne-
cessary for the vegetation of the plant.

The cotyledons now assume the appearance of leaves, Seminal
leaves.
and appear above the ground, forming what are called the
seminal leaves of the plant. After this the *plumula* gra-
dually increases in size, rises out of the earth, and expands
itself into branches and leaves. The seminal leaves, soon
after this, decay and drop off, and the plant carries on all
the processes of vegetation without their assistance.

As it does not appear that there is any communication
between the cotyledons and the plumula, it must follow that
the nourishment passes into the plumula from the radicle;
and accordingly we see that the plumula does not begin to
vegetate till the radicle has made some progress. Since the
plant ceases to vegetate, even after the radicle has been
converted into a root, if the cotyledons be removed before
the plumula is developed, it follows that the radicle is in-
sufficient of itself to carry on the processes of vegetation,
and that the cotyledons still continue to perform a part.
Now we have seen already what that part is; they prepare Digest the
food sent by
food for the nourishment of the plant. The root, then, is the root.
of itself insufficient for this purpose. When the cotyle-
dons assume the form of seminal leaves, it is evident that
the nourishment which was originally laid up in them for
the support of the embryo plant is exhausted, yet they still
continue as necessary as ever. They must therefore re-
ceive the nourishment which is imbibed by the root; they
must produce some changes on it, render it suitable for the
purposes of vegetation, and then send it back again to be
transmitted to the plumula.

After the plumula has acquired a certain size, which
must be at least a *line*, if the cotyledons be cut off, the
plant, as Mr. Bonnet ascertained by a number of experi-
ments, afterwards repeated with equal success by Mr. Sen-

nebier, does not cease to vegetate, but it continues always a mere pigmy : its size, when compared with that of a plant whose cotyledons are allowed to remain, being only as two to seven.*

When the plumula has expanded completely into leaves, the cotyledons may be removed without injuring the plant, and they very soon decay of themselves. It appears, then, that this new office of the cotyledons is afterwards performed by that part of the plant which is above ground.

Thus we have traced the phenomena of germination as far as they have been detected. The facts are obvious; but the *manner* in which they are produced is a profound secret. We can neither explain how the food enters into the vessels, how it is conveyed to the different parts of the plant, how it is deposited in every organ, nor how it is employed to increase the size of the old parts, or to form new parts. These phenomena are analogous to nothing in mechanics or chemistry, but resemble exactly the organization and nourishment of animals. They belong therefore to that difficult branch of science known by the name of Physiology.

SECT. II.

OF THE FOOD OF PLANTS.

PLANTS, after they have germinated, do not remain stationary, but are continually increasing in size. A tree, for instance, every season adds considerably to its former bulk. The root sends forth new shoots, and the old ones become larger and thicker. The same increment takes place in the branches and the trunk. When we examine this increase more minutely, we find that a new layer of wood, or rather of alburnum,† has been added to the tree

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* Encyc. Method. Physiol. Veget. 42.

† The *wood*, when we inspect it with attention, is not, through its whole extent, the same; the part of it next the bark is much softer and whiter, and more juicy than the rest, and has for that reason obtained a particular name ; it has been called the *alburnum* or *aubier*. The *perfect wood* is browner, and harder, and denser than the alburnum, and the layers increase in density the nearer they are to the centre.

in every part, and this addition has been made just under
the bark. We find, too, that a layer of alburnum has
assumed the appearance of perfect wood. Besides this ad-
dition of vegetable fibre, a great number of leaves have
been produced, and the tree puts forth flowers, and forms
seeds.

It is evident from all this, that a great deal of new matter Plants re-
is continually making its appearance in plants. Hence, quire food.
since it would be absurd to suppose that they *create* new
matter, it must follow that they receive it by some channel
or other. Plants, then, require food as well as animals.
Now, what is this food, and whence do they derive it?
These questions can only be answered by an attentive sur-
vey of the substances which are contained in vegetables,
and an examination of those substances which are necessary
for their vegetation. If we could succeed completely, it
would throw a great deal of light upon the nature of soils
and of manures, and on some of the most important
questions in agriculture. But we are far indeed at present
from being able to examine the subject to the bottom.

1. In the first place, it is certain that plants will not ve- Water ne-
getate without water; for whenever they are deprived of cessary.
it, they wither and die. Hence the well-known use of
rains and dews, and the artificial watering of ground.
Water, then, is at least an essential part of the food of
plants. But many plants grow in pure water; and there-
fore it may be questioned whether water is not the only
food of plants. This opinion was adopted very long ago,
and numerous experiments have been made in order to de-
monstrate it. Indeed it was the general opinion of the
17th century; and some of the most successful improvers
of the physiology of plants, in the 18th century, have em-
braced it. The most zealous advocates for it were, Van
Helmont, Boyle, Bonnet, Duhamel, and Tillet.

Van Helmont planted a willow, which weighed five Supposed
pounds, in an earthen vessel filled with 200 lbs of soil pre- the sole
viously dried in an oven, and moistened with rain water. food of
This vessel he sunk into the earth, and he watered his plants;
willow, sometimes with rain, and sometimes with distilled
water. After five years it weighed $169\frac{1}{4}$ lbs, and the earth
in which it was planted, when again dried, was found to

Book IV. have lost only two ounces of its original weight.* Here, it has been said, was an increase of 164 lbs. and yet the only food of the willow was pure water; therefore it follows that pure water is sufficient to afford nourishment to plants. The insufficiency of this experiment to decide the question was first pointed out by Bergman in 1773.† He showed, from the experiments of Margraff, that the rain water employed by Van Helmont contained in it as much earth as could exist in the willow at the end of five years. For, according to the experiments of Margraff, one pound of rain water contains one grain of earth.‡ The growth of the willow, therefore, by no means proves that the earth which plants contain has been formed out of water. Besides, as Mr. Kirwan has remarked, § the earthen vessel must have often absorbed moisture from the surrounding earth, impregnated with whatever substance the earth contained; for unglazed earthen vessels, as Hales ‖ and Tillet **

But without out reason. have shown, readily transmit moisture. Hence it is evident, that no conclusion whatever can be drawn from this experiment; for all the substances which the willow contained, except water, may have been derived from the rain water, the earth in the pot, and the moisture imbibed from the surrounding soil.

The experiments of Duhamel and Tillet are equally inconclusive; so that it is impossible from them to decide the question, Whether water be the sole nourishment of plants or not? But all the attempts hitherto made to raise plants from pure water have failed; the plants vegetating only for a certain time, and never perfecting their seeds. These experiments were made by Hassenfratz, Saussure, and others, with the same unfavourable result. Duhamel found, that an oak, which he had raised by water from an acorn, made less and less progress every year. We see, too, that those bulbous roots, such as hyacinths, tulips, &c. which are made to grow in water, unless they be planted in the earth every other year, refuse at last to flower, and even to vegetate; especially if they produce new bulbous roots

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* Opera Van Helmont, p. 105. Complexionum atque Mistionum Elementalium Figmentum, Sect. 30.

† Opusc. v. 92.   ‡ Ibid. ii. 15 and 19.   § Irish Trans. v. 160.

‖ Veget. Stat. i.   ** Mem. Par. 1772, 29.

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annually, and the old ones decay. From all these facts and experiments, it is reasonable to conclude that water is not the sole food of plants.*

So far, indeed, is water from being the sole food of plants, A certain that in general only a certain proportion of it is serviceable, proportion too much being equally prejudicial to them as too little. only requi- site. Some plants, it is true, grow constantly in water, and will not vegetate in any other situation ; but the rest are entirely destroyed when kept immersed in that fluid beyond a certain time. Most plants require a certain degree of mois- ture in order to vegetate well. This is one reason why different soils are required for different plants. Rice, for instance, requires a very wet soil: were we to sow it in the ground on which wheat grows luxuriously, it would not succeed : and wheat, on the contrary, would rot in the rice ground.

We should, therefore, in choosing a soil proper for the plants which we mean to raise, consider the quantity of moisture which is best adapted for them, and choose our soil accordingly. Now the dryness or moisture of a soil depends upon two things ; the nature and proportions of the earths which compose it, and the quantity of rain which falls upon it. Every soil contains at least three earths, silica, lime, and alumina, and sometimes also magnesia. The silica is always in the state of sand. Now soils retain moisture longer or shorter according to the proportions of these earths. Those which contain the greatest quantity of sand retain it the shortest, and those which contain the greatest quantity of alumina retain it longest. The first is a dry, the second a wet soil. Lime and magnesia are inter- mediate between these two extremes : they render a sandy soil more retentive of moisture, and diminish the wetness of a clayey soil. It is evident, therefore, that by mixing toge- ther proper proportions of these four earths, we may form a soil of any degree of dryness and moisture that we please.

* The experiments of Braconnot, who has endeavoured to prove that water is the sole food of plants, are by no means decisive. See Ann. de Chim. lxi. 187. He raised plants on sand and metallic oxides by means of water, and found that the plants had all the usual vegetable, earthy, and alkaline constituents. But in experiments of that nature it is impos- sible to guard against every channel, by means of which these substances may have access to plants.

But whatever be the nature of the soil, its moisture must depend in general upon the quantity of rain which falls. If no rain at all fall, a soil, however retentive of moisture it be, must remain dry ; and if rain were very frequently falling, the soil must be open indeed, if it be not constantly wet. The proportion of the different earths in a soil, therefore, must depend upon the quantity of rain which falls. In a rainy country, the soil ought to be open ; in a dry country, it ought to be retentive of moisture. In the first, there ought to be a greater proportion of sand ; in the second of clay.

Plants absorb food from the atmosphere ; 2. That air is necessary for the vegetation of plants has been completely proved ; and that a considerable portion at least of the carbonaceous matter which they contain is absorbed from the air, has been rendered probable by the late experiments of chemical philosophers. Three articles which furnish nourishment to plants are supplied by the atmosphere; namely, *carbonic acid, oxygen,* and *moisture ;* but it has been disputed how far plants are capable of absorbing carbonic acid, without the assistance of the soil on which they usually vegetate.

Mr. Hassenfratz analysed the bulbous roots of hyacinths, in order to discover the quantity of water, carbon, and hydrogen, which they contained ; and by repeating the analysis on a number of bulbs, he discovered how much of these ingredients was contained in a given weight of the bulb. He analysed also kidney beans and cress seeds in the same manner. Then he made a number of each of these vegetate in pure water, taking the precaution to weigh them before hand, in order to ascertain the precise quantity of carbon which they contained. The plants being then placed, some within doors, and others in the open air, grew and flowered, but produced no seed. He afterwards dried them, collecting with care all their leaves and every other part which had dropped off during the course of the vegetation. On submitting each plant to a chemical analysis, he found that the quantity of carbon which it contained, was somewhat less than the quantity which existed in the bulb or the seed from which the plant had sprung.[*]

These experiments have been repeated by Saussure with

* Ann. de Chim. xiii. 188.

a very different result. Sprigs of *mentha piperita*, allowed to vegetate for some time in distilled water, nearly doubled the portion of carbon which they originally contained ;* but when the same experiment was repeated in a place where but little light had access, the carbon, instead of being increased, was somewhat diminished, as Hassenfratz had found. Hence it is probable, that the result obtained by Hassenfratz was owing to the want of light. Thus it cannot be doubted, that plants, even when they vegetate in pure water, are capable of absorbing nourishment from the air; but as plants in this situation cannot produce perfect seeds, and as they gradually decay and cease to vegetate, it is obvious that water and air alone are not sufficient.

3. The third, and only remaining source from which plants can draw their food, is the soil on which they grow. Now this soil consists of two parts; namely, *pure earths,* which constitute its basis, and the *remains* of animals and vegetables applied as manure.

One use of the earthy part of the soil is to furnish a support for the plants, and to administer the proper quantity of water to them ; but as all plants contain earthy and saline matters, and as these substances are constantly present, we cannot avoid considering them as in some measure constituting an essential part of plants. Now there is reason to believe that the proportion of earthy and saline matters in plants is considerably influenced by the soil on which they vegetate. Saussure made beans grow in three different situations. The first set was supported by distilled water; the second was planted in sand and supported by rain water; the third set was planted in a pot filled with mould, and placed in a garden. The ashes yielded by these different plants were to each other in the following proportions.†

1. Those fed by distilled water .. 3·9
2. Those fed by rain water ...... 7·5
3. Those growing in soil .... 12·0

Here the quantity of fixed matter yielded by the beans which had vegetated in soil was more than three times greater than what was obtained from those which had been fed solely by distilled water.

* Recherches Chimiques sur la Vegetation, p. 51. † Ibid. p. 281.

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The same philosopher examined the ashes of various plants growing on a granitic and on a calcareous soil.* The plants which grew on the granitic soil contained a considerable proportion of silica and metallic oxides; those which grew in the calcareous, little or none of these bodies, but a greater proportion of calcareous earth than the granitic plants. Thus the pinus abies, the product of each of these soils, yielded the following proportions of fixed bodies :

	Granitic.	Calcar.
Potash	3·60	
Alkaline sulphates and muriates	4·24	15
Carbonate of lime	46·34	63
Carbonate of magnesia	6·76	0
Silica	13·49	0
Alumina	14·86	16
Metallic oxides	10·52	0
	99·82	94†

Thus it cannot be doubted, that the proportion of earthy matter contained in plants is considerably influenced by the nature of the soil on which they grow; but whether plants derive the whole of these fixed principles from the soil, or whether they are capable of forming them to a certain extent by the unknown powers of vegetation, are questions not yet finally decided. The experiments of Saussure would lead us to believe, that all the earths found in plants are absorbed from the soil; while those of Schrader seem to prove, that a portion of them is formed by vegetation, even when plants are so situated that they can derive no fixed principle from the soil on which they grow.

Whether plants generate earth.

The Berlin Academy proposed as a prize question, *To determine the earthy constituents of the different kinds of corn,*

* These soils were composed of the following ingredients :

Granitic.		*Calcareous.*	
Silica	75·25	Carbonate of lime ..	98·000
Alumina	13·25	Alumina...........	0·625
Lime	1·74	Oxide of iron......	0·625
Iron and manganese..	9·00	Petroleum	00·25
	99·24		99·275

† Phil. Mag. viii. 185. Jour. de Phys. lii. 27. See the table of incinerations printed in p. 194 of this vol., where the result of all the experiments of this philosopher is given.

and to ascertain whether these earthy parts are formed by the
process of vegetation. The prize was gained by Schrader, an apothecary in Berlin, and the result of his experiments was published by the Academy in 1800. He analysed the seeds of *wheat, rye, barley,* and *oats,* and ascertained the portion of earth which each contains. He analysed in the same manner rye-straw.* After having in this manner determined the proportion of earth which these seeds contained, he endeavoured to make them grow in some medium which could not furnish any earthy ingredient whatever. For a long time his attempts were baffled, every substance tried containing less or more of earth, and being therefore improper. At last he found that sulphur, in the state of flowers, might be used with success, as it contained no earthy matter whatever, and as the seeds grew in it, and sent out their roots perfectly well, when it was properly moistened with water. The oxides of antimony and zinc were the substances which answered best after sulphur. The seeds, then, were planted in sulphur, placed in a garden at a distance from all dust, put into a box to which the light and the air had free access, but from which all dust and rain were carefully excluded, and they were watered with distilled water. The corn raised in this manner was found by Schrader to contain *more* earthy matter than had existed in the seeds from which it had grown.† Here, then, it would appear was the formation of earthy matter, unless we conceive that the air might have contained a sufficient quantity floating in it to furnish all that was found. Since the publication of his prize dissertation, Schrader has given to the public additional experiments on the same subject. In these he notices the trials of Saussure, and the results which were obtained from vegetables growing in calcareous and granitic soils; and particularly draws the attention of chemists to the fact ascertained by Saussure, that plants vegetating in a calcareous soil, which contained little or no silica, were yet found to yield a considerable portion of that earth.‡ Einhof likewise found in the ashes of a *pinus syl-*

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* The result of these analyses have been given in page 193 of this Volume.

† Braconnot's experiments agree with those of Schrader, but they were not made with the same precautions. See Ann. de Chim. lxi, 187.

‡ Gehlen's Jour. iii. 538.

Book IV. *vestris*, which had grown in a soil that yielded no traces of lime, no less than 65 per cent. of that earth. He informs us also, that he has frequently observed the *lichen prunastri* and *ciliaris* encrusted in the months of August and September with a coat of carbonate of lime, when no lime was to be found in the neighbourhood, and when other plants were not encrusted in that manner.*

Saussure has observed very justly, that the absorption of earthy matter does not depend so much upon the earths which constitute the basis of the soil on which they grow, as upon the portion of earth held in solution in the liquid part of the soil. This observation will explain several of the facts above stated, but is by no means sufficient to set aside the experiments of Schrader, which go directly to prove that earths are formed by the processes of vegetation.

Soil contains salts,

4. Besides earths, plants always contain a portion of saline matter. Those that grow at a distance from the sea contain potash, while sea-plants contain soda and common salt. Phosphate of lime is a constant ingredient, and phosphate of potash a very common one. Some plants contain peculiar salts. Thus nitrate of soda is usually present in barley,

Which act on plants.

nitrate of potash in nettles and the sun-flower, &c. It appears, from the experiments that have been made, that peculiar salts promote the vegetation of peculiar plants. Sea-plants require common salt, and languish in soils where it is not to be found. Borage, nettles, and pellitory, thrive only in soils which contain nitrate of lime or potash; gypsum promotes the vegetation of lucern and clover.†

Salts then are not inactive; and when properly applied, they promote the growth of vegetables. In these cases they appear to be absorbed by the plants which they invigorate. Duhamel found that sea-plants made little progress in soils which contain no common salt. Bullion made seeds of sun-flower to grow in a sandy soil containing no trace of nitre. On examining the plants, no nitrate of potash could be detected in them, but the salt made its appearance as usual when the plants were watered with a weak nitrous solution.

From the experiments of Saussure, we learn that plants absorb saline solutions in very different proportions, and that in general those are absorbed in greatest quantity which

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* Gehlen's Jour. iii. 563.   † Saussure, Recherches, p. 264.

are most injurious to vegetation. He dissolved the follow-
ing substances in water, in such proportions, that each so-
lution contained $\frac{1}{100}$th part of its weight of the substance
dissolved, except the last, which contained $\frac{1}{25}$th part.

1. Muriate of potash.
2. Muriate of soda.
3. Nitrate of lime.
4. Sulphate of soda effloresced.
5. Muriate of ammonia.
6. Acetate of lime.
7. Sulphate of copper.
8. Crystals of sugar.
9. Gum arabic.
10. Extract of soil.

Into each of these solutions he put plants of *polygonum persicaria*, or of *bidens cannabina*, furnished with their roots.

The polygonum grew for five weeks in the solutions of muriate of potash, nitrate of lime, muriate of soda, sulphate of soda, and extract of soil; and the roots increased in them as usual. It languished in the solution of sal-ammoniac, and the roots made no progress. It died in eight or ten days in the solutions of gum and of acetate of lime, and in less than three days in the solution of sulphate of copper.

When such a number of plants of polygonum were put into the solutions as to absorb one half of each in two days, the remaining half was found to have lost very different proportions of the salt which it had originally contained. Suppose the portion of salt originally in solution to be 100, the following table exhibits the quantity of each which had disappeared when one half of the liquid was absorbed:

Muriate of potash ..... 14·7
Muriate of soda 13
Nitrate of lime 4
Sulphate of soda ...... 14·4
Muriate of ammonia 12
Acetate of lime 8
Sulphate of copper 47
Sugar 29
Gum 9
Extract of soil 5

The *bidens* absorbed pretty much the same proportions, but in general did not vegetate so long as the polygonum. In these trials, it was the sulphate of copper and the sugar that were absorbed in greatest abundance, and these were the substances which proved most injurious to the plant. Saussure explains this apparent anomaly by supposing that a portion of the roots were soon destroyed in these liquids, and that then they absorbed the solution indiscriminately.

When various salts were dissolved at once in the same solutions, and plants made to vegetate in them, it was found that different proportions of the salts were absorbed. The following table exhibits the result of these trials, supposing as before, the original weight of each salt to have been 100. Each solution contains $\frac{1}{100}$th part of its weight of each salt.

1	{ Sulphate of soda effloresced ..	11·7
	Muriate of soda	22·0
2	{ Sulphate of soda effloresced ..	12
	Muriate of potash	17
3	{ Acetate of lime	8
	Muriate of potash	33
4	{ Nitrate of lime	4·5
	Muriate of ammonia	16·5
5	{ Acetate of lime	31
	Sulphate of copper	34
6	{ Nitrate of lime	17
	Sulphate of copper	34
7	{ Sulphate of soda	6
	Muriate of soda	10
	Acetate of lime	0
8	{ Gum	26
	Sugar	34

These experiments succeeded nearly equally with other plants, as *the mentha piperita* and the Scotch fir. When the roots were cut or removed, the plants absorbed all solutions indiscriminately. On examining the plants, the salts absorbed were found in them unaltered.

* Saussure, Recherches, p. 247, 261.

Thus it appears that plants do not absorb saline bodies indiscriminately. Saussure supposes that the difference depends rather upon the degree of liquidity which the solution possesses, than upon any discriminating power in the root. But if this were the case, it would be difficult to explain how so much greater a proportion of water should be absorbed than of the salt which it holds in solution.

5. Water, then, carbonic acid, and oxygen, and perhaps also earths and salts, constitute a part of the food of plants; but it is very clear that the whole food is not furnished by these substances. It is well known, that if vegetables be successively raised on the same ground, they at last exhaust it, or render it sterile; and to prevent this, farmers are obliged to supply their grounds annually with a quantity of manure. Without this manure, or some equivalent, plants cannot be made to thrive, or to perfect their seeds. Neither water, air, nor earths, nor salts, will prevent them from perishing. Giobert mixed together the four earths, silica, alumina, lime, and magnesia, in the proper proportions to constitute a fertile soil; and after moistening them with water, planted several vegetables in them : but none of them grew well till he moistened his soil with water from a dunghill. Lampadius planted different vegetables in compartments of his garden, filled each with one of the pure earths, and watered them with the liquor which exuded from a dunghill. They all grew, notwithstanding the diversity of the soil; and each contained the usual earthy constituents of plants, notwithstanding the absence of these constituents from the soil.

It is not the earths which constitute a fertile soil, but the remains of animal and vegetable substances, and the proportion of these capable of being held in solution by water. It appears from the experiments of Mr. Hassenfratz, that substances employed as manures produce effects in times proportioned to their degree of putrifaction; those substances which are most putrid producing the most speedy effects, and of course soonest losing their efficacy. Having manured two pieces of the same kind of soil, the one with a mixture of dung and straw highly putrified, the other with the same mixture newly made, and the straw almost fresh, he observed, that during the first year, the plants which grew on the land manured with the putrified

dung produced a much better crop than the other : but the second year (no new dung being added), the ground which had been manured with the unputrified dung produced the best crop ; the same thing took place the third year; after which, both seemed to be equally exhausted.*   Here it is evident that the putrified dung acted soonest, and was soonest exhausted. It follows from this, that carbon only acts as a manure when in a particular state of combination ; and this state, whatever it may be, is evidently produced by putrifaction. Another experiment of the same chemist renders this truth still more evident. He allowed shavings of wood to remain for about ten months in a moist place till they began to putrify, and then spread them over a piece of ground by way of manure. The first two years this piece of ground produced nothing more than others which had not been manured at all; the third year it was better, the fourth year it was still better, the fifth year it reached its maximum of fertility; after which it declined constantly till the ninth, when it was quite exhausted.† Here the effect of the manure evidently depended upon its progress in putrifaction.

Vegetable
manure ;
. When vegetables are allowed to putrify in the open air, they are converted into a loose black substance, well known under the name of *vegetable mould*. On this mould plants grow with great vigour. It is the substance which renders newly cultivated lands in America, &c. so fertile. When exposed to the air, in the course of cultivation, it is gradually wasted and destroyed, and the lands are thus impoverished. This vegetable mould, therefore, is obviously one of the grand sources of the food of plants. It deserves, therefore, an accurate examination.

Its proper-
ties,
To Saussure and Einhof we are indebted for a chemical examination of its properties and constituents. Saussure employed in his experiments pure vegetable soil, which he procured either from the trunks of trees or from elevated rocks, where it was unmixed with any animal matter ; and by passing it through a searce, he removed from it the remains of undecayed vegetables with which it was mixed.‡ By distilling 200 grains (French) of mould from the oak,

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* Ann. de Chim. xiv. 57.   † Ann. de Chim. xiv. 58.
‡ Recherches sur la Vegetation, p. 162.

he obtained the following products; while the same quantity of undecayed oak yielded him the following proportions of the same constituents:

	Mould.	Oak.
Carbureted hydrogen gas ..	124 inches (French)	116
Carbonic acid	34	29
Water, containing pyrolignate of ammonia .... }	53 grains (French)	80
Empyreumatic oil..........	10	13
Charcoal.................	51	$41\frac{1}{2}$
Ashes...................	8	$0\frac{1}{2}$

Nearly the same results were obtained by making similar experiments on other vegetables, and the mould which they yield when decayed. It appears from them, that the mould contains more charcoal, weight for weight, than the vegetables from which it proceeded. It yields also more ammonia, and therefore contains more azote.

Acids do not act powerfully on mould. Alcohol takes up a portion of extractive and resin. The fixed alkalies dissolve it almost completely, and ammonia is disengaged during the solution. Acids throw down a small portion of a brown combustible powder. Water dissolves a portion of extractive; but the quantity is small, especially from the mould of fertile soils. Ten thousand parts of water, left for five days on the mould of turf, were found to have dissolved only 26 parts of extract; and the same quantity, left on the soil of a field which bore a fine crop of wheat, was found to have dissolved but four parts. It appears from the experiments of Saussure, that a mould which yielded to boiling water, by repeated decoctions, $\frac{1}{11}$th of its weight of extract, did not produce so good an effect upon beans as a mould which contained only half that quantity of soluble matter. But when mould is deprived of its soluble part by boiling water, though its appearance is not altered, yet it does not support plants nearly so well as mould which has not been thus exhausted.[*]

The extract thus obtained from mould by Saussure did not deliquesce when exposed to the air. When distilled it yielded carbonate of ammonia. It produced no change on vegetable blues. When reduced to the consistence of a

* Recherches, p. 170.

Book IV. syrup it had a sweet taste; it precipitated by exposure to the air, and became turbid when mixed with lime-water, carbonate of potash, and most metallic solutions. Alcohol dissolves only a portion of it, and this part is very deliquescent. *

And constituents.
From the experiments of Einhof, it appears that the extract obtained from mould possesses very nearly the properties of the *extractive principle.* The mould which he employed in his experiments was from the soil of a wood, and had been formed by the leaves of the trees and the putrified herbs. It was black, firm, produced no change on vegetable blues, and contained no undecayed plants. †
Water in which this mould was boiled was at first colourless; but by exposure to the air it acquired a brownish tint. The substance which it held in solution possessed exactly the characters of extractive.

Experiments upon vegetable mould have been made also by Braconnot. He found no portion of it soluble in water. His other results resembled those of Saussure. When an alkaline ley was boiled with mould a portion was dissolved. The residue had the exact appearance of pit coal.‡

Acid vegetable mould.
Besides this fertile vegetable mould, Einhof has examined another of a different nature, to which he has given the name of *acid vegetable mould.* It occurs in low-lying meadows and marshes, and the plants which grow upon it in these situations are the different species of *carex, juncus,* and *eriophorum.* It constitutes also the principal part of the mould in high-lying situations, and moors where the soil is covered with heath (*erica vulgaris.*) This mould is distinguished from the preceding by containing a notable portion of phosphoric and acetic acids, which give it the property of reddening vegetable blues. The extractive which it contains is chiefly insoluble in water.§ This sour vegetable mould bears a considerable resemblance to peat, into which indeed it probably passes. Like it, peat contains a portion of phosphoric acid, and probably also of acetic acid, and an extractive readily soluble in alkalies, though but sparingly in water.||

* Recherches, p. 174.   † Gehlen's Jour. vi. 373.
‡ Ann. de Chim. lxi. 191.   § Gehlen, vi. 379.
|| Einhof, Gehlen's Jour. iii. 400.

Einhof has observed, that acid vegetable mould never occurs in those soils which abound in lime, and that it is counteracted and brought to the state of good mould by the Effect of lime on action of lime and marl. It is clear that these manures mould. will neutralize the acids, and thus enable the extractive, and other vegetable substances, to be acted upon by the atmosphere, to yield carbonic acid, and to assume those states which are proper for the nourishment of vegetables. It is probable that they act also directly upon the vegetable matter, and occasion decompositions favourable for vegetation. Hence the efficacy of lime when applied to peat moss, and to sour lands in general.

Upon the whole, then, it appears, that plants are fed chiefly by that portion of vegetable matter which becomes soluble in water, and assumes the properties of extractive; that the quantity of it in soil must neither be too great nor too small; that the insoluble part of vegetable mould gradually assumes this state, either by the action of the atmosphere, or of earths or salts; that the presence of an acid, by counteracting this change, injures the nourishing quality of vegetable mould; and that lime is serviceable, partly by neutralizing the acid, and partly by accelerating decomposition of vegetable mould.

Animal manures probably supply similar materials with Animal vegetable mould. They probably prevent the formation of manures. acids, or neutralize them when formed: and likewise promote the decomposition and solubility of vegetable matter. The striking effects which animal manure produces on the growth of vegetables are well known; though it is not possible at present to point out the way in which they act. Two elaborate and ingenious sets of experiments on this subject have been lately published. The first, by Einhof and Thaer, consists of an examination of the excrements of black cattle; * and the second, by Berzelius, is upon the human excrementitious matter.† These add considerably to our knowledge of animal substances, and shall therefore be noticed in a subsequent part of this Work; but as they throw little light on the use of these matters as manures, it is unnecessary to give a detail in this place of the constituents of which they found them composed.

* Gehlen's Jour. iii. 276.   † Ibid. vi. 509.

Such is the present state of our knowledge respecting the food of plants, as far as it is supplied by the soil in which they vegetate. It is probable that it is imbibed by the extremities of the roots only; for Duhamel observed, that the portion of the soil which is soonest exhausted is precisely that part in which the greatest number of the extremities of roots lies.* This shows us the reason why the roots of plants are continually increasing in length. By this means they are enabled, in some measure, to go in quest of nourishment. The extremities of the roots seem to have a peculiar structure adapted for the imbibing of moisture. If we cut off the extremity of a root, it never increases any more in length : therefore its use as a root has been in a great measure destroyed. But its sides send out fibres which act the part of roots, and imbibe food by their extremity. Nay, in some cases, when the extremity of a root is cut off, the whole decays, and a new one is formed in its place. This, as Dr. Bell informs us, is the case with the hyacinth.†

The extremities of the roots contain no visible opening. Hence we may conclude that the food which they imbibe, whatever it may be, must be in a state of solution; while the absolute necessity of water renders it probable that water is the solvent. And, in fact, the carbonaceous matter in all active manures is in such a state of combination that it is soluble in water. All the salts which we can suppose to make a part of the food of plants are more or less soluble in water. This is the case also with lime, whether it be pure or in the state of a salt; magnesia and alumina may be rendered so by means of carbonic acid gas; and Bergman, Macie, and Klaproth, have shown that even silica may be dissolved in water. We can see, therefore, in general, though we have no precise notions of the very combinations which are immediately imbibed by plants, that all the substances which form essential parts of that food *may* be dissolved in water.

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Food absorbed by the ends of the roots.

It must be in a state of solution.

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* Physique des Arbres, iii. 239.   † Manch. Mem. ii. 412.

SECT. III.

OF THE MOTION OF THE SAP.

SINCE the food of plants is imbibed by their roots in a fluid state, it must exist in plants in a fluid state; and unless it undergoes alterations in its composition just when imbibed, we may expect to find it in the plant unaltered. If there were any method of obtaining this fluid food from plants before it has been altered by them, we might analyse it, and obtain by that means a much more accurate knowledge of the food of plants than we can by any other method. This plan indeed must fail, provided the food undergoes alteration just when it is absorbed by the roots: but if we consider, that when one species of tree is grafted upon another, each bears its own peculiar fruit, and produces its own peculiar substances, we can scarcely avoid thinking that the *great* changes at least which the food undergoes after absorption, are produced, not in the roots, but in other parts of the plant.

If this conclusion be just, the food of plants, after being *Sap of* imbibed by the roots, must go directly to those organs *Plants.* where it is to receive new modifications, and to be rendered fit for being assimilated to the different parts of the plant. There ought therefore to be certain juices continually ascending from the roots of plants; and these juices, if we could get them pure and unmixed with the other juices or fluids which the plant must contain, and which have been secreted and formed from these primary juices, would be, very nearly at least, the food as it was imbibed by the plant. Now, during the vegetation of plants, there actually is a *juice* continually ascending from their roots. This juice has been called the *sap*, the *succus communis*, or the *lymph* of plants.

The sap is most abundant during the spring. At that *Flows out* season, if a cut be made through the bark and part of the *in the* wood of some trees, the sap flows out very profusely. The *spring.* trees are then said to *bleed.* By this contrivance any quantity of sap we think proper may be collected. It is not probable, indeed, that by this method we obtain the ascending sap in all its purity; it is no doubt mixed with the peculiar juices of the plant: but the less progress vegetation has made, the purer we may expect to find it; both be-

Book IV. cause the peculiar juices must be in much smaller quantity, and because its quantity may be supposed to be greater. We should therefore examine the sap as early in the season as possible, and at all events before the leaves have expanded.

Though a number of experiments, as we have seen in the last Chapter, have been made upon the sap, they are not of such a nature as to throw much light upon the food absorbed by plants. Chemistry has not made such progress as to enable even the most expert analysis to separate and distinguish small quantities of the vegetable matter. It is even possible that the food, after it has been imbibed, may be, to a certain extent, modified and altered by the roots. In what manner this is done we cannot say, as we know very little about the vascular structure of the roots. We may conclude, however, that this modification is nearly the same in most plants : for one plant may be engrafted on another, and each continue to produce its own peculiar products; which could not be, unless the proper substances were conveyed to the digestive organs of all. There are several circumstances, however, which render the modifying power of the roots somewhat probable. It is even possible that the roots may, by some means or other, throw out again some part of the food which they have imbibed as excrementitious. This has been suspected by several physiologists; and there are several circumstances which render it probable. It is well known that some plants will not vegetate well after others; and that some again vegetate unusually well when planted in ground where certain plants had been growing. These facts, without doubt, may be accounted for on other principles. If there be any excrementitious matter emitted by the roots, it is much more probable that this happens in the last stage of vegetation; that is to say, when the food, after digestion, is applied to the purposes which the root requires. But the fact ought to be supported by experiments, otherwise it cannot be admitted.

Mixed with true sap in its ascent. Mr. Knight, to whose ingenious and important experiments and observations vegetable physiology lies under so many obligations, has rendered it extremely probable that the sap, as it ascends, is mixed with a quantity of matter, previously deposited in the alburnum for that purpose,

and ready prepared to be assimilated to the different vege- table organs.* According to him, plants, after they have attained their full growth, are employed during the latter part of summer in preparing food for the expanding of the buds and blossoms in the succeeding spring. This food when prepared is deposited in the alburnum. Here it continues during the winter; and in next spring, mixing with the ascending sap, it affords nourishment to the buds and leaves. This ingenious opinion Mr. Knight has supported by experiments and observations, sufficient, I think, to establish its truth. It constitutes a very important step in vegetable physiology, as it enables us to explain many circumstances in a satisfactory manner that appeared formerly altogether anomalous.

He ascertained, by experiments, that the sap increases in density as it ascends towards the leaves. Sap extracted from the sycamore, close to the ground, was of the specific gravity 1·004; while that which flowed out at the height of seven feet was 1·008, and at the height of 12 feet 1·012. The sap of the birch was somewhat lighter, but its comparative increase of density, according to its height, was the same. When extracted near the ground, the sap, both of the sycamore and birch, was nearly tasteless; but it became sensibly sweet at some height, and the sweetness increased with the distance from the ground. Thus it appears, that the quantity of vegetable matter in sap increases as it flows towards the leaves; a direct proof that it imbibes and mixes with something during its passage. That this matter was lodged in the alburnum was rendered probable by comparing with each other the alburnum in winter and in summer. For if nutriment be laid up in the alburnum in winter, and employed in summer for the purposes of vegetation, it is obvious that the alburnum during winter ought to be denser, and ought to yield more extract to water, than the same substance in summer: both of which Mr. Knight found to be the case. Oak poles, of the same age, and growing from the same stool, were felled, partly in December and partly in May. They were placed in the same situation, and dried for seven weeks by a fire. The

* On the State in which the True Sap of Trees is deposited during Winter. Phil. Trans. 1805,

specific gravity of the winter felled wood was 0·679, of the summer 0·609. When the alburnum alone was weighed, the specific gravity of the winter felled was 0·583; of the summer felled 0·533. One thousand grains of each being mixed with six ounces of boiling water, and left to macerate for 24 hours, the winter felled infusion was much deeper coloured than the other. Its specific gravity was 1·002; while that of the summer felled infusion was 1·001. This deposition of nutritious matter explains why the alburnum of trees felled in winter is much more solid and valuable than the alburnum of trees felled in summer.

The sap, as Dr. Hales has shown us, ascends with a very considerable force. It issued during the bleeding season with such impetuosity from the cut end of a vine branch, that it supported a column of mercury 32½ inches high.*

Now, what is the particular channel through which the sap ascends, and what is the cause of the force with which it moves? These are questions which have excited a great deal of the attention of those philosophers who have made the physiology of vegetables their particular study; but the examination of them is attended with so many difficulties that they are very far from being decided.

Sap ascends, It is certain that the sap flows from the roots towards the summit of the tree. For if in the bleeding season a number of openings be made in the tree, the sap begins first to flow from the lowest opening, then from the lowest but one, and so on successively, till at last it makes its appearance at the highest of all; and when Duhamel and Bonnet made plants vegetate in coloured liquors, the colouring matter, which was deposited in the wood, appeared first in the lowest part of the tree, and gradually ascended higher and higher, till at last it reached the top of the tree, and tinged the very leaves.

Through the wood, It seems certain too that the sap ascends through the wood, and not through the bark of the tree: for a plant continues to grow even when stripped of a great part of its bark; which could not happen if the sap ascended through the bark. When an incision, deep enough to penetrate the bark, and even part of the wood, is carried quite round

* Veg. Stat. i. 105.

a branch, provided the wound be covered up from the ex-
ternal air, the branch continues to vegetate as if nothing
had happened; which could not be the case if the sap
ascended between the bark and the wood. It is well known,
too, that in the bleeding season little or no sap can be got
from a tree unless our incision penetrate deeper than the
bark.

These conclusions have been confirmed by the experi-
ments made by Coulomb and Knight. Coulomb observed
that no sap ever flows from the poplar till the tree be cut
nearly to the centre.* Mr. Knight observed that coloured
infusions always pass through the alburnum, and that when-
ever the alburnum is cut through the plant dies.†

As the sap is never found in the parenchyma, it must of In peculiar
necessity be confined in particular vessels; for if it were vessels.
not, it would undoubtedly make its appearance there. Now,
what are the vessels through which the sap ascends?

Grew and Malpighi, the first philosophers who examined
the structure of plants, took it for granted that the woody
fibres were tubes, and that the sap ascended through them.
For this reason they gave these fibres the name of *lymphatic
vessels*. But they were unable, even when assisted by the
best microscopes, to detect any thing in these fibres which
had the appearance of a tube; and succeeding observers
have been equally unsuccessful. The conjecture therefore
of Malpighi and Grew, about the nature and use of these
fibres, remains totally unsupported by any proof. Duha-
mel has even gone far to overturn it altogether: for he
found that those woody fibres are divisible into smaller
fibres, and these again into still smaller; and even, by the
assistance of the best microscopes, he could find no end of
this subdivision.‡ Now, granting these fibres to be vessels,
it is scarcely possible, after this, to suppose that the sap
really moves through tubes, whose diameters are almost
infinitely small. There are, however, vessels in plants
which may easily be distinguished by the help of a small
microscope, and even in many cases by the naked eye.
These were seen, and distinctly described, by Grew and
Malpighi. They consist of a fibre twisted round like a

* Jour. de Phys. xlix. 392.   † Phil. Trans. 1801, p. 336.
‡ Physique des Arbres, i. 57.

corkscrew. If we take a small cylinder of wood, and wrap round it a slender brass wire, so closely that all the rings of the wire touch each other, and if, after this, we pull out the wooden cylinder altogether, the brass wire thus twisted will give us a very good representation of these vessels. If we take hold of the two ends of the brass wire thus twisted, and pull them, we can easily draw out the wire to a considerable length. In the same manner, when we lay hold of the two extremities of these vessels, we can draw them out to a great length. Malpighi and Grew, finding them always empty, concluded that they were intended for the circulation of the air through the plant, and therefore gave them the name of *tracheæ;* which word is used to denote the *windpipe* of animals. These *tracheæ* are not found in the bark; but Hedwig has shown that they are much more numerous in the wood than was supposed; and that they are of very different diameters; and Reichel has demonstrated that they go to the minutest branches, and spread through every leaf. He has shown, too, that they contain sap; and Hedwig has proved that the notion which generally prevailed of their containing nothing but air, arose from this circumstance, that the larger *tracheæ*, which alone were attended to, lose their sap as soon as they are cut; and of course, unless they are inspected the instant they are divided, they appear empty.* Is it not probable, then, from the discoveries of that very ingenious physiologist, that the tracheæ are, in reality, the sap vessels of plants? Indeed it seems established, by the experiments both of Reichel and Hedwig, that almost all the vessels of plants may, if we attend only to their structure, be denominated *tracheæ*. But whether the structure of the sap vessels be similar to that of the tracheæ or not, it has been perfectly ascertained that the sap ascends in vessels, and that these vessels are situated in the wood, chiefly indeed in the alburnum. Hence Mr. Knight has given them the name of *alburnous* vessels.

Its ascension.   But by what powers is the sap made to ascend in these vessels? and not only to ascend, but to move with very considerable force; a force, as Hales has shown, sufficient

* Fundament. Hist. Nat. Muscov. Frondes. Part I. p. 54.

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to overcome the pressure of 43 feet perpendicular of Chap. III. water?*

Grew ascribed this phenomenon to the levity of the sap; Ascribed to which, according to him, entered the plant in the state of its levity; a very light vapour. But this opinion will not bear the slightest examination. Malpighi supposed that the sap was To the con- made to ascend by the contraction and dilatation of the air traction of air; contained in the air vessels. But even were we to grant that the tracheæ are air vessels, the sap, according to this hypothesis, could only ascend when a change of temperature takes place; which is contrary to fact. And even if we were to wave every objection of that kind, the hypothesis would not account for the circulation of the sap, unless the sap vessels be provided with valves. Now the experiments of Hales and Duhamel show that no valves can possibly exist in them: for branches imbibe moisture nearly equally by either end; and consequently the sap moves with equal facility both upwards and downwards, which it could not do were there valves in the vessels. Besides, it is known, from many experiments, that we may convert the roots of a tree into the branches, and the branches into the roots, by covering the branches with earth, and exposing the roots to the air.† Now this would be impossible if the sap vessels were provided with valves. The same remarks overturn the hypothesis of Mr. de la Hire, which is merely that of Malpighi, expressed with greater precision, and with a greater parade of mechanical knowledge. Like Borelli, he placed the ascending power of the sap in the parenchyma. But his very experiments, had he attended to them with care, would have been sufficient to show the imperfection of his theory.

The greater number of philosophers (for it is needless to mention those who, like Perrault, had recourse to fermentation, nor those who introduced the weight of the atmosphere) have ascribed the motion of the sap to *capillary attraction.*

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* Veget. Stat. i. 107.

† Mr. Knight has lately shown that the inverted shoots by no means grow so well as when in their natural position; and has even made it probable that the vessels of the bark are furnished with valves, or with something equivalent. But no evidence has been adduced to induce us to believe that this is the case with the sap vessels.—See his Observations on the Motion of the Sap of Trees. Phil. Trans. 1804.

There exists an attraction between many solid bodies and liquids; in consequence of which, if these solid bodies be formed into small tubes, the liquid enters them, and rises in them to a certain height. But this is perceptible only when the diameter of the tube is very small. Hence the attraction has been denominated *capillary*. We know that there is such an attraction between vegetable fibres and watery liquids; for such liquids will ascend through dead vegetable matter. It is highly probable, therefore, that the food of plants enters the roots, in consequence of the capillary attraction which subsists between the sap vessels and the liquid imbibed. This species of attraction, then, will account perfectly well for the entrance of moisture into the mouths of the sap vessels: but will it account also, as some have supposed, for the ascent of the sap, and for the great force with which it ascends?

The nature and laws of capillary attraction have been very much overlooked by philosophers. But we know enough concerning it to enable us to decide the present question. It consists in a certain attraction between the particles of the liquid and of the tube. It has been demonstrated, that it does not extend, or at least that it produces no sensible effect, at greater distances than $\frac{1}{1000}$th part of an inch. It has been demonstrated, that the water ascends, not by the capillary attraction of the whole tube, but of a slender film of it; and Clairaut has shown that this film is situated at the lowermost extremity of the tube.* This film attracts the liquid with a certain force; and if this force be greater than the cohesion between the particles of the liquid, part enters the tube, and continues to enter, till the quantity above the attracting film of the tube just equals, by its weight, the excess of the capillary attraction between the tube and the liquid above the cohesion of the liquid. The quantity of water, therefore, in the tube is pretty nearly the measure of this excess; for the attracting film is probably very minute.

* The action of all the other films, of which the tube is composed, on the water, as far as it is measured by its effect, is nothing at all. For every particle of water in the tube (except those attracted by the undermost film) is attracted upwards and downwards by the same number of films: it is therefore precisely in the same state as if it were not attracted at all.

It has been demonstrated, that the heights to which li-
quids rise in capillary tubes are inversely at the diameter
of the tube. Consequently the smaller the diameter of the
tube, the greater is the height to which the liquid will rise.
But the particles of water are not infinitely small; there-
fore, whenever the diameter of the tube is diminished be-
yond a certain size, water cannot ascend in it, because its
particles are now larger than the bore of the tube. Con-
sequently the rise of water in capillary tubes must have a
limit: if they exceed a certain length, how small soever
their bore may be, water will either not rise to the top of
them, or it will not enter them at all. We have no method
of ascertaining the precise height to which water would
rise in a capillary tube, whose bore is just large enough to
admit a single particle of water. Therefore we do not
know the limit of the height to which water may be raised
by capillary attraction. But whenever the bore is dimi-
nished beyond a certain size, the quantity of water which
rises in it is too small to be sensible. We can easily as-
certain the height which water cannot exceed in capillary
tubes before this happens; and if any person calculate, he
will find that this height is not nearly equal to the length of
the sap vessels of many plants. But besides all this, we see
in many plants very long sap vessels, of a diameter too
large for a liquid to rise in them a single foot by capillary
attraction, and yet the sap rises in them to very great
heights.

If any person says that the sap vessels of plants gradually
diminish in diameter as they ascend; and that, in conse-
quence of this contrivance, they act precisely as an inde-
finite number of capillary tubes, one standing upon ano-
ther, the inferior serving as a reservoir for the superior—
I answer, that the sap may ascend by that means to a
considerable height: but certainly not in any greater quan-
tity than if the whole sap vessel had been precisely of the
bore of its upper extremity; for the quantity of sap raised
must depend upon the bore of the upper extremity, be-
cause it must all pass through that extremity.

But farther, if the sap moved only in the vessels of plants
by capillary attraction, it would be so far from flowing out
at the extremity of a branch, with a force sufficient to over-
come the pressure of a column of water 43 feet high, that

it could not flow out at all. It would be impossible in that case for any such thing as the bleeding of trees ever to happen.

If we take a capillary tube, of such a bore that a liquid will rise in it six inches, and after the liquid has risen to its greatest height, break it short three inches from the bottom, none of the liquid in the under half flows over. The tube, thus shortened, continues indeed full, but not a single particle of liquid ever escapes from it. And how is it possible for it to escape? The film, at the *upper* extremity of the tube, must certainly have as strong an attraction for the liquid as the film at the *lower* extremity. As part of the liquid is within its attracting distance, and as there is no part of the tube above to counterbalance this attraction, it must of necessity attract the liquid nearest it, and with a force sufficient to counterbalance this attraction of the undermost film, how great soever we may suppose it. Of course no liquid can be forced up, and consequently none can flow out of the tube. Since, then, the sap *flows out* at the upper extremity of the sap vessels of plants, we are absolutely certain that it does not ascend in them merely by its capillary attraction, but that there is some other cause.

It is impossible, therefore, to account for the motion of the sap in plants by any mechanical or chemical principles whatever; and he who ascribes it to these principles has not formed to himself any clear or accurate conception of the subject. We know indeed that heat is an agent; for Dr. Walker found that the ascent of the sap is much promoted by heat, and that after it had begun to flow from several incisions, cold made it give over flowing from the higher orifices while it continued to flow at the lower.* But this cannot be owing to the dilating power of heat; for unless the sap vessels of plants were furnished with valves, dilatation would rather retard than promote the ascent of the sap.

The vessels must contract. We must, therefore, ascribe it to some other cause: the vessels themselves must certainly act. Many philosophers have seen the necessity of this, and have accordingly

* Edin. Trans. i.

ascribed the ascent of the sap to *irritability*. But the first
person who gave a precise view of the manner in which the
vessels probably act was Saussure. He supposes that the
sap enters the open mouths of the vessels at the extremity
of the roots; that these mouths then contract, and by that
contraction propel the sap upwards; that this contraction
gradually follows the sap, pushing it up from the extremity
of the root to the summit of the plant. In the mean time
the mouths are receiving new sap, which in the same man-
ner is pushed upwards.* Whether we suppose the con-
traction to take place precisely in this manner or not, we
can scarcely deny that it must take place; but by what
means it is impossible at present to say. The agents cannot
precisely resemble the muscles of animals; because the
whole tube, however cut or maimed, still retains its contract-
ing power, and because the contraction is performed with
equal readiness in every direction.† It is evident, however,
that they must be the same in kind. Perhaps the particular
structure of the vessels may fit them for their office. Does
ring after ring contract its diameter? The contracting
agents, whatever they are, seem to be excited to act by
some stimulus communicated to them by the sap. This
capacity of being excited to action is known in physiology
by the name of *irritability*; and there are not wanting proofs
that plants are possessed of it. It is well known that dif-
ferent parts of plants move when certain substances act
upon them. Thus the flowers of many open at sunrise,
and close again at night. Linnæus has given us a list of
these plants. Des Fontaines has shown that the stamina
and antheræ of many plants exhibit distinct motions.‡ Dr.
Smith has observed, that the stamina of the barberries are

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* Encycl. Meth. Phys. Veget. p. 267.

† Mr. Knight thinks it probable that the sap is propelled by the con-
traction and expansion of what is called by carpenters the *silver grain* of
the wood, between the lamina of which the vessels run. (Phil. Trans.
1801, p. 344.) By *silver grain* is meant those thin longitudinal fibres,
diverging in every direction from the pith, and composed of the lymphatic
vessels of Grew and Malpighi. I do not see how the contraction of these
laminæ could propel the sap through the sap vessel, destitute as they are
of valves, unless it were a contraction precisely similar to what Saussure
supposed to take place in the sap vessels.

‡ Mem. Par. 1787.

thrown into motions when touched.* Roth has ascertained that the leaves of the *drosera longifolia* and *rotundifolia* have the same property. Mr. Coulomb, too, who has adopted the opinion that the motion of the sap in plants is produced by the contraction of vessels, has even made a number of experiments in order to show this contraction. But the fact is, that every one has it in his power to make a decisive experiment. Simply cutting a plant, the *euphorbia peplis* for instance, in two places, so as to separate a portion of the stem from the rest, is a complete demonstration that the vessels actually do contract. For whoever makes the experiment, will find that the milky juice of that plant flows out at both ends so completely, that if afterwards we cut the portion of the stem in the middle no juice whatever appears. Now it is impossible that these phenomena could take place without a contraction of the vessels; for the vessels in that part of the stem which has been detached cannot have been more than full; and their diameter is so small, that if it were to continue unaltered, the capillary attraction would be more than sufficient to retain their contents, and consequently not a drop would flow out. Since, therefore, the whole liquid escapes, it must be driven out forcibly, and consequently the vessels must contract.

It seems pretty plain, too, that the vessels are excited to contract by various stimuli; the experiments of Coulomb and Saussure render this probable, and an observation of Dr. Smith Barton makes it next to certain. He found that plants growing in water vegetated with much much greater vigour, provided a little camphor was thrown into the water.†

SECT. IV.

OF THE FUNCTIONS OF THE LEAVES.

Peculiar juice formed by the leaves. 1   IT has been ascertained that the sap ascends to the leaves, that it there undergoes certain alterations, and is converted into another fluid called the *succus proprius, peculiar juice,* or

* Phil. Trans. lxxviii.   † Ann. de Chim. xxiii. 63.

true sap; which, like the blood in animals, is afterwards employed in forming the various substances found in plants. Now, the changes which the sap undergoes in the leaves, provided we can trace them, must throw a great deal of light upon the nature of vegetation. These changes are produced in part during the day, in part during the night. Now, as the functions of the leaves during the day are very different from what they are during the night, it will be proper to consider them separately.

I. No sooner has the sap arrived at the leaves, than a great part of it is thrown off by evaporation.

1. The quantity thus perspired bears a very great proportion to the moisture imbibed. Mr. Woodward found that a sprig of mint, weighing 27 grains, in 77 days imbibed 2558 grains of water, and yet its weight was only increased 15 grains; therefore it must have given out 2543 grains. The same experiment was repeated by this philosopher on other plants; the following table exhibits the result: *

	Weight.			
Plants and Water.	When put in.	When taken out.	Gain in 77 days.	Water wasted.
	gr.	gr.	gr.	gr.
Spearmint in spring water	27	42	15	2558
Spearmint in rain water	$28\frac{1}{2}$	$45\frac{3}{4}$	$17\frac{1}{2}$	3004
Spearmint in Thames water	28	54	26	2493
Common nightshade in spring water ..	49	106	57	3708
Lathyris in spring water............	98	$101\frac{1}{2}$	$3\frac{1}{2}$	2501

These experiments demonstrate the great quantity of matter which is constantly leaving the plant. Dr. Hales found that a cabbage transmitted daily a quantity of moisture equal to about half its weight; and that a sun-flower, three feet high, transmitted in a day 1 lb. 14 oz. avoirdupois.† He showed, that the quantity of transpiration in the same plant was proportional to the surface of the leaves, and that when the leaves were taken off the transpiration nearly ceased.‡ By these observations, he demonstrated

* Phil. Trans. 1699, xxix. 193.   † Veget. Stat. i. 5 and 15.
‡ Veget. Stat. p. 30.

Book IV. that the leaves are the organs of transpiration. He found, too, that the transpiration was nearly confined to the day, very little taking place during the night; * that it was much promoted by heat, and stopped by rain and frost : † and Millar,‡ Guettard,§ and Sennebier, have shown that the transpiration is also very much promoted by sunshine.

The quantity of moisture imbibed by plants depends very much upon what they transpire ; the reason is evident : when the vessels are once filled with sap, if none be carried off, no more can enter ; and, of course, the quantity which enters must depend upon the quantity emitted.

2. In order to discover the nature of the transpired matter, Hales placed plants in large glass vessels, and by that means collected a quantity of it.‖ He found that it resembled pure water in every particular, excepting only that it sometimes had the odour of the plant. He remarked, too, as Guettard and Duhamel did after him, that when kept for some time it putrified, or at least acquired a stinking smell. Sennebier subjected a quantity of this liquid to a chemical analysis.

Nature of the perspired matter.

He collected 13030 grains of it from a vine during the months of May and June. After filtration he gradually evaporated the whole to dryness. There remained behind two grains of residuum. These two grains consisted of nearly $\frac{1}{2}$ grain of carbonate of lime, $\frac{1}{12}$ grain of sulphate of lime, $\frac{1}{2}$ grain of matter soluble in water, and having the appearance of gum, and $\frac{1}{2}$ grain of matter which was soluble in alcohol, and apparently resinous. He analysed 60768 grains of the same liquid, collected from the vine during the months of July and August.   On evaporation, he obtained $2\frac{1}{8}$ grains of residuum, composed of $\frac{3}{4}$ grain of carbonate of lime, $\frac{1}{4}$ grain of sulphate of lime, $\frac{1}{2}$ grain of mucilage, and $\frac{1}{2}$ grain of resin.   The liquid transpired by the *aster Novæ Angliæ* afforded precisely the same ingredients.**

Proportion to the liquid absorbed.

3. Sennebier attempted to ascertain the proportion which the liquid transpired bore to the quantity of moisture imbibed by the plant. But it is easy to see that such experiments are liable to too great uncertainties to be depended

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* Veget. Stat. p. 5.   ‡ Ibid. p. 27 and 48.   ‡ Ibid. p. 22.
§ Mem. Par. 1748.   ‖ Veget. Stat. i. 49.
** Encyc. Meth. Phys. Veget. 287.

on. His method was as follows: he plunged the thick end of the branch on which he made the experiment into a bottle of water, while the other end, containing all its leaves, was thrust into a very large glass globe. The apparatus was then exposed to the sunshine. The quantity imbibed was known exactly by the water which disappeared from the bottle, and the quantity transpired was judged of by the liquid which condensed and trickled down the sides of the glass globe. The following table exhibits the result of his experiments:

Plants.	Imbibed.	Perspired.	Time.
Peach	100 gr........	35 gr........	—
Ditto.........	210	90	—
Ditto.........	220	120	—
Mint.........	200	90	2 days
Ditto.........	575	120	10
Rasp.........	725	560	2
Ditto.........	1232	765	2
Peach.	710	295	1
Apricot.	210	180	1

In some of his experiments no liquid at all was condensed. Hence it is evident that the quantity of matter transpired cannot be deduced from these experiments. The mouth of the glass globe does not seem to have been accurately closed; the air within it communicated with the external air; consequently the quantity condensed must have depended entirely upon the state of the external air, the heat, &c.

4. The first great change, then, which takes place upon the sap after it arrives at the leaves, is the evaporation of a great part of it; consequently what remains must be very different in its proportions from the sap. The leaves seem to have particular organs adapted for throwing off part of the sap by transpiration; for the experiments of Guettard,[*] Duhamel,[†] and Bonnet,[‡] show that it is performed chiefly by the upper surfaces of leaves, and may be nearly stopped altogether by varnishing that surface.

The leaves of plants become gradually less and less fit for this transpiration; for Sennebier found that when all

Peculiar organ of transpiration.

Why the leaves fall off.

* Mem. Par. 1749.   † Physique des Arbres, i. 158.
‡ Traite des Fouilles, 1. Mem.

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other things are equal, the transpiration is much greater in May than in September.* Hence the reason that the leaves are renewed annually. Their organs become gradually unfit for performing their functions, and therefore it is necessary to renew them. Those trees which retain their leaves during the winter were found by Hales and succeeding physiologists to transpire less than others. It is now well known that these trees also renew their leaves.

II. Leaves have also the property of absorbing carbonic acid gas from the atmosphere.

1. We are indebted for this very important discovery to the experiments of Dr. Priestley. It has been long known that when a candle has been allowed to burn out in any quantity of air, no candle can afterwards be made to burn in it. In the year 1771, Dr. Priestley made a sprig of mint vegetate for ten days in contact with a quantity of such air: after which he found that a candle would burn in it perfectly well.† This experiment he repeated frequently, and found that it was always attended with the same result. According to the opinion at that time universally received, that the burning of candles rendered air impure by communicating phlogiston to it, he concluded from it, that plants, while they vegetate, absorb phlogiston.

Carbonic acid gas was at that time supposed to contain phlogiston. It was natural, therefore, to suppose that it would afford nourishment to plants, since they had the property of absorbing phlogiston from the atmosphere. Dr. Percival had published a set of experiments, by which he endeavoured to show that this was actually the case.

These experiments induced Dr. Priestley, in 1776, to consider the subject with more attention. But as, in all the experiments which he made, the plants confined in carbonic acid gas very soon died, he concluded that carbonic acid gas was not a food, but a poison to plants.‡ Mr. Henry of Manchester was led in 1784, probably by the contrariety of these results, to examine the subject. His experiments, which were published in the Manchester Transactions,§ perfectly coincided with those of Dr. Percival. For he found that carbonic acid gas, so far from

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* Encyc. Meth. Veget. 285.   † On Air, iii. 251.
‡ On Air, i. 100.   § Vol. ii. 341.

killing plants, constantly promoted their growth and vigour. Meanwhile Mr. Sennebier was occupied at Geneva with the same subject; and he published the result of his researches in his Memoires Physico-Chymiques about the year 1780. His experiments showed, in the clearest manner, that carbonic acid gas is used by plants as food. The same thing was supported by Ingenhousz in his second volume. The experiments of Saussure junior, published in 1797, have at last put the subject beyond the reach of dispute. From a careful comparison of the experiments of these philosophers, it will not be difficult for us to discover the various phenomena, and to reconcile all the seeming contradictions which occur in them. The facts are as follows:

2. Plants will not vegetate in an atmosphere of pure carbonic acid, nor if their atmosphere contains $\frac{3}{4}$ths of its bulk of that gas. They vegetate in the sun when confined in atmospheres containing $\frac{1}{2}$, $\frac{1}{4}$th, or $\frac{1}{8}$th, of that gas, and the vegetation improves as the quantity of gas diminishes. When the atmosphere contains only $\frac{1}{12}$th of carbonic acid gas, plants grow in it considerably better in the sun, than when placed in an atmosphere of common air; but when plants are placed in the shade, the presence of carbonic acid always injures their vegetation instead of promoting it.*

3. Mr. Saussure has shown, that plants will not vegetate in the sun when totally deprived of carbonic acid gas. They vegetate indeed well enough in air which has been previously deprived of carbonic acid gas; but when a quantity of lime was put into the glass vessel which contained them, they no longer continued to grow, and the leaves in a few days fell off.† The air, when examined, was found to contain no carbonic acid gas. The reason of this phenomenon is, that plants (as we shall see afterwards) have the power of forming and giving out carbonic acid in certain circumstances; and this quantity is sufficient to continue their vegetation for a certain time. But if this new formed gas be also withdrawn, by quicklime for instance, which absorbs it the instant it appears, the leaves

* Saussure, Recherches Chimiques sur la Vegetation, p. 30.
† Ann. de Chim. xxiv. 145, 148.

Book IV. droop, and refuse to perform their functions.* Carbonic
acid gas, then, applied to the leaves of plants, is *essential*
to vegetation.

4. The direct contrary takes place in the shade. Plants
not only continue to vegetate when deprived of all carbonic
acid by means of lime; but they flourish more than if it
were allowed to remain.†

Emit
oxygen gas.
5. Dr. Priestley, to whom we are indebted for many of
the most important facts relative to vegetation, observed,
in the year 1778, that plants, in certain circumstances,
emitted oxygen gas;‡ and Ingenhousz very soon after dis-
covered that this gas is emitted by the *leaves* of plants, and
only when they are exposed to the bright light of day.
His method was to plunge the leaves of different plants
into vessels full of water, and then expose them to the sun,
as Bonnet, who had observed the same phenomenon, though
he had given a wrong explanation of it, had done before
him. Bubbles of oxygen gas very soon detached them-
selves from the leaves, and were collected in an inverted
glass vessel.§ He observed, too, that it was not a matter
of indifference what kind of water was used. If the water,
for instance, had been previously boiled, little or no
oxygen gas escaped from the leaves; river water afforded
but little gas; but pump-water was the most productive of
all.‖

By decom-
posing car-
bonic acid.
Sennebier proved, that if the water be previously de-
prived of all its air by boiling, the leaves do not emit a
particle of air; that those kinds of water which yield most
air contain in them the greatest quantity of carbonic acid
gas; that leaves do not yield any oxygen when plunged in
water totally destitute of carbonic acid gas; that they emit
it abundantly when the water, rendered unproductive by
boiling, is impregnated with carbonic acid gas; that the
quantity of oxygen emitted, and even its purity, is pro-
portional to the quantity of carbonic acid gas which the
water contains; that water impregnated with carbonic acid

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* Braconnot has rendered it probable, that in this experiment it was
not the absence of carbonic acid, but the deleterious effects of the
lime that killed the plants in Saussure's experiments. Ann. de Chim.
lxi. 187.   † Saussure, Recherches, p. 36.
‡ On Air, iii. 284.   § Ingenhousz on Veget. i. 15, &c.
‖ Ingenhousz on Veget. i. 15, 33.

gas gradually loses the property of affording oxygen gas Chap. III.
with leaves; and that whenever this happens, all the car-
bonic acid gas has disappeared; and on adding more
carbonic acid gas the property is renewed.* These expe-
riments prove, in a most satisfactory manner, that the
oxygen gas which the leaves of plants emit depends upon
the presence of carbonic acid gas; that the leaves absorb
carbonic acid gas, decompose it, give out the oxygen, and
retain the carbon. They have been lately confirmed by
the experiments of Dr. Woodhouse. To this gentleman
likewise we are indebted for a very full set of experiments
on the quantity of gas produced by exposing different plants
in water to sunshine for given times.†

6. Sennebier has ascertained, that the decomposition of The decom-
the carbonic acid takes place in the parenchyma. He found position
performed
that the epidermis of a leaf would, when separated, give by the pa-
out no air, neither would the nerves in the same circum- renchyma.
stances; but upon trying the parenchyma, thus separated
from its epidermis and part of its nerves, it continued to
give out oxygen as before.‡

That the decomposition is performed by peculiar organs,
is evident from an experiment of Ingenhousz. Leaves cut
into small pieces continued to give out oxygen as before;
but leaves pounded in a mortar lost the property entirely.
In the first state, the peculiar structure remained; in the
other, it was destroyed. Certain experiments of Count
Rumford, indeed, may seem incompatible with this con-
clusion; and they will naturally occur to the reader as an
objection. He found that dried leaves of black poplar, fibres
of raw silk, and even glass, when plunged into water, gave
out oxygen gas by the light of the sun; but when Senne-
bier repeated these experiments, they did not succeed. §
It was probably the air contained in the water which sepa-
rated in the Count's experiments.||

* Encyc. Method. Physiol. Veget. 181.
† See Nicholson's Jour. ii. 154, and Ann. de Chim. xlii. 200.
‡ Encyc. Method. Physiol. Veget. 180.   § Ann. de Chim. i. 115.
|| Dr. Woodhouse tried the experiments with filaments of asbestus,
baked horse-hair, cotton, pannicles of rhus cotinus, cotton of asclepias
syriaca, hairy plumes of clematis crispa, spikes of panicum glaucum,
charcoal powder; each of these, he affirms, yielded in water a little
oxygen gas, but less pure than the leaves of plants. Nicholson's Jour.
ii. 158.

Carbonic a-
cid absorb-
ed varies in
different
plants.

7. From the experiments of Saussure, we learn that the quantity of carbonic acid thus absorbed and decomposed varies greatly in different plants, even when placed in the same circumstances. The *lythrum salicaria* was found to absorb seven or eight times its bulk of this gas in a day; while the *cactus opuntia*, and other fleshy-leaved plants, did not absorb above a fifth of that quantity. The portion absorbed, according to Saussure, depends upon the surface of the plant; and therefore thin leaved plants must absorb more than those that have fleshy leaves.*

The whole
oxygen not
emitted.

8. It does not appear that the whole of the oxygen contained in the carbonic acid absorbed is emitted again by the plant. A considerable portion of it seems to be retained. This, at least, is the result which follows from a set of experiments made by Saussure on purpose to ascertain the point. He mixed carbonic acid with common air, in such a proportion that it occupied $7\frac{1}{2}$ hundredths of the mass. Jars, standing over mercury (covered with a thin film of water), were filled with this mixture; and plants of *vinca minor*, growing in a small vessel filled with water, were introduced into the jar. These plants, thus placed, were exposed for six successive days to the sun, from five in the morning to eleven, while the temperature of the air was 70°; during all which time they vegetated with great vigour. The bulk of the air in the jar was not sensibly altered. No carbonic acid could be detected in it. The proportion of oxygen was $24\frac{1}{2}$ per cent. The following table exhibits the proportion of the constituents of this air, in French cubic inches, when put into the jar, and after the plants had vegetated in it six days.†

	When put in.	When taken out.
Azote	211·92	218·95
Oxygen	56·33	71·05
Carbonic acid ..	21·75	0·00
	290·00	290·00

Some azote
emitted.

Thus the whole 21·75 inches of carbonic acid were absorbed; but the oxygen emitted was only 14·72 inches, whereas the whole oxygen in the carbonic acid would have

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* Recherches Chimiques, p. 56.   † Ibid. p. 40.

amounted to 21·75 inches. The difference, amounting to about seven inches, was made up by a quantity of azote, which had been given out by the plants along with the oxygen. The following table exhibits the result of similar experiments, made by this philosopher, on other plants. All the numbers denote cubic inches.

Plants.	Bulk of plants.	Air in jar.	Carbonic acid, per cent, in ditto.	Duration of experiment. (Days.)	Carbonic acid, per cent, in residuary air.	Oxygen per cent, in do.	Carbonic acid absorbed.	Gas emitted. Oxygen.	Gas emitted. Azote.	Diminution of bulk of residuary gas.
Mentha aquatica	0·5	328	7·5	10	2·5	23·5	15·6	11·26	4·34	0
Lythrum salicaria	0·14	75	10	7	0	27·25	7·5	6·13	1·1	0·5
Pinus Genevensis	0·5	280	7	18	1·5	24·5	15·5	12·5	1	2
Cactus opuntia	1·1	155	10	8	4	24	9·3	6·4	2·9	0

9. Thus it appears that plants, when exposed to the light, absorb carbonic acid, decompose it, and throw out again the greatest part of the oxygen of this gas mixed (it would seem) with a little *azote:** It is extremely probable that

* I presume that Saussure ascertained merely that the new portion

plants, by this process, acquire the greatest part of the carbonaceous matter which they contain ; for if we compare the quantity of carbon contained in plants vegetating in the dark, where this process does not go on, with the quantity which those plants contain which vegetate in the usual manner, we shall perceive a very conspicuous difference. Chaptal found that a byssus, which was vegetating in the dark, contained only $\frac{1}{89}$th of its weight of carbonaceous matter ; but the same plant, after being made to vegetate in the light for 30 days, contained $\frac{1}{24}$th of its weight of carbonaceous matter.* Hassenfratz ascertained that plants growing in the dark contain much more water, and much less carbon and hydrogen, than plants growing in the light. Sennebier analysed both with the same result. Plants growing in the dark yielded less hydrogen gas and oil : their resinous matter was to that of plants growing in the light as 2 to 5·5, and their moisture as 13 to 6 ; they contained even one-half less of fixed matters.

The quantity of carbonic acid thus absorbed is considerable. In Saussure's experiments, the plants absorbed daily more than their own bulk of this gas : But when they grow in the open air, where the quantity of carbonic acid is much less considerable, not exceeding $\frac{1}{500}$th part, the proportion absorbed is no doubt less.

10. Ingenhousz found that plants emit no oxygen when made to vegetate in the dark, and that in these circumstances they rather injure air than improve it. Now, as the emission of oxygen has been found to depend upon the absorption of carbonic acid, it is probable that this acid is absorbed only in the light. Saussure indeed has endeavoured to prove, that plants, even in the dark, absorb and decompose carbonic acid; but the quantity, if any, must be so extremely small, that it cannot well be appreciated.

III. The green colour of plants has been shown, by Sennebier, to depend upon the absorption of carbonic acid. It

of gas, to which he has given the name of azote, did not diminish with oxygen, and did not render lime-water turbid. Many other gases possess these properties. It might have been some inflammable gas. Hydrogen would have detonated ; but some of the compound inflammable gases would not, when diluted so largely with common air.

* Mem. Par. 1786.

appears only when plants vegetate in the light: for when they vegetate in the dark they are white; and when exposed to the light they acquire a green colour in a very short time, in whatsoever situation they are placed, even though plunged in water, provided always that oxygen be present; for Mr. Gough has shown, that light without oxygen has not the power of producing the green colour.*

Sennebier has observed, that when plants are made to vegetate in the dark, their etiolation is much diminished by mixing a little hydrogen gas with the air that surrounds them.† Ingenhousz had already remarked, that when a little hydrogen gas is added to the air in which plants vegetate, even in the light, it renders their verdure deeper: ‡ and he seems to think also, that he has proved by experiments, that plants absorb hydrogen gas in these circumstances. § Mr. Humboldt has observed that the *poa annua* and *compressa, plantago lanceolata, trifolium arvense, cheiranthus cheiri, lichen verticillatus,* and several other plants which grow in the galleries of mines, retain their green colour even in the dark, and that in these cases the air around them contains a quantity of hydrogen gas. This philosopher concludes, from his observations, that the white colour of etiolated plants is occasioned by their retaining an unusual proportion of oxygen, and that this is prevented by surrounding them with hydrogen gas. This may perhaps be true in certain cases; but the experiments of Mr. Gough, mentioned above, are sufficient to prove that the retention of oxygen is not the only difference between green and etiolated plants. ||

The green colouring matter of plants has been shown by Rouelle to be of a resinous nature. From this, and from the circumstance of its being formed only in the light, Berthollet has inferred that the leaves of plants have the property of decomposing water as well as carbonic acid when exposed to the light of the sun. The oxygen emitted, according to him, is derived partly from the decomposed carbonic acid and partly from the water, while the

Plants supposed to decompose water.

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* Man. Mem. iv. 501.   † Encyc. Meth. Physiol. Veget. 75.
‡ Ann. de Chim. iii. 57.   § Ibid. 61.
|| Plants of a white colour, from vegetating in the dark, are called *etiolated,* from a French word which signifies a *star,* as if they grew by *star light.*

Book IV. carbon and hydrogen enter into the composition of the inflammable parts of the plant. This ingenious theory, though sufficiently probable, is not susceptible of direct proof. From the experiments of Saussure, we learn that when plants are made to vegetate in pure water, in atmospheres destitute of carbonic acid gas, the quantity of their fixed matter does not increase; but when their atmospheres contain this acid gas, the increase of weight which they receive is considerably greater than can be accounted for by the carbon and oxygen derived from the carbonic acid absorbed.* Hence it is clear, that a portion of the water must enter into their composition. It is more likely that the elements of this portion arrange themselves in a different way, than that they still continue in the state of water. These facts certainly strengthen the hypothesis of Berthollet. Indeed, if we consider the great quantity of hydrogen contained in plants, it is difficult to conceive how they should obtain it, provided the water which they absorb does not contribute to furnish it.

Plants absorb oxygen,   IV. Plants will not vegetate unless atmospheric air or oxygen gas have access to their leaves. This was rendered probable by those philosophers who, about the end of the 17th century, turned their attention particularly towards the physical properties of the air; but Dr. Ingenhousz was perhaps the first of the modern chemists who put it beyond doubt. He found that carbonic acid gas, azotic, and hydrogen gas, destroyed plants altogether, unless they were mixed with atmospheric air or oxygen gas. He found also, that plants grew very well in oxygen gas and in atmospheric air.† From these experiments, it was pretty clear that the leaves of plants absorb oxygen; and the whole series of chemical experiments on plants led to the supposition that this absorption was confined to the night. The subject has lately been very fully investigated by Saussure, who has not only confirmed these suppositions by decisive experiments, but added many new facts not previously suspected.‡

1. The greater number of plants refuse to vegetate when confined in azotic gas. Those only continue to live which are abundantly supplied with green parts, as the *cactus*

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* Recherches, p. 217.   † Ingenhousz, ii. passim.
‡ Recherches, p. 60.

opuntia, &c.   When plants continue to vegetate in azote, it is because they give out a portion of oxygen during the day; the absorption of which during the night preserves them.*

2. When the leaves of plants are put in contact with common air during the night, they diminish the bulk of their atmosphere by absorbing oxygen.   Some plants change, at the same time, a portion of the oxygen into carbonic acid, while others form no perceptible quantity of this last gas.   The leaves, for example, of the *cactus opuntia, crassula cotyledon, sempervivum tectorum, agave Americana*, and *stapelia variegata*, simply absorb oxygen; while the leaves of the *quercus robur, sedum reflexum, æsculus hyppocastanum*, and *robinia pseudo-acacia*, absorb oxygen, and form a portion of carbonic acid, inferior in quantity to the oxygen which has disappeared.†

3. This inspiration of oxygen takes place only when the leaves retain their organized form.   If this be destroyed, by reducing them to a paste for example, all absorption of oxygen is prevented, though a portion of it is even then converted into carbonic acid by the action of the carbonaceous matter present. ‡

4. The oxygen thus inspired by the leaves of plants, is not separated from them again by putting them into the exhausted receiver of the air pump.   By that means, indeed, they yield a little air, but always much less than the oxygen absorbed; and this air is precisely of the same nature with the atmosphere in which they were confined. Neither is the oxygen extricated by exposing the leaves to the greatest heat which they are capable of bearing without being destroyed. §.

5. There is reason to believe that the oxygen gas thus absorbed by plants is converted into carbonic acid within the plant, and that it is only after the plant is *saturated* with this acid (if the expression may be permitted), that the surrounding oxygen is partly converted into carbonic acid, by combining with the carbonaceous matter of the plant. When the leaves are exposed to the light, this carbonic

And convert it into carbonic acid.

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* Recherches, p. 197.   † Saussure, ibid. p. 61.

‡ Saussure, ibid. p. 74.   § Recherches, p. 69.

Book IV. acid is decomposed, and a quantity of oxygen thrown out, usually greater than what was inspired. But the oxygen given out in the light (when plants grow in atmospheres destitute of carbonic acid) is always proportional to the oxygen inspired during the night; being always greatest when the plant has absorbed the greatest quantity of oxygen.

Differ in the quantity absorbed. 6. Plants differ very much from each other in the quantity of oxygen which their leaves absorb during the night. Fleshy-leaved plants absorb the least oxygen; probably because they emit no carbonic acid gas. Hence they can vegetate in high situations where the atmosphere is rarefied. Next in order come the evergreen trees, which, though they absorb more oxygen than the fleshy-leaved plants, yet require much less than those trees which lose their leaves during winter. Those plants which flourish in marshy ground likewise absord but little oxygen. The following tables exhibit the result of Saussure's experiments on this point. The first column contains the names of the plants whose leaves were employed; the second the month in which the experiments were made; and the third the bulk of oxygen absorbed, supposing the bulk of the leaves used in each experiment to be always 1·00.*

Tables of the proportion absorbed.

I. *Leaves of Evergreen Trees.*

Leaves of	Time.	Oxygen absorbed.
Illex aquifolium	September	0·86
Buxus semper virens	September	1·46
Prunus laurocerasus	May	3·20
Ditto	September	1·36
Viburnum tinus	September	2·23
Hedera helix	September	1
Vinca minor	June	1·5
Ditto	September	0·93
Pinus abies	September	3
Beupleurum fruticosum	May	4
Juniperus sabina	June	2·6
Juniperus communis	June	2·4

* Recherches, p. 99.

II. *Leaves of Trees which lose their Leaves in Winter.*

Leaves of	Time.	Oxygen absorbed.
Fagus sylvatica	August	8
Carpinus betulus	May	5
Ditto	September	6
Quercus robur	May	5·5
Ditto	September	5·5
Æsculus hypocastanus	September	4·8
Populus alba	May	6·2
Ditto	September	4·36
Prunus Armeniaca	September	8
Amygdalus Persica	June	6·6
Ditto	September	4·2
Juglans regia	May	6·6
Ditto	September	4·4
Platanus occidentalis	September	3
Robinia pseudo-acacia	May	5
Ditto	September	6·7
Syringa vulgaris	May	3·36
Ditto	September	2·2
Fraxinus excelsior	May	4·32
Ditto	September	3·71
Pyrus	May	5·2
Ditto	September	3·4
Rosa centifolia	June	5·4
Fagus castanea	July	5·6

III. *Leaves of Herbaceous Plants, not Aquatic.*

Leaves of	Time.	Oxygen absorbed.
Solanum tuberosum	September	2·5
Brasica oleracea	Ditto, young leaves	2·4
Ditto	Sept. old leaves	2
Urtica urens	September	2
Mercurialis annua	Sept. in flower	2·33
Daucus carota	September, ditto	1·9
Vicia faba	Before flowering	3·7
Ditto	In flower	2
Ditto	After ditto	1·6
Lilium candidum	May, in flower	0·66
Ditto	Sept. after ditto	0·5

Leaves of	Time.	Oxygen absorbed.
Tropæolum majus	Sept. in flower	3
Digitalis ambigua	July	2
Brassica rapa	Sept. in flower	1·25
Avena sativa	June, before ditto	2·7
Triticum æstivum	May, before ditto	5·0
Pisum sativum	May, in flower	3·72
Ruta graveolens	August	2

IV. *Leaves of Aquatic Plants.*

Leaves of	Time.	Oxygen absorbed.
Alisma plantago	August	0·7
Inula dysenterica	September	1·6
Epilobium molle	Sept. in flower	1·9
Sisymbrium nasturtium	September	1·6
Polygonum Persicaria	Sept. in flower	2
Veronica beccabunga	September	1·7
Ranunculus reptans	September	1·5
Lythrum salicaria	May, before flower	2·3
Caltha palustris	May	1
Carex acuta	May	2·25

V. *Leaves of the Fleshy Plants.*

Leaves of	Time.	Oxygen absorbed.
Cactus opuntia	August	1
Agave Americana	August	0·8
Sempervivum tectorum	July	1
Sedum globosum	September	1·5
Saxifraga cotyledon	September	0·6
Sedum reflexum	June	1·7
Stapelia variegata	July	0·63
Mesembryanthemum deltoides	July	1·7

Heat may be evolved.   7. It is not improbable, that by the absorption of oxygen, and the formation of carbonic acid, a portion of heat may be evolved, as Saussure supposes; though the quantity must be too small to be appreciated. It appears that in certain cases a very considerable degree of heat is produced by vegetables; though it has not yet been ascertained whether the appearance of it is connected with the absorption of oxygen. A very extraordinary instance of this is related

by Bory de St. Vincent on the authority of Hubert. The stamina of the *arum cardifolium*, at the moment of bursting, produced so great a heat, that twelve of them placed round the bulb of a thermometer raised it from 79° to 143°. The experiment was repeated a great number of times with similar results.*

8. It appears, from the experiments of Saussure, that Roots absorb oxygen as well as the leaves, and that they transmit the carbonic acid formed to the leaves to be decomposed. The branches likewise absorb it. Flowers do not expand without its presence.

Thus it appears that during the night plants absorb oxygen; that they form with it carbonic acid; that a portion of this gas is sometimes emitted, together with a little azote; but that the greatest part is retained and decomposed by the leaves during the day. Plants will not live without this nightly inspiration, even though supplied with carbonic acid, provided the oxygen formed by them during the day be constantly withdrawn at the approach of night.

V. The leaves of plants absorb water as well as oxygen Leaves absorb water. from the air. This had been suspected in all ages: the great effect which dew, slight showers, and even wetting the leaves of plants, have in recruiting their strength, and making them vegetate with vigour, are so many proofs that the leaves imbibe moisture from the atmosphere. Hales rendered this still more probable, by observing that plants increase considerably in weight when the atmosphere is moist; and Mr. Bonnet put the matter beyond doubt in his Researches concerning the Use of the Leaves. He showed that leaves continue to live for weeks when one of their surfaces is applied to water; and that they not only vegetate themselves, but even imbibe enough of water to support the vegetation of a whole branch, and the leaves belonging to it. He discovered also, that the two surfaces of leaves differ very considerably in their power of imbibing moisture; that in trees and shrubs the under surface possesses almost the whole of the property, while the contrary holds in many of the other plants; the kidney bean for instance.

These facts prove not only that the leaves of plants have

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* Jour. de Phys. lix. 281.

Book IV. the power of absorbing moisture, but also that the absorp-
tion is performed by very different organs from those which
emit moisture; for these organs lie on different sides of the
leaf. If we consider that it is only during the night that
the leaves of plants are moistened with dew, we can scarcely
avoid concluding, that, except in particular cases, it is
during the night that plants imbibe almost all the moisture
which they do imbibe.

Thus we have seen that the leaves of plants perform very
different operations at different times. During the day they
are giving out moisture, absorbing carbonic acid gas, and
emitting oxygen gas; during the night, on the contrary,
they are absorbing moisture, giving out carbonic acid gas,
and absorbing oxygen gas.

Sap con-
verted into
nutritive
juices by
these pro-
cesses.

By these processes, and perhaps also by others which
have not yet been detected, the sap of plants is new modell-
ed, and brought to the state which is adapted for the nou-
rishment of the plant. To describe in what manner these
changes take place is impossible; because we neither know
precisely the substance into which the sap has been con-
verted by the operations performed during the day, nor the
new substances formed by the operations of the night.
We have reason, however, to conclude, that during the
day the carbon of the sap is increased, and that during the
night the hydrogen and oxygen are increased; but the
precise new substances formed are unknown to us. Nor
let any one suppose that the increase of the hydrogen and
of the oxygen of the sap is the same thing as the addition
of a quantity of water. In water, oxygen and hydrogen
are already combined together in a certain proportion; and
this combination must be broken before these elementary
bodies can enter into those triple compounds with carbon,
of which a great part of the vegetable products consist.
We have not the smallest conception of the manner in
which these triple combinations are formed, and as little of
the manner in which the bodies which compose vegetable
substances are combined together. The combination may,
for any thing we know to the contrary, be very compli-
cated: though it consists wholly of three ingredients; and
analogy leads us to suppose that it actually is very compli-
cated: for in chemistry it may be considered as a truth, to
which at present few or no exceptions are known, that

bodies are decomposed with a facility inversely as the simplicity of their composition; that is to say, that those bodies which consist of the fewest ingredients are most difficultly decomposed, and that those which are formed of many ingredients are decomposed with the greatest facility.

Neither let any one suppose that the absorption of carbonic acid gas during the day is balanced by the quantity emitted during the night; and that therefore there is no increase of carbon: for Ingenhousz and Saussure have shown that the quantity of oxygen gas emitted during the day is much greater than the carbonic acid gas emitted during the night; and that in favourable circumstances, the quantity of oxygen gas in the air surrounding plants is increased, and the carbonic acid gas diminished; so much so, that both Dr. Priestley and Dr. Ingenhousz found, that air which had been spoiled by a lighted candle, or by animals, was rendered as good as ever by plants. Now we know that combustion and respiration diminish the oxygen gas, and add carbonic acid gas to air; therefore vegetation, which restores the purity of air altered by these processes, must increase the oxygen, and diminish the carbonic acid gas of that air; consequently the quantity of carbonic acid gas absorbed by plants during the day is greater than the quantity emitted by them during the night; and of course the carbon of the sap is increased in the leaves.

It is true, that when plants are made to vegetate for a number of days in a given quantity of air, its ingredients are not found to be altered. Thus Hassenfratz ascertained that the air, in which young chesnuts vegetate for a number of days together, was not altered in its properties, whether the chesnuts were vegetating in water or in earth;* and Saussure, junior, proved that peas growing for ten days in water did not alter the surrounding air.† But this is precisely what ought to be the case, and what must take place, provided the conclusions which I have drawn be just. For if plants only emit oxygen gas by absorbing and decomposing carbonic acid gas, it is evident, that unless carbonic acid gas be present, they can emit no oxygen gas; and whenever they have decomposed all the carbonic acid

* Ann. de Chim. xiii. 325.   † Ibid. xxiv. 139.

Book IV. gas contained in a given quantity of air, we have no longer any reason to look for their emitting any more oxygen gas; and if the quantity of carbonic acid gas emitted during the night be smaller than that absorbed during the day, it is evident that during the day the plant will constantly decompose all the acid which had been formed during the night. By these processes the mutual changes of day and night compensate each other; and they are prevented from more than compensating each other by the forced state of the plant. It is probable, that when only part of a plant is made to vegetate in this forced state, some *carbureted sap* (if I may be allowed the expression) is supplied by the rest of the plant; and that therefore the quantity of carbonic acid gas emitted during the night may bear a nearer proportion to that emitted in a state of nature than that of the absorption of fixed air can possibly do. And probably, even when the whole plant is thus confined, the nightly process goes on for a certain time at the expense of the carbon already in the sap; for Hassenfratz found, that in these cases the quantity of carbon in the plant, after it had vegetated for some time in the dark, was less than it had been when it began to vegetate.* This is the reason that plants growing in the dark, when confined, absorb all the oxygen gas, and emit carbonic acid gas: and whenever this has happened, they die; because then neither the daily nor nightly processes can go on.

SECT. V.

OF THE PECULIAR JUICES OF PLANTS.

By these changes which go on in the leaves, the nature of the sap is altogether changed. It is now converted into what is called the *peculiar juice*, or *true sap*, and is fit for being assimilated to the different parts of the plant, and for being employed in the formation of those secretions which are necessary for the purposes of the vegetable economy.

* Ann. de Chim. xiii. 188.

The leaves, therefore, may be considered as the digesting organs of plants, and as equivalent in some measure to the stomach and lungs of animals. The leaves consequently are not mere ornaments; they are the most important parts of the plant. Accordingly we find, that whenever we strip a plant of its leaves, we strip it entirely of its vegetating powers till new leaves are formed. It is well known that when the leaves of plants are destroyed by insects they vegetate no longer, and that their fruit never makes any farther progress in ripening, but decays and dries up. Even in germination no progress is made in the growth of the stem till the seed-leaves appear. As much food indeed is laid up in the cotyledons as advances the plant to a certain state: the root is prepared, and made ready to perform its functions; but the sap which it imbibes must be first carried to the seed-leaves, and digested there, before it be proper for forming the plumula into a stem. Accordingly if the seed-leaves are cut off, the plant refuses to vegetate.

It will be very natural to ask, if this be true, how come the leaves themselves to be produced? I had endeavoured to render it probable, that food for the purpose of nourishing and developing them was laid up in the buds themselves; but the late experiments of Mr. Knight, formerly detailed, have shown that the alburnum is the part of the tree in which this food is deposited. After the plant has developed all the parts which are to appear during the summer, and after the buds are fabricated and rolled up, the leaves still continue to manufacture new food, and to send it to the alburnum. Here it is deposited, and employed next spring in feeding and developing those organs of plants which are absolutely necessary for enabling them to perform the functions of vegetation. From this important fact, Mr. Knight has drawn a number of curious consequences, of great importance to the practical gardener and farmer.

This deposition of food for the future supply of the plant explains to us why the branch of a vine, if it be introduced into a hot-house during the winter, puts forth leaves and vegetates with vigour, while every other part of the plant gives no signs of life. It explains to us also why the sap flows out of trees very readily in spring before the leaves appear, but after that the bleeding ceases altogether. It is

Book IV. evident that there can be scarcely any circulation of sap
before the leaves appear; for as there is no outlet, when
the vessels are once full they can admit no more. It ap-
pears, however, from the bleeding, that the roots are capa-
ble of imbibing, and the vessels of circulating, the sap with
vigour. Accordingly, whenever there is an outlet, they
perform their functions as usual, and the tree bleeds; that
is, they send up a quantity of sap to be digested as usual:
but as there are no digesting organs, it flows out, because
the sap that flows out would not have been imbibed at all,
had it not been for the artificial opening. But when the
digestive organs appear, the tree will not bleed; because
these organs require all the sap, and it is constantly flowing
to them.

Absolutely   If a tree be deprived of its leaves, new leaves make their
necessary. appearance, because they are already prepared for that pur-
pose. But what would be the consequence if a tree were
deprived of its leaves and of all its buds for five years back?
That plants do not vegetate without leaves is evident from
an experiment of Duhamel. He stripped the bark off a tree
in ringlets, so as to leave five or six rings of it at some dis-
tance from each other, with no bark in the intervals. Some
of these rings had buds and leaves; these increased con-
siderably in size; but one ring which had none of these re-
mained for years unaltered. Mr. Knight found that a shoot
of the vine, when deprived of its leaves died altogether.[*]

Form the   The *succus proprius,* or *peculiar juice* of plants, may be
peculiar   considered as analogous to the blood of animals. It is the
juice.   food altered by digestion, and rendered fit for being assimi-
lated and converted into a part of the plant itself by the
subsequent processes of vegetation. That it flows from the
leaves of the plant towards the roots appears from this cir-
cumstance, that when we make an incision into the plant,
into whatever position we put it, much more of the *succus*
Which   *proprius* flows from that side of the wound which is next the
flows from leaves and branches than from the other side: and this
the leaves. happens even though the leaves and branches be held un-
dermost.[†] When a ligature is tied about a plant, a swelling
appears above but not below the ligature.

In vessels.   The vessels containing the peculiar juice have been traced

* Phil. Trans. 1801, p. 333.   † Bell, Manch. Mem. ii. 402.

by Mr. Knight from the leaves into the cortical layers of the inner bark.* Hedwig, who has examined the vessels of plants with very great care, seems to consider them as of the same structure with the tracheæ; but Mr. Knight is of a different opinion. It appears evidently from the experiments of this last gentleman, that they communicate with no part of the plant which is situated at a greater distance from the root than the leaf from which they themselves originate. For when two circular incisions are made through the bark of a branch above and below a leaf, and at some distance from it, only that part of the portion confined between the two incisions which is tituated below the leaf increases in size. From the experiments of Mr. Knight, there is reason to believe that these vessels are much better calculated to carry the true sap from the leaves towards the roots, than in the contrary direction. By passing the slender shoots of a vine through the earth of a garden-pot, he made them send out roots. The shoots were then cut off from the parent tree, leaving an equal portion on each side of this new root. Each of these portions was turned up at a similar angle, and had a bud at a little distance from the cut-off extremity. Here were two stems growing from one root. But the one was obviously inverted, while the other was in its natural position. In the first, the wood between the bud and the cut-off extremity increased in size; but in the other it did not: indicating a disposition in the true sap to move in its original direction from the leaves to the root. In like manner, when shoots of gooseberry and currant bushes were planted inverted, the upper part always decayed.† These experiments are favourable to the opinion, that these vessels are furnished with valves.

When all communication between the leaves and roots is cut off, by removing a portion of the bark all round the tree, it appears, from the experiments of Knight, that the alburnous vessels acquire the property of transmitting a portion of the true sap to the roots, so as to maintain the powers of vegetating; but the quantity is greatly diminished. The surplus appears to be lodged in the alburnum, which thus becomes denser; and if the plant be allowed to vegetate, this food is expended next season upon the upper

* Phil. Trans. 1801, p. 337.   † Nicholson's Jour. x. 289.

part of the plant. Thus the quantity of blossom on the branch of an apple tree is greatly increased by removing a section of its bark the season before the blossom is to appear.*

Its proper-
ties.
     The true sap is easily known by its colour and its consist-
ence. In some plants it is green, in some red, in many milky. It cannot be doubted that its motion in the vessels is performed in the same way as that of the sap.

     If we had any method of obtaining this peculiar juice in a state of purity, the analysis of it would throw a great deal of light upon vegetation; but this is scarcely possible, as we cannot extract it without dividing at the same time the vessels which contain the sap. In many cases, however, the peculiar juice may be known by its colour, and then its analysis may be performed with an approach towards ac-
curacy. The facts respecting its constituents, hitherto as-
certained by chemists, have, as far as I am acquainted with them, been detailed in the preceding Chapter. These ex-
periments prove, as might have been expected, that the peculiar juices differ very considerably from each other, and that every plant has a juice peculiar to itself. Hence it follows, that the processes which go on in the leaves of plants must differ at least in degree, and that we have no right to transfer the conclusions deduced from experiments on one species of plants to those of another species. It is even probable, that the processes in different plants are not the same in kind; for it is not reasonable to suppose that the phenomena of vegetation in an agaric or a boletus are precisely the same as those which take place in trees and in larger vegetables, on which alone experiments have hitherto been made.

     The true sap is conveyed to every part of the plant; and all the substances which we find in plants, and even the organs themselves by which they perform their functions, are formed from it. But the thickest veil covers the whole of these processes; and so far have philosophers hitherto been from removing this veil, that they have not even been able to approach it. All these operations indeed, are evi-
dently chemical decompositions and combinations; but we

     * Knight on the Inverted Action of the Alburnous Vessels of Trees.
Phil. Trans. 1806.

neither know what these decompositions and combinations are, nor the instruments in which they take place, nor the agents by which they are regulated.

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SECT. VI.

OF THE DECAY OF PLANTS.

SUCH, as far as I am acquainted with them, are the Plants de-changes produced by vegetation. But plants do not con- cay and die. tinue to vegetate for ever; sooner or later they decay and wither, and rot, and are totally decomposed. This change indeed does not happen to all plants at the end of the same time. Some live only for a single season, or even for a shorter period; others live two seasons, others three, others a hundred or more; and there are some plants which continue to vegetate for a thousand years; but sooner or later they all cease to live; and then those very chemical and mechanical powers which had promoted vegetation combine to destroy the remains of the plant. Now, What is the cause of this change? Why do plants die?

This question can only be answered by examining with some care what it is which constitutes the *life* of plants: for it is evident, that if we can discover what that is which constitutes the life of a plant, it cannot be difficult to dis-cover whatever constitutes its death.

Now the phenomena of vegetable life are in general *ve-* Phenomena *getation.* As long as a plant continues to vegetate, we say of vegetable that it lives; when it ceases to vegetate, we conclude that it life. is dead.

The life of vegetables, however, is not so intimately con-nected with the phenomena of vegetation that they cannot be separated. Many seeds may be kept for years without giving any symptom of vegetation; yet if they vegetate when put into the earth, we say that they possess life; and if we would speak accurately, we must say also that they possessed life even before they were put into the earth: for it would be absurd to suppose that the seed *obtained* life merely by being put into the earth. In like manner many plants decay, and give no symptoms of vegetation during

Book IV. winter; yet if they vegetate when the mild temperature of spring affects them, we consider them as having lived all winter. The life of plants, then, and the phenomena of vegetation, are not precisely the same thing; for the one may be separated from the other, and we can even suppose the one to exist without the other. Nay, what is more, we can, in many cases, *decide*, without hesitation, that a vegetable is not dead, even when no vegetation appears; and the proof which we have for its life is, that it *remains unaltered;* for we know that when a vegetable is dead, it soon changes its appearance, and falls into decay.

Thus it appears that the *life* of a vegetable consists in two things: 1. In remaining unaltered, when circumstances are unfavourable to vegetation; 2. In exhibiting the phenomena of vegetation when circumstances are favourable. When neither of these two things happens, we may say that a vegetable is dead.

The phenomena of vegetation have been enumerated above. They consist in the formation or expansion of the organs of the plant, in the taking in of nourishment, in carrying it to the leaves, in digesting it, in distributing it through the plant, in augmenting the bulk of the plant, in repairing decayed parts, in forming new organs when they are necessary, in producing seeds capable of being converted into plants similar to the parent. The *cause* of these phenomena, whatever it may be, is the *cause* also of vegetable life, and may be distinguished by the name of the *vegetative principle.* But an inquiry into the nature of this principle belongs to the science of *physiology*, and would be foreign to the nature of this work.

Owing to a vegetative principle.

Death of plants. The death of plants, if we can judge from the phenomena, is owing to the organs becoming at last altogether unfit for performing their functions, and incapable of being repaired by any of the powers which the vegetative principle possesses. The changes which vegetable substances undergo after death come now to be examined. They shall form the subject of the ensuing Chapter.

CHAP. IV.

OF THE DECOMPOSITION OF VEGETABLE SUBSTANCES.

THE most striking distinction between the substances belonging to the mineral kingdom and those which make a part of animals or vegetables, is the following: mineral bodies show little or no tendency to change their nature; and when left to themselves, undergo no spontaneous decompositions: whereas animal and vegetable substances are continually altering; and when left to themselves in favourable circumstances, always run through a regular set of decompositions. I propose in this chapter to treat of the spontaneous decompositions of vegetable bodies; those of animal bodies belong to the next Book.

Difference between minerals and living matter.

We have seen in the last Chapter, that during vegetation the constituents of plants are continually going through a regular set of changes, losing the properties of one substance, and assuming those of another. Thus a substance which in the young plant has the properties of mucilage, assumes in the old the properties of starch; what in green fruit is an acid, in ripe fruit becomes sugar. Vegetable principles, then, are not fixed or stationary in the living plant; they are gradually running into one another. But this tendency to change, or rather this continual decomposition in consequence of the mutual reaction of the different simple substances of which the vegetable principles are composed, is by no means confined to the living state. It goes on with equal or with greater energy in favourable circumstances in vegetable matter after it has been completely separated from the living plants. It has been observed that this tendency to spontaneous decomposition is usually greater in animal than in vegetable bodies; and that those vegetable bodies, in which the tendency is greatest, bear the closest resemblance to animal matter. Hence the common chemical phrase, that such substances are *more animalized*. This is the case with *gluten* in particular, which undergoes spontaneous decomposition more rapidly than most other vegetable bodies.

Vegetable substances go through a series of changes.

During the spontaneous decomposition which vegetable substances undergo, it is obvious that the simple substances of which they are composed must unite together in

These spontaneous alterations

a different manner from that in which they were formerly united, and form a new set of compounds which did not formerly exist. Now it has been observed that the specific gravity of these new compounds is almost always less than that of the old body. Some of them usually fly off in the state of gas or vapour. Hence the odour that vegetable bodies emit during the whole time that they are running through the series of their changes. When the odour is very offensive or noxious, the spontaneous decomposition is called *putrifaction;* but when the odour is not offensive, or when any of the new compounds formed is applied to useful purposes, the spontaneous decomposition is called

fermentation. This word was first introduced into chemistry by Van Helmont.* It is supposed by some to have originated from the intestine motion which is always perceptible while vegetable substances are fermenting; while by others it is derived from the heat which in these cases is always generated. The term *fermentation* is now very often applied to all the spontaneous changes which vegetable bodies undergo without regard to the products. It therefore, in that sense, includes *putrifaction;* and certainly there is no impropriety in thus extending the term so as to make it comprehend every case of spontaneous decomposition. By fermentation, then, is now meant all the spontaneous changes which take place in vegetable substances after they are separated from the living plant.

All the phenomena of fermentation lay for many years concealed in the completest darkness, and no chemist was bold enough to hazard even an attempt to explain them. They were employed, however, and without hesitation too, in the explanation of other phenomena; as if giving to one process the name of another, of which we are equally ignorant, could, in reality, add any thing to our knowledge. The darkness which enveloped these phenomena has lately begun to disperse; but they are still surrounded with a very thick mist; and we must be much better acquainted with the composition of vegetable substances, and the mutual affinities of their ingredients, than we are at present, before we can explain them in a satisfactory manner.

Fermentation never takes place unless vegetable substan-

* Stahl's Fundament. Chem. i. 124.

ces contain a certain portion of water, and unless they are exposed to a temperature at least above the freezing point. When dry or freezing, many of them continue long without alteration. Hence we have an obvious method of preventing fermentation.

If we take a view of all the vegetable principles described *Tendency* in the first Chapter of this Book, we shall find that they *differs in* *different* differ much from one another in their tendency to run into *bodies.* fermentation. Gum, sarcocol, starch, indigo, wax, resins, camphor, caoutchouc, gum resins, wood, and suber, though mixed with water, and placed in the most favourable temperature, show scarcely any tendency to change their nature. Oils absorb oxygen from the atmosphere but too slowly to produce any intestine motion. Tannin, some of the acids, and extractive, are gradually decomposed; the surface of the liquid becomes mouldy, and an insipid sediment falls to the bottom; and when the process has once begun, it goes on with greater rapidity. Albumen and fibrin putrify very quickly, but the products have not been ascertained; gluten gradually changes into a kind of cheese.

But it is when several of the vegetable principles are *Greatest in* mixed together, that the fermentation is most perceptible, *com-* *pounds.* and the change most remarkable. Thus when gluten is added to a solution of sugar in water, the liquid soon runs into vinegar, or in certain cases to alcohol and vinegar. When gluten is mixed with starch and water, alcohol and vinegar usually make their appearance; but the greatest part of the starch remains unaltered. It has been observed that certain substances are peculiarly efficacious in exciting fermentation in others. These substances have received the name of *ferments.*

But the phenomena of fermentation do not appear in their greatest perfection in our artificial mixture of vegetable principles. Those complicated parts of plants in which various principles are already mixed by Nature, especially the liquid parts, exhibit the finest specimens of it; such as the sap of trees, the juices of fruits, the decoctions of leaves, seeds, &c. It is from such natural mixtures that we obtain all the products of fermentation which mankind have applied to useful purposes; such as indigo, beer, bread, vinegar, wine, &c. In the present imperfect state of the subject, I shall satisfy myself with an account of the most

Book IV. important of these products of fermentation, and of the phenomena which take place during their formation. I Division. shall divide this Chapter into three Sections : in the first, I shall treat of the fermentation which produces intoxicating liquors; in the second, of the fermentation which produces vinegar; and in the third, of that which reduces the substance to *soil*. These are usually called the *vinous*, *acetous*, and *putrifactive* fermentations.

SECT. I.

OF THE VINOUS FERMENTATION.

UNDER this name is comprehended every species of fermentation which terminates in the formation of an intoxicating liquid. Now these liquids, though numerous, may be comprehended under two general heads; namely, those which are obtained from the *decoctions of seeds*, and those which are obtained from the *juices of plants*. The liquids of the first class are denominated *beer* or *wash*, those of the second *wine*.

I. BEER.

The method of making beer was known in the most remote ages. The Greek writers give the honour of the invention to the Egyptians. Almost every species of corn has been employed for the purpose. In Europe it is usually made from barley, in India from rice, in the interior of Africa from the *holcus spicatus*; * but whatever grain is employed, the process is nearly the same. We shall therefore select, as an example, the beer made in this country from barley.

1. As the grain in its natural state has been found unsuitable for yielding good beer, it is usual, in the first place, to convert it into *malt*.

Malt.   The term *malt* is applied to grain which has been made

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* Park's Travels, p. 63, 8vo Edition.

to germinate artificially to a certain extent, after which the process is stopped by the application of heat.

The barley is steeped in cold water for a period which (as regulated by law) must not be less than 40 hours; but beyond that period the steeping may be continued as long as is thought proper. Here it imbibes moisture, and increases in bulk; while at the same time a quantity of carbonic acid is emitted, and a part of the substance of the husk is dissolved by the steep-water. The proportion of water imbibed depends partly on barley, and partly on the length of time that it is steeped. From the average of a good many trials, it appears that the medium increase of weight from steeping, may be reckoned 0·47; that is to say, every 100 pounds of barley when taken out of the steep weighs 147 pounds. The average increase of bulk is about a fifth; that is to say, that 100 bushels of grain, after being steeped, swell to the bulk of 120 bushels. The carbonic acid emitted while the barley is in the steep is inconsiderable; and it is probable, from the experiments of Saussure, that it owes its formation, at least in part, to the oxygen held in solution by the steep-water.

The steep-water gradually acquires a yellow colour, and the peculiar smell and taste of water in which straw has been steeped. The quantity of matter which it holds in solution varies from $\frac{1}{50}$th to $\frac{1}{100}$th of the weight of barley. It consists chiefly of an extractive matter of a yellow colour and disagreeable bitter taste, which deliquesces in a moist atmosphere, and contains always a portion of nitrate of soda. It holds in solution most of the carbonic acid disengaged. This extractive matter is obviously derived from the husk of the barley, and is that substance to which that husk owes its colour. Accordingly grain becomes much paler by steeping.

After the grain has remained a sufficient time in the steep, the water is drained off, and the barley thrown out of the cistern upon the malt-floor, where it is formed into a rectangular heap, called the *couch*, about 16 inches deep. In this situation it is allowed to remain about 26 hours. It is then turned, by means of wooden shovels, and diminished a little in depth. This turning is repeated twice a day or oftener, and the grain is spread thinner and thinner, till at last its depth does not exceed a few inches.

When placed on the couch, it begins gradually to absorb oxygen from the atmosphere, and to convert it into carbonic acid; at first very slowly, but afterwards more rapidly. The temperature, at first the same with that of the external air, begins slowly to increase; and in about 96 hours the grain is, at an average, about 10° hotter than the surrounding atmosphere. At this time the grain, which had become dry on the surface, becomes again so moist that it will wet the hand, and exhales at the same time an agreeable odour, not unlike that of apples. The appearance of this moisture is called *sweating*. A small portion of alcohol appears to be volatilized at this period. The great object of the maltmen is to keep the temperature from becoming excessive. This they do by frequent turning. The temperature which they wish to preserve varies from 55° to 62°, according to the different modes of malting pursued.

At the period of the sweating the roots of the grains begin to appear, at first like a small white prominence, at the bottom of each seed, which soon divides itself into three rootlets, and increases in length with very great rapidity, unless checked by turning the malt. About a day after the sprouting of the roots, the rudiments of the future stem, called *acrospire* by the maltsters, may be seen to lengthen. It rises from the same extremity of the seed with the root, and advancing within the husk, at last issues from the opposite end: but the process of malting is stopped before it has made such progress.

As the acrospire shoots along the grain, the appearance of the kernel, or mealy part of the corn, undergoes a considerable change. The glutinous and mucilaginous matter is taken up and removed, the colour becomes white, and the texture so loose that it crumbles to powder between the fingers. The object of malting is to produce this change: when it is accomplished, which takes place when the acrospire has come nearly to the end of the seed, the process is stopped by drying the malt upon the kiln. The temperature at first does not exceed 90°; but it is raised very slowly up to 140°, or higher, according to circumstances. The malt is then cleaned, to separate the rootlets, which are considered as injurious.

Such is a short sketch of the process of malting. Barley, by being converted into malt, generally increases two or

three per cent. in bulk; and loses at an average, about a fifth of its weight, or 20 per cent. But of these 20 parts 12 are to be ascribed to kiln-drying, and consist of water, which the barley would have lost had it been exposed to the same temperature: so that the real loss does not exceed eight per cent. From a good many trials, made with as much attention to all the circumstances as possible, the following seems to be the way of accounting for this loss:

Carried off by the steep-water .... 1·5
Dissipated in the floor .... 3·0
Roots, separated by cleaning ...... 3·0
Waste .... 0·5
                              ———
                              8·0

The loss on the floor ought to be entirely owing to the separation of carbon by the oxygen of the atmosphere; but were this the only cause, it would be much smaller than three per cent. Two other causes concur to produce this loss:—1. Many of the roots are broken off during the turning of the malt; these wither and are lost, while others grow in their place:—2. A certain portion of the seeds lose the power of germinating, by bruises or other accidents, and these lose a much greater portion than three per cent. of their real weight. From a good many trials, made with as much care as possible, I am disposed to conclude that the quantity of carbon, separated during the whole process of malting, by the formation of carbonic acid gas, does not exceed two per cent. and that the weight of the roots formed amounts often to four per cent. These two, in reality, include the whole real loss of weight which barley sustains when malted. What is lost in the steep, being husk, need scarcely be reckoned.

The roots appear, from the process, to be formed chiefly from the mucilaginous and glutinous parts of the kernel. The starch is not employed in their formation; but undergoes a change, intended no doubt to fit it for the future nourishment of the plumula. It acquires a sweetish taste, and the property of forming a transparent solution with hot water. In short, it approaches somewhat to the nature of sugar; but is much more soluble, and much more easily decomposed, than that principle. From the experiments

of Saussure on the conversion of starch into sugar, of which an account has been given in a preceding Chapter, there is reason to conclude that this change is brought about by the combination of the starch with water. The action of hot water on barley-meal seems gradually to induce a similar one.

Brewing.   2. Malt thus prepared is ground in a mill, and infused in a large cylindrical vessel, called the *mash-tun*, with somewhat more than its own bulk of water, of a temperature varying from 160° to 180°, according to the fancy of the brewer. The infusion is left covered for two or three hours, and then the liquid drawn off by a cock at the bottom of the vessel. More hot water is afterwards added, and the infusions repeated in a similar manner, till the malt is sufficiently exhausted.

Constituents of wort.   The liquid thus obtained is called *wort*. It has a brown colour, a luscious sweet taste, a peculiar smell, and when the process is properly conducted is perfectly transparent. It consists of the water employed holding the mealy part of the malt in solution. When examined by reagents, it appears to consist chiefly of four different substances held in solution together: namely, 1. A sweet-tasted substance, to which the name of *saccharine matter* has been given. It is by far the greatest in point of quantity. This substance when separated has a light-brown colour; when dried at 160°, it forms a brittle mass with a glazed surface; at the temperature of 180°, or a little higher, its colour becomes darker; and if we keep it in that temperature, moistening it occasionally, it becomes at last almost black, loses its sweet taste altogether, and acquires a sharp disagreeable one. In a temperature somewhat higher, but under the boiling point, it is charred. It is very soluble in water, and if once dissolved can scarcely be recovered again by evaporation without considerable loss. Alcohol dissolves it very imperfectly cold, and when heat is applied it deprives the alcohol of a portion of water, and forms a tough mass like turpentine, which refuses to dissolve. The specific gravity of this saccharine matter is 1·552. It appears to be the essential constituent of wort. 2. Starch. The presence of this substance is easily detected by dropping the infusion of nutgalls into wort; a precipitate appears, which is mostly redissolved by heating the liquid to 120°. 3. The

insoluble part of the precipitate is a combination of gluten and tannin. The proportion of gluten in wort is very inconsiderable. That of the starch probably diminishes in proportion as the barley is more completely malted. I have detected starch in pretty old and perfectly transparent ale; but the gluten had disappeared. New ale, however, often contains traces of it. 4. The fourth ingredient in wort is *mucilage*, which precipitates in flakes when the wort is dropped into alcohol. Its quantity is more considerable in the worts last drawn off than in the first worts.

The wort is boiled with a quantity of hops, which vary considerably, but which may be stated in general at about $\frac{1}{40}$th of the weight of the malt. When sufficiently concentrated, it is thrown into very wide flat vessels called *coolers*, placed in the most open situation that can be had. Here it is cooled down to the temperature of about 52°, and then let down into a deep round wooden vessel called the *fermenting tun*. The specific gravity of the wort when put into the fermenting tun varies very much. The wort of strong ale is sometimes as low as 1·060; sometimes as high as 1·127. In the first case it contains 14·25 per cent. of solid matter; in the second 28·2 per cent. The wort of small beer varies from 1·015 to 1·040; the first containing not quite 3·5 per cent. and the second about 9·5 per cent. of solid matter.

The use of the hops is partly to communicate a peculiar flavour, from the oil which they contain; partly to cover the sweetness of saccharine matter by the bitter principle which they contain; and partly to counteract the tendency which wort has to run into acidity.

If the wort be let down into the fermenting tun at the temperature of 60°, or rather higher, the substances which it holds in solution begin gradually to act upon each other, and to decompose each other. The temperature rises, an intestine motion takes place, a scum collects on the surface, and carbonic acid gas is emitted. This intestine motion is called *fermentation*. The disposition of wort to ferment is not sufficiently great to induce it to do so with the requisite rapidity. It takes place so slowly and imperfectly, that the liquor runs into acidity before the formation of ale has made sufficient progress. To prevent this, it is requisite to add to the wort some substance which has

the property of inducing speedy fermentation.   The sub-
stance made choice of is *yeast*, or the frothy matter which
collects on the surface of the beer while fermenting.   The
quantity of yeast used by brewers is but small, generally
about a gallon to every three barrrels of the wort.

The yeast thus added appears to act chiefly upon the
saccharine matter held in solution in the wort, to decom-
pose it while it undergoes partial decomposition itself.   By
this mutual action the saccharine matter disappears, the
specific gravity of the wort diminishes, and its properties
alter, being converted into the intoxicating liquor called
ale.   During this mutual action the temperature of the
liquid increases, and the increase depends upon the vio-
lence of the fermentation.   In ale worts the rise of tem-
perature is but small, amounting at an average to about
15°, because the quantity of yeast is small; but in the fer-
mentation of wash, it often amounts to 50°, or even more
in some cases.

Analysis of   Considerable exertions have been made by chemists, of
yeast.   late, to ascertain the nature of the substance in yeast which
produces this striking effect upon wort, and to discover it
if possible in other substances.   Westrumb examined the
yeast of beer.   From 15360 parts of it he obtained the
following substances:

Potash	13
Carbonic acid	15
Acetic acid	10
Malic acid	45
Lime	69
Alcohol.............	240
Extractive...........	120
Mucilage............	240
Saccharine matter	315
Gluten..............	480
Water...............	13595

15142

Besides some traces of phosphoric acid and of silica.*   But
it is obvious, that all these ingredients are not essential.
From the experiments of Westrumb, it appears that when

* Crell's Annals, 1796, i. 13.

the yeast is filtered, a matter remains upon the filter which possesses the properties of gluten; that when this substance is separated the yeast loses the property of exciting fermentation, but recovers it again when the gluten is added. Hence it follows that this glutinous matter is the Gluten its essential constituent of the yeast. When yeast is kept for essential constituent. some time in cylindrical glass vessels, a white substance not ent. unlike curd separates, and swims upon the surface. If this substance be removed, the yeast loses the property of exciting fermentation. This substance possesses many of the properties of gluten, though it differs from it in others. Its colour is much whiter; it has not the same elasticity; and its particles do not adhere with the same force. It dissolves more readily in acids. I have little doubt that this is the part of yeast which is the real ferment. It may be considered as gluten somewhat altered, and much more disposed to decomposition. It existed, no doubt, in the raw grain, but underwent considerable modifications during the process of malting, and probably others during the fermentation of the beer from which it separated.

That a substance analogous to gluten is the real ferment, appears also from the experiments of Fabroni, who published a Treatise on Wine-making in 1785, which gained the prize proposed by the Florence Academy. By heating the juice of grapes, and passing it through a filter, he separated an adhesive matter which possessed the properties of gluten. The juice deprived of this substance refused to ferment, but it fermented as usual when the glutinous matter was again added. The observations of Thenard confirm those of Fabroni. He found in the juices of all fruits examined, a substance similar to that described by Fabroni, and which, according to him, is absolutely the same with pure yeast. This substance is insipid, does not change vegetable blues, is insoluble in water, loses $\frac{3}{4}$ths of its weight when dried, and is decomposed like animal substances. When eight parts of it were distilled, they left 2·83 of charcoal, and yielded 1·61 of water, 1·81 of oil, and a quantity of ammonia, which, when saturated with muriatic acid, formed 1·46 of sal-ammoniac; the gas obtained weighed 0·33, and consisted of $\frac{1}{5}$th carbonic acid, and $\frac{4}{5}$ths of carbureted hydrogen, requiring $1\frac{1}{2}$ time its bulk of oxygen to consume it. Nitric acid, even when

diluted, converts it into a species of tallow. With potash it forms a soap, while ammonia is disengaged. When mixed with sugar and a sufficient quantity of water, fermentation takes place, carbonic acid is disengaged, and a vinous liquor formed. By this action the ferment loses the whole of its azote, and becomes incapable of exciting fermentation when mixed with a new portion of sugar.* An experiment of Kirchhoff throws considerable light on the nature of yeast. Barley-meal contains both gluten and starch. If pure starch be infused in hot water it is not converted into sugar. Neither does gluten become saccharine matter when treated in the same way. But if a mixture of pure, dried, pulverized wheat gluten and potatoe starch be infused in hot water, the starch is converted into sugar. During the process an acid is evolved. The gluten is little altered in appearance, and if the liquid be filtered most of it remains upon the filter. But it cannot be employed successfully a second time to convert starch into sugar. It appears then that it is some substance connected with the gluten that acts upon the starch, and converts it into sugar.†

The essential constituent of yeast, then, may be considered as a species of gluten, differing in several respects from the gluten of wheat. When mixed with the wort, this substance acts upon the saccharine matter; the temperature rises, carbonic acid is disengaged, and the saccharine matter is converted into ale. The yeast soon collects on the top of the liquid, but the brewer occasionally mixes it again to continue the fermentation. The quantity of yeast employed being small, the saccharine matter is but imperfectly decomposed. Hence a considerable portion of it still remains in the ale, and gives it that glutinousness and body for which it is remarkable. The specific gravity of ale varies very much according to the original strength of the wort, and the extent to which the fermentation has been carried. The limits may be stated at about 1·035 and 1·012.

Ale.

The properties of ale are so well known that no description is deemed necessary. It possesses intoxicating quali-

* Thenard, Ann. de Chim. xlvi. 308.
† Schweigger's Jour. xiv. 389.

ties, and holds a quantity of alcohol in solution; which Chap. IV. varies considerably according to the original strength of the wort. I distilled a quantity of London brewed ale. The specific gravity of the wort was 1·0676. The specific gra- Alcohol in vity of the ale was 1·0255. One hundred parts of it by ale and beer. weight yielded

9·354 parts of proof spirit of specific gravity .. 0·91985
Or,
5·817 parts of alcohol of the specific gravity . 0·825

Another specimen of ale was distilled. The specific gra-vity of the wort was 1·0813. The specific gravity of the ale after fermentation was 1·02295. One hundred parts of it by weight yielded

11·13 parts of proof spirit.
6·92 parts of alcohol of the specific gravity 0·825.

Mr. Brande* distilled ale and brown stout porter. The quantity of alcohol which he extracted from each by mea-sure was as follows:

Brown stout .. 6·80 per cent.
Ale .... 8·88

When reduced to weight, the quantity of alcohol of the specific gravity 0·825 obtained from each, will be as follows:

Brown stout .. 5·61 per cent.
Ale .... 7·33

II. WASH.

Ale being intended as an article of food, and its value de-pending in a great measure on its flavour and appearance, particular attention is paid to obtain these in as great per-fection as possible. But there is another species of ale which is brewed by the distillers for the express purpose of procuring from it ardent spirits by a subsequent process. The method which they follow is in several respects differ-ent. In particular, they endeavour to carry the fermenta-tion to as great a length as possible, because the quantity of spirits is proportional to the saccharine matter decom-posed, whatever remains unaltered yielding none. It is

* Phil. Trans. 1811, p. 346.

Book IV. here, therefore, that the effects of fermentation can be best observed.

Brewing. 1. In this country the distillers do not brew from pure malt; they use chiefly raw grain. The proportion of malt varies from a third to a tenth part of the raw grain employed. This mixture they grind to meal, infuse with water at a heat considerably lower than that of the water used by the brewers, and employ much more agitation to mix it completely. The wort is drawn off and cooled in the usual way, and fresh water poured on to exhaust the grain.

The wort thus formed is not so transparent as that from malt, but its taste is nearly as sweet. It would appear, therefore, that the starch in the raw grain undergoes a certain change during the mashing, and is brought towards the state of saccharine matter.

In this country, where the duty is levied chiefly upon the *wash*,* the distillers make the specific gravity of their wort as high as from 1·084 to 1·110: this they do not by boiling, but by *lobbing*; that is, by preparing a strong infusion of the flour of malt, or of barley and malt and hot water, and adding this almost saturated solution to the wort till it has acquired the requisite strength. But in Holland, where the duties are levied in a different way, the specific gravity of the wort is much lower.

Fermenta-
tion. The wort thus made is let down into the fermenting tun at a temperature varying from 55° to 70°, according to the quantity, the season, the goodness of the yeast, and the skill of the distiller. Here it is mixed successively with considerable portions of the best yeast that can be procured, and the fermentation is urged as far as it can be made to go. The process lasts about ten days, and the temperature rises usually to between 90° and 100°, and sometimes even higher. Great quantities of carbonic acid are disengaged, and the liquid becomes specifically lighter; sometimes sinking to 1·000, and usually to from 1·007 to 1·002. The success of the fermentation is estimated by this loss of specific gravity.

The wash thus prepared is distilled. What comes over first is denominated *low wine*, and is concentrated by a second distillation.

* This is the name given to the fermented wort of distillers.

This fermentation is obviously the consequence of the action of the peculiar ferment in yeast upon the saccharine matter of the wort. Even when the fermentation is carried to its greatest extent, it does not appear that the whole solid matter held in solution by the wort is decomposed. Nine trials were made upon the wort of pure malt; in all of them the fermentation went on pretty successfully, as may be seen from the following table :

Specific gravity of the wort.	Specific gravity of the wash.
1·040	1·0014
1·056	1·0016
1·050	1·000
1·0492	1·0012
1·0465	1·0045
1·045	1·0047
1·0465	1·0007
1·051	1·0007
1·0524	1·0004

When a portion of these different liquids was evaporated to dryness, the quantity of solid matter which it left was found to amount to $\frac{1}{5}$th, at an average, of the original quantity. Thus $\frac{4}{5}$ths had been decomposed by the fermentation, and $\frac{1}{5}$th still remained. This matter was still capable of fermentation, when redissolved in water and mixed with fresh yeast. On comparing the quantity of alcohol of 0·825, obtained in these trials with the weight of solid matter of the malt which had been decomposed by the fermentation, the result was, that every pound weight of solid matter, so decomposed, furnished almost exactly half a pound of alcohol, of the specific gravity 0·825.

When sugar, dissolved in four times its weight of water, and mixed with yeast, is placed in the proper temperature, it ferments precisely as wort does, and yields the same products. It has been employed, therefore, by chemists as a less complicated means of ascertaining the phenomena of fermentation. Thenard mixed 60 parts of yeast with 300 of sugar, and fermented them in the temperature of 59°. In four or five days, he informs us, that all the saccharine matter had disappeared.* The quantity of carbonic acid

* There is reason to doubt the precision of this assertion, as it never happens in the great scale, where every thing is much more favourable.

Book IV. evolved amounted, by weight, to 94·6 parts.   It was per-
fectly pure, being completely absorbed by water.*   The
fermented liquid, being distilled, yielded 171·5 parts of
alcohol, of the specific gravity ·822.   When the residue
of the distillation was evaporated, 12 parts of a nauseous
acid substance were obtained; and 40 parts of the yeast
still remained; but, upon examination, it had lost the
whole of its azote.   This experiment gives us the following
quantities :

1. *Substances fermented.*

Sugar 300
Yeast 60
                     ———
                     360

2. *Products of fermentation.*

Alcohol of ·822 .... 171·5
Carbonic acid .... 94·6
Nauseous residue ..... 12·0
Residual yeast........ 40·0
                       ———
                       318·1
Loss .... 41·9

But as the nauseous residue and residual yeast, nearly
make up the quantity of yeast employed, let us consider
only the products of decomposed sugar, supposing the loss
to be proportionally divided between the carbonic acid and
alcohol.   Now alcohol of the specific gravity 0·822 contains
one tenth of its weight of water which can be separated from
it; and if we suppose with Saussure, that absolute alcohol
contains 8·3 per cent. of water, then the products of sugar
decomposed by fermentation, according to the preceding
experiment, are as follows :

Alcohol .... 47·70
Carbonic acid .. 35·34
                 ———
                 83·04

* The very pungent aromatic odour which carbonic acid has when dis-
engaged from the fermenting tun shows that it contains a portion of the
wash ; and this has been verified by actual experiment.

Or in 100 parts

$$\text{Alcohol} \ldots\ldots 57\cdot44$$
$$\text{Carbonic acid} \ldots 42\cdot56$$
$$\overline{\hspace{2cm}}$$
$$100\cdot00$$

This result approaches so nearly that of Lavoisier, that there is reason to suspect that the coincidence is more than accidental.

We have found reason to conclude that sugar is composed of

$$5 \text{ atoms oxygen} \ldots = 5$$
$$6 \text{ atoms carbon} \ldots = 4\cdot5$$
$$5 \text{ atoms hydrogen} = 0\cdot625$$
$$\overline{\hspace{2cm}}$$
$$10\cdot125$$

Alcohol appears to be a compound of

$$1 \text{ atom oxygen} \ldots = 1$$
$$6 \text{ atoms carbon} \ldots = 1\cdot5$$
$$3 \text{ atoms hydrogen} = 0\cdot375$$
$$\overline{\hspace{2cm}}$$
$$2\cdot875$$

And carbonic acid of

$$2 \text{ atoms oxygen} = 1$$
$$1 \text{ atom carbon} = 1\cdot5$$
$$\overline{\hspace{2cm}}$$
$$2\cdot5$$

Now if we suppose 1 atom of sugar and 1 atom of water to be decomposed by the fermentation, it is obvious, that they may be converted into 2 atoms of alcohol and 2 atoms of carbonic acid. For an atom of alcohol and an atom of water are composed of

$$6 \text{ atoms oxygen.}$$
$$6 \text{ atoms carbon.}$$
$$6 \text{ atoms hydrogen.}$$

	Oxygen.	Carbon.	Hydrogen.
2 atoms of alcohol consist of ..	2 atoms,	4 atoms,	6 atoms.
2 atoms of carbonic acid of ..	4	2	
Making together	6	6	6

On that supposition, the weight of } 5·75
the alcohol evolved ought to be }

And that of the carbonic acid . . . . . . 5·5

Or per cent.

Alcohol . . . . . . 51·12
Carbonic acid . 48·88
—————
100·00

Whether an acid be necessary for fermentation.   Fabroni found that the gluten of wheat acted but imperfectly as a ferment; but that its efficacy was much improved by the addition of tartar. Berthollet repeated these experiments successfully. He ascribes the efficacy of tartar to the property which it has of promoting the solubility of the gluten. The presence of an acid was supposed formerly to be necessary for fermentation; but this does not seem to be the case. It is true, indeed, that an acid usually makes its appearance during fermentation. The formation of this acid has been ascribed to the action of the yeast upon the mucilaginous or starchy parts of the wort: but from the experiments of Fourcroy and Vauquelin, it appears that it always makes its appearance when wort is fermented without any yeast. In these trials they obtained only vinegar, and no alcohol. When the wort, either of raw grain or of malt, is fermented at the temperature of 80°, without any yeast, the gas which comes over consists of one-half carbonic acid and one-half hydrogen; but at a lower temperature pure malt-wort does not yield any inflammable gas.*

III. WINE.

There is a considerable number of ripe fruits from which a sweet liquor may be expressed, having at the same time **Fruits affording wine.** a certain degree of acidity. Of such fruits we have in this country the apple, the cherry, the gooseberry, the currant, &c. but by far the most valuable of these fruits is the *grape*, which grows luxuriantly in the southern parts of Europe. From grapes, fully ripe, may be expressed a liquid of a sweet taste, to which the name of *must* has been **Must.** given. This liquid is composed almost entirely of five

———
* Ann. des Mus. d'Hist. vii. 16.

1

ingredients; namely, *water, sugar, jelly, gluten,* and *tartaric acid* partly saturated with potash. The quantity of sugar which grapes fully ripe contain is very considerable; it may be obtained in crystals by evaporating must to the consistence of syrup, separating the tartar which precipitates during the evaporation, and then setting the must aside for some months. The crystals of sugar are gradually formed.* From a French pint of must, the Marquis de Buillion extracted half an ounce (French) of sugar, and $\frac{1}{16}$ ounce of tartar.† According to Proust, the Muscadine grape contains about 30 per cent. of a peculiar species of sugar. ‡

When must is put into the temperature of about 70°, the different ingredients begin to act upon each other, and what is called *vinous fermentation* commences. The phenomena of this fermentation are an intestine motion in the liquid; it becomes thick and muddy, its temperature increases, and carbonic acid gas is evolved. In short, the very same changes take place as have been remarked when describing the fermentation of ale. In a few days the fermentation ceases, the thick part subsides to the bottom, or rises to the surface, the liquid becomes clear, it has lost its saccharine taste, and assumed a new one; its specific gravity is diminished; and it has become the liquid well known under the name of *wine.*

Undergoes the vinous fermentation.

As this fermentation takes place without adding any *ferment,* it is obvious that the requisite substance is present in the juice. This substance was separated, and found by Fabroni to be analogous to the gluten of plants; and gluten being substituted for it, the fermentation succeeded. Fabroni has shown that the saccharine part of must resides in the cells of the grapes; while the glutinous matter, or ferment, is lodged on the membranes that separate the cells. Hence it follows, that in the fruit these two substances are not in contact. It is only after the juice is squeezed out that they are mixed. All other juices which undergo a spontaneous fermentation at the requisite temperature, have been shown by Thenard and Seguin to contain a similar substance. The formation of wine, then, is owing to the action of this glutinous matter on the saccharine sub-

* Bullion, Jour. de Phys. xxix. 3.   † Ibid. p. 5.   ‡ Ibid. lvi. 113.

stance of the juice, precisely as happens in the fermentation of ale.

Gay-Lussac has shown that the juice of grapes, and indeed the juice of all fruits will not ferment, if completely excluded from the air. But if a little oxygen gas be let up to it, this gas is immediately absorbed, a brisk fermentation commences, and the quantity of carbonic acid gas evolved is 100 times as great as that of the oxygen gas absorbed.[*] It would be curious to know whether the same thing holds with respect to the wort of malt. It is not improbable that it does ; but wort ferments so imperfectly without the addition of yeast, that it would not be easy to try the experiment.

All those juices of fruits which undergo the vinous fermentation, either with or without the addition of sugar, contain an acid. We have seen already in the First Chapter, that the vegetable acids are obtained chiefly from fruits. The apple, for instance, contains malic acid; the lemon, citric acid ; the grape, tartaric and malic acids. The Marquis de Bullion has ascertained that must will not ferment if all the tartar which it contains be separated from it; but it ferments perfectly well on restoring that salt.[†] The same chemist ascertained that the strength of wine is considerably increased by adding tartar and sugar to the must.[‡] We may conclude from these facts, that the presence of a vegetable acid is of importance in these spontaneous fermentations. It deserves attention, that Bullion obtained more tartar from verjuice than from wine ; and he observed, that the more the proportion of sugar in grapes increased, the more that of tartar diminished. [§]

It seems more than probable, from the experiments of Bullion and Chaptal, that the tartaric acid is partly decomposed during the fermentation, and that a portion of malic acid is formed. The process, therefore, is more complicated than was suspected by Lavoisier. It is obviously analogous to combustion, as is evident from the evolution of caloric and the formation of carbonic acid, which is a product of combustion. Proust has ascertained that, during

* Ann. de Chim. lxxvi. 245.

† Jour. de Phys. xxix. 4. But the addition of salt of wood sorrel did not restore the fermentation.

‡ Ann. de Chim. xxxvi. 20.   § Jour. de Phys. xxix. 4.

the fermentation, not only carbonic acid, but azotic gas also, is disengaged. This is a demonstration that all the constituents of must are concerned; for sugar does not contain that principle.* Thenard could detect no azote in the carbonic acid from wort.

After the fermentation has ceased, the liquor is put into casks, where the remainder of the sugar is decomposed by a slow fermentation; after which the wine, decanted off the extractive matter, is put up in bottles.

The properties of wine differ very much from each other, according to the nature of the grapes from which the must was extracted, and according to the manner in which the process was conducted. These differences are too well known to require a particular description. But all wines contain less or more of the following ingredients; not to mention water, which constitutes a very great proportion of every wine.

<div style="text-align: right">Component parts of wine.</div>

1. *An Acid.*—All wines give a red colour to paper stained with turnsole, and of course contain an acid. Chaptal has ascertained that the acid found in greatest abundance in wine is the malic, but he found traces also of citric acid; and it is probable that wine is never entirely destitute of tartar. All wines which have the property of frothing when poured into a glass contain also carbonic acid, to which they owe their briskness. This is the case with champagne. These wines are usually weak; their fermentation proceeds slowly, and they are put up in close vessels before it be over. Hence they retain the last portions of carbonic acid that have been evolved.

<div style="text-align: right">An acid,</div>

2. *Alcohol.*—All wine contains less or more of this principle, to which it is indebted for its strength; but in what particular state of combination it exists in wine cannot easily be ascertained. It is undoubtedly intimately combined with the other component parts of wine; but Mr. Brande has shown by very decisive experiments that all wines contain alcohol ready formed, and that it is merely separated during the distillation of these liquids, and not formed as had been advanced by Fabroni.† These experiments were afterwards confirmed by Gay-Lussac.‡ When

<div style="text-align: right">Alcohol,</div>

* Jour. de Phys. lvi. 113.
† Phil. Trans. 1811, p. 337; and 1813, p. 82.
‡ Ann. de Chim. lxxxvi. 175.

Book IV. wine is distilled, the alcohol readily separates. The distil-
lation is usually continued as long as the liquid which
comes over is inflammable. The quantity obtained varies
according to the wine, from a fourth to a fourteenth part of
the wine distilled. The spirit thus obtained is well known
under the name of *brandy*. Bullion has observed, that
when wine is distilled new it yields more alcohol than if it
be allowed to get old.* What remains after this distilla-
tion is distinguished in France by the name of *vinasse*. It
consists of tartar, &c. and when evaporated to dryness, and
subjected to combustion, yields potash.

Extract,   3. *Extractive matter.*—This matter exists in all wines :
but its proportion diminishes according to the age of the
wine, as it gradually precipitates to the bottom.

Oil,   4. Every wine is distinguished by a peculiar flavour and
odour, which probably depends upon the presence of a
volatile oil, so small in quantity that it cannot be separated.

And co-   5. The *colouring matter* of wine is originally contained
louring
matter.   in the husk of the grape, and is not dissolved till the alco-
hol be developed. This matter is analogous to the other
colouring matters of plants : a set of bodies possessed of
remarkable properties, but too little examined hitherto to
be introduced with much advantage into a System of Che-
mistry. This colouring matter precipitates when the wine
is exposed to the heat of the sun. It sometimes also pre-
cipitates in old wine, and it may be easily separated by
pouring lime-water into wine.†

The following table, containing the different substances
which Neumann extracted from various wines, is worth
preserving. ‡

* Jour. de Phys. xxix. 6.
† The most precise account of wine and of the vinous fermentation,
hitherto published, is by Chaptal, and is contained in the 36th and 37th
volumes of the Ann. de Chim.
‡ Neumann's Chemistry, p. 447.

A quart of	Highly rectified Spirit.			Thick, oily, unctuous, resinous matter.			Gummy and tartarous matter.			Water.			
	oz.	dr.	gr.	oz.	dr.	gr.	oz.	dr.	gr.	lb.	oz.	dr.	gr.
Aland	1	6	00	3	2	00	1	5	00	2	5	3	00
Alicant......	3	6	00	6	0	20	0	1	40	2	2	6	00
Burgundy ...	2	2	00	0	4	00	0	1	40	2	9	0	20
Carcassone...	2	6	00	0	4	10	0	1	20	2	8	4	30
Champagne ..	2	5	20	0	6	40	0	1	00	2	8	3	00
French	3	0	00	0	6	40	0	1	00	2	8	0	20
Frontignac...	3	0	00	3	4	00	0	5	20	2	4	6	30
Vin de Grave..	2	0	00	0	6	00	0	2	00	2	9	0	00
Hermitage. ...	2	7	00	1	2	00	0	1	40	2	7	5	20
Madeira.	2	3	00	3	2	00	2	0	00	2	4	3	00
Malmsey.......	4	0	00	4	3	00	2	3	00	2	1	2	00
Vino de Monte Pulciano	2	6	00	0	3	00	0	2	40	2	8	0	20
Moselle.	2	2	00	0	4	20	0	1	30	2	9	0	10
Muscadine. ...	3	0	00	2	4	00	1	0	00	2	5	4	00
Neufschatel ..	3	2	00	4	0	00	1	7	00	2	2	7	00
Palm Sec	2	3	00	2	4	00	4	4	00	2	2	5	00
Pontac	2	0	00	0	5	20	0	2	00	2	9	0	40
Old Rhenish .	2	0	00	1	0	00	0	2	20	2	8	5	40
Rhenish......	2	2	00	0	3	20	0	1	34	2	9	1	06
Salamanca...	3	0	00	3	4	00	2	0	00	2	3	4	00
Sherry	3	0	00	6	0	00	2	2	00	2	0	6	00
Spanish.	1	2	00	2	4	00	9	4	00	1	10	6	00
Vino Tinto ..	3	0	00	6	4	00	1	6	00	2	0	6	00
Tokay	2	2	00	4	3	00	5	0	00	2	0	3	00
Tyrol red wine	1	4	00	1	2	00	0	4	00	2	8	6	00
Red wine	1	6	00	0	4	40	0	2	20	2	9	3	20
White.......	2	0	00	0	7	00	0	3	00	2	7	0	00

To this head belong not only common wine, but all the intoxicating liquors made from vegetable juices; as *cyder* from apples, *perry* from pears, *currant* wine, &c. likewise the liquor made from the juice of the sugar cane, the sugar maple, &c.

I shall here subjoin a table of the quantity of alcohol by measure of the specific gravity 0·825 which different wines

Book IV. yielded to Mr. Brande in his different experiments. The results of these trials are the more valuable, because the wines examined were all genuine.*

	Alcohol per cent. by measure.		Alcohol per cent. by measure.
Lissa	26·00	Marsala	17·26
Ditto	24·00	Ditto	26·30
Port	21·40	Ditto	25·50
Ditto	22·30	Red Champagne	11·30
Ditto	23·39	White Champagne	12·80
Ditto	23·71	Burgundy	14·53
Ditto	24·29	Ditto	11·95
Ditto	25·83	White Hermitage	17·43
Ditto	21·40	Red Hermitage	12·32
Ditto	19·00	Hock	14·37
Madeira	19·34	Ditto	8·88
Ditto	21·40	Vin de Grave	12·80
Ditto	23·93	Frontignac	12·79
Ditto	24·42	Cole Roti	12·32
Sherry	18·25	Rousillon	17·26
Ditto	18·79	Cape Madeira	18·11
Ditto	19·81	Cape Muschat	18·25
Ditto	19·83	Constantia	19·75
Claret	12·91	Tent	13·30
Ditto	14·08	Sheraaz	15·52
Ditto	16·32	Syracus	15·28
Calcavella	18·10	Nice	14·63
Lisbon	18·94	Tokey	9·88
Malaga	17·26	Raisin Wine	25·77
Ditto, kept since 1666	18·00	Grape Wine	18·11
		Currant Wine	20·55
Bucellas	18·49	Gooseberry Wine	11·84
Red Madeira	18·40	Elder Wine	9·87
Malmsey Madeira	16·40	Cyder	9·87
Marsala	25·87	Perry	9·87

* Phil. Trans. 1811, p 345; 1813, p. 87. Journal of the Royal Institution, i. 136.

SECT. II.

OF THE ACETOUS FERMENTATION.

IF wine or beer be kept in a temperature between 70° and 90°, it gradually becomes thick, its temperature augments, filaments are seen moving through it in every direction, and a kind of hissing noise may be distinguished. These intestine motions gradually disappear, the filaments attach themselves to the sides and bottom of the vessel, and the liquor becomes transparent. But it has now lost its former properties, and is converted into acetous acid. This intestine decomposition has been long distinguished by the name of *acetous fermentation*, because its product is *acetic acid*. That this fermentation may take place, certain conditions must be attended to. The most important of these will appear from the following observations :

Wine ferments and becomes sour.

1. Neither pure alcohol, nor alcohol diluted with water, is susceptible of this change. The weaker the wine or the beer is on which the experiment is made, the more readily it is converted into vinegar : the stronger they are they resist the change with the greater obstinacy. But it results from the experiments of Beccher, that strong wines, when they are made to undergo the acetous fermentation, yield a much better and stronger vinegar than weak wines. Hence it follows that alcohol, though of itself it refuses to undergo the change, yet when other bodies are present which readily ferment, is decomposed during the process, and contributes to the formation of the acetic acid.

Alcohol not susceptible of this change.

2. Wine, entirely deprived of glutinous matter, either by spontaneous deposition or by clarification, does not undergo the acetous fermentation, unless some mucilaginous matter be mixed with it. Chaptal exposed old wine destitute of this matter, in open bottles, to the greatest summer heat of Montpelier for 40 days, and yet it did not become sour : but upon adding some vine leaves to the same wine, it became acid in a few days.* When the water in which gluten of wheat has been allowed to ferment is mixed with sugar, the liquid is converted into vinegar without fermentation, without effervescence, and without the contact of

Glutinous matter necessary.

* Ann. de Chim. xxxvi. 245.

3

Book IV. air.* The nature of this curious change has not been ex-
plained.

Carbonic acid form- ed.

3. Wine never becomes sour, provided it be completely deprived of all access to atmospheric air. The reason is, that during the acetous fermentation the oxygen of the atmosphere is partly converted into carbonic acid. It was supposed to have been absorbed; but the late experiments of Saussure have shown that this is not the case. He found, that when wine was converted into vinegar in a given portion of air, the bulk was not diminished; the quantity of carbonic acid just compensating the oxygen which had disappeared, excepting in as far as that carbonic acid was absorbed by the liquid. The quantity of carbonic acid formed during this conversion of wine into vinegar does not seem to be great; amounting, in Saussure's trials, to about twice the bulk of the wine.† Hence the reason that wine or beer is apt to become sour after the cork has been drawn, and still more apt when part has been poured out of the bottle.

A certain tempera- ture requir- ed.

4. A pretty high temperature is necessary for the commencement of the acetous fermentation. Wine or beer (unless very weak) scarcely becomes sour under the temperature of 65° or 70°. The fermentation is very apt to commence when the temperature suddenly rises. It is said, too, that wine and beer are more apt to become sour at certain seasons of the year than at others.

The vinegar makers in this country keep their wash in stoves, heated to about the temperature of 80°, till the change is completed. From the experiments of Fourcroy and Vauquelin, it appears that vinegar made from grain holds in solution a quantity of gluten, and that a great part of it is separated by heating the vinegar boiling hot. This separation prevents the vinegar from being so apt to spoil.

Effects of the fermen- tation.

5. When the acetous fermentation is completed, the whole of the malic acid originally contained in the wine has disappeared as well as the alcohol. We must conclude, therefore, that they have been both converted into acetic acid. Part of the glutinous matter has also undergone the same change, and seems indeed to have been the substance

* Fourcroy and Vauquelin, Ann. de Mus. d'Hist. Nat. vii. 4.
† Recherches Chimique sur la Vegetation, p. 144.

that first began the change. Part of it is deposited in the state of flakes; part remains in solution, and disposes the vinegar to decomposition. Vinegar also contains a little tartar, and probably also citric acid. Malic acid is also found in new vinegar; a proof that this part of the wine is the last to undergo the acetous fermentation.

6. From the experiments of Cadet it appears, that sugar is the essential constituent in liquors to be converted into vinegar, and that the quantity of vinegar formed is proportional to the sugar. But if the sugar exceed an eighth part of the liquid, the whole is not decomposed. Seven water, one sugar, and some yeast, ferment in a proper temperature, and form an excellent vinegar.*

7. Acetic acid is formed in many other cases of the decomposition of vegetables besides the acetous fermentation. These have been pointed out with much ingenuity by Vauquelin and Fourcroy. They may be reduced under three heads. First, when sugar, gum, wood, &c. are distilled in a retort, or even burnt in the open fire, acetic acid separates in combination with an empyreumatic oil, which gives it a peculiar odour. Hence it was mistaken for other acids, and distinguished by the names of *pyromucous, pyrolignous, acids,* till its real name was ascertained by these distinguished chemists.† Secondly, when concentrated sulphuric acid is poured upon the same vegetable bodies, they are decomposed in a very different manner; being converted into water, charcoal, and acetic acid. Thirdly, acetic acid is evolved in considerable quantity during the spontaneous decomposition of urine and some other animal substances. Thus it appears that the component parts of acetic acid are extremely apt to combine together in those proportions which constitute that important acid.

Acetic acid formed by other processes.

SECT. III.

OF PUTRIFACTION.

ALL vegetable substances, both complete plants and their component parts separately, when left entirely to them-

Nature of putrifaction.

* Ann. de Chim. lxii. 248.   † Ibid. xxxv. 83.

Book IV. selves, are gradually decomposed and destroyed, provided moisture be present, and the temperature be not much under 45°, nor too high to evaporate suddenly all the moisture. This decomposition has obtained the name of *putrifaction*.

It proceeds with most rapidity in the open air; but the contact of air is not absolutely necessary. Water is in all cases essential to the process, and therefore is most probably decomposed.

Putrifaction is constantly attended with a fetid odour, owing to the emission of certain gaseous matters, which differ according to the putrifying substance. Some vegetable substances, as gluten and cruciform plants, emit ammonia; others, as onions, seem to emit phosphureted hydrogen gas. Carbonic acid gas and hydrogen gas, impregnated with unknown vegetable matters, are almost constantly emitted in abundance. From the experiments of Saussure, we learn, that when moist wood is left exposed to the air, a portion of the oxygen of the atmosphere is converted into carbonic acid; for the quantity of this acid formed is just equal to the bulk of the oxygen which disappears. When the experiment is made under receivers, no other gas can be detected except carbonic acid; but in the open air the wood loses a much greater proportion of its weight than can be accounted for by the carbon thus abstracted. This he ascribes to the escape of oxygen and hydrogen under the form of water. Hence the quantity of carbon in a given weight of rotten wood is greater than in the same weight of fresh; but when the putrifaction goes on in water without the contact of air, the wood becomes white and light, and contains a smaller proportion of carbon than when fresh.* The nature and constituents of vegetable mould, as far as known, have been detailed in the preceding Chapter. Our chemical knowledge of vegetable compounds is still by far too limited to enable us to follow this very complicated process of putrifaction with any chance of success.

* Recherches Chimique sur la Vegetation.

BOOK V.

OF ANIMALS.

WHEN we compare animals and vegetables together, each in their most perfect state, nothing can be easier than to distinguish them. The plant is confined to a particular spot, and exhibits no mark of consciousness or intelligence; the animal, on the contrary, can remove at pleasure from one place to another, is possessed of consciousness, and a high degree of intelligence. But on approaching the contiguous extremities of the animal and vegetable kingdom, these striking differences gradually disappear, the objects acquire a greater degree of resemblance, and at last approach each other so nearly, that it is scarcely possible to decide whether some of those species which are situated on the very boundary belong to the animal or vegetable kingdom.

Animals and vegetables

To draw a line of distinction, then, between animals and vegetables, would be a very difficult task: but it is not necessary at present to attempt it; for almost the only animals whose bodies have been hitherto examined with any degree of chemical accuracy, belong to the most perfect classes, and consequently are in no danger of being confounded with plants. Indeed, the greater number of facts which I have to relate apply only to the human body, and to those of a few domestic animals. The task of analysing all animal bodies is immense, and must be the work of ages of indefatigable industry.

Not easily distinguished.

This part of the subject naturally divides itself into four Chapters. In the First Chapter, I shall give an account of the different ingredients hitherto found in animals, such of them at least as have been examined with any degree of accuracy: in the second, I shall treat of the different members of which animal bodies are composed; which must consist each of various combinations of the ingredients described in the first Chapter: in the third, I shall treat of those animal functions which may be elucidated by chemistry: and, in the fourth, of the changes which animal bodies undergo after death.

CHAP. I.

OF ANIMAL SUBSTANCES.

THE substances which have been hither detected in the animal kingdom, and of which the different parts of animals, as far as these parts have been analysed, are found to be composed, may be arranged under the following heads:

1. Gelatin.	10. Cantharidin.
2. Albumen.	11. Cochenealin.
3. Fibrin.	12. Oils.
4. Colouring matter of blood.	13. Resins.
	14. Sulphur.
5. Mucus.	15. Phosphorus.
6. Osmazome.	16. Acids.
7. Picromel.	17. Alkalies.
8. Urea.	18. Earths.
9. Sugar.	19. Metals.

These substances shall form the subject of the following sections.

SECT. I.

OF GELATIN.

How obtained.

1. IF a piece of the fresh skin of an animal, an ox, for instance, after the hair and every impurity is carefully separated, be washed repeatedly in cold water till the liquid ceases to be coloured, or to abstract any thing; if the skin, thus purified, be put into a quantity of pure water, and boiled for some time, part of it will be dissolved. Let the decoction be slowly evaporated till it is reduced to a small quantity, and then put aside to cool. When cold, it will be found to have assumed a solid form, and to resemble precisely that tremulous substance well known to every body under the name of *jelly*. This is the substance called in chemistry *gelatin*. If the evaporation be still farther continued, by exposing the jelly to dry air, it becomes hard, semitransparent, breaks with a glassy fracture, and is in

short the substance so much employed in the different arts under the name of *glue*. Gelatin, then, is precisely the same with glue; only that it must be supposed always free from those impurities with which glue is so often contaminated.

2. Gelatin is semitransparent and colourless when pure. Its consistency and hardness vary considerably. The best kinds are very hard, brittle, and break with a glassy fracture. Its taste is insipid, and it has no smell.

When thrown into water it swells very much, but does not readily dissolve; and when taken out, it is soft and gelatinous; but when allowed to dry, it recovers its former appearance. If it be put in this gelatinous state into warm water, it very soon dissolves, and forms a solution of an opal colour, and the more opaque according to the quantity of gelatin which it contains. Tremulous gelatin dissolves in a very small portion of hot water; but as the solution cools, it gelatinizes afresh. If this solution, as soon as it assumes the tremulous form, be mixed with cold water and shaken, a complete solution takes place.

From the experiments of Dr. Bostock, we learn, that when one part of isinglass (which is nearly pure galatin) is dissolved in 100 parts of hot water, the solution on cooling is wholly converted into a jelly. But one part of isinglass, in 150 parts of water, does not become concrete; though the solution is to a certain degree gelatinous.*

Dry gelatin undergoes no change when kept; but in the gelatinous state, or when dissolved in water, it very soon putrifies; an acid makes its appearance in the first place (probably the acetic,) a fetid odour is exhaled, and afterwards ammonia is formed.

When dry gelatin is exposed to heat, it whitens, curls up like horn, then blackens, and gradually consumes to a coal; but tremulous gelatin first melts, assuming a black colour. When distilled, it yields, like most animal substances, a watery liquid impregnated with ammonia, and a fetid empyreumatic oil; leaving a bulky charcoal of difficult incineration. It is by no means a very combustible substance.

3. Acids dissolve gelatin with facility, even when diluted,

* Nicholson's Jour. xi. 250.

especially when assisted by heat; but we are still ignorant of the changes produced upon it by these agents except by nitric acid. When this acid is digested on it, a small quantity of azotic gas is disengaged, then abundance of nitrous gas; the gelatin is dissolved, except an oily matter which appears on the surface, and converted partly into oxalic and malic acids.*

Muriatic acid dissolves glue with great ease. The solution is of a brown colour, and still continues strongly acid. It gradually lets fall a white powder. This solution precipitates tan in great abundance from water; and may be employed with advantage to detect tan when an alkali conceals it. Sulphuric acid acts much more slowly. The solution is brown, and gradually deepens; sulphurous acid is exhaled during the action of sulphuric acid on glue. Neither sulphuric nor muriatic acid occasion any change in the solution of glue in water.

When a current of chlorine gas is passed through a solution of gelatin in water, a white solid matter collects on the surface, and whitish filaments swim through the liquid. This solid matter, when separated by the filter and purified, possesses the following properties: its colour is white; it is specifically lighter than water; it has little or no taste; when dried in the open air it falls to powder; it is not soluble in boiling water; it dissolves in hot nitric and acetic acids, but precipitates again as the solution cools; when triturated with potash it emits the smell of ammonia; it does not affect vegetable blues.† Bouillon La Grange, to whom we are indebted for these facts, has given the gelatin thus altered the name of *oxygenized gelatin*.

Of alkalies and earths. Alkalies dissolve gelatin with facility, especially when assisted by heat; but the solution does not possess the properties of soap.

None of the earths seem to combine with gelatin; at least they do not precipitate it from its solution in water. The following table exhibits the effect of different earthy solutions when mixed with a pretty concentrated solution of common glue:

* Scheele, Crell's Annals, ii. 17. Eng. Trans.
† Bouillon La Grange, Nicholson's Jour. xiii. 209.

Substances.	Effects.
Lime water	No change.
Strontian water	No change.
Barytes water	Became milky. Precipit. not dissolved by acetic acid.
Muriate of barytes........	The same as the last.
Silicated potash	No change.
Aluminated potash	No change.
Oxalate of ammonia......	Became milky.
Phosphate of soda	Became slightly milky.

The milkiness produced by some of these reagents was not owing to their effect upon the gelatin, but upon the lime and the sulphuric acid which it contained.

The metals in their pure state have no effect upon gelatin; but several of the metallic oxides, when agitated in a solution of gelatin, have the property of depriving the water of the greatest part of that body, with which they form an insoluble compound. Several of the metallic salts likewise precipitate gelatin from water. The following table exhibits the result of mixing various metallic salts with a concentrated solution of gelatin, as far as my experiments have gone :

Of the metallic oxides.

Metallic solutions.	Effects.
Nitromuriate of gold ...	A copious yellowish-white precipitate. Soluble by adding water.
Nitrate of silver	Becomes slightly milky.
Nitrate of mercury	A very copious curdy precipitate.
Corrosive sublimate*	A copious white precipitate.
Superpersulph. of merc. .	No change.
Dry persulph. of merc...	Crystals become yellow, white flakes appear, and the liquid becomes transparent.
Prussiate of mercury	No change.
Pernitrate of copper	No change.
Muriate of copper	Becomes milky.
Persulphate of copper	No change.
Cuprate of ammonia	No change.

* Dr. Bostock, in his excellent paper on animal fluids, informs us, that a solution of one part of isinglass in 100 parts of water is not affected by corrosive sublimate. The result of my experiments with common glue was different; probably owing to the impurity of that substance.

Metallic solutions.	Effects.
Sulphate of iron *	A few yellow flakes appear.
Persulphate of iron † ...	Becomes slightly milky, as when alcohol is added.
Pernitrate of iron	Assumes a pink colour.
Permuriate of iron	Becomes green.
Nitromuriate of tin ‡	No change.
Permuriate of tin	Becomes slowly milky.
Nitrate of lead .... Acetate of lead .... Plumbate of potash .... Plumbate of lime	No change.
Muriate of zinc	No change.
Muriate of antimony	A copious flaky precipitate.
Tartar emetic	No change.
Nitrate of bismuth precipitable by water	Becomes milky.
Ditto, not precipitable by water	No change.
Muriate of arsenic	No change.

Of alcohol.   Gelatin is insoluble in alcohol. When alcohol is mixed with a solution of gelatin, the mixture becomes milky; but becomes again transparent when agitated, unless the solution be concentrated, and the quantity of alcohol considerable. Gelatin is most probably equally insoluble in ether; though I believe the experiment has not been tried.

Of tannin.   When the solution of tannin is dropped into gelatin, a copious white precipitate appears, which soon forms an elastic adhesive mass, not unlike vegetable gluten. This precipitate is composed of gelatin and tannin; it soon dries in the open air, and forms a brittle resinous-like substance, insoluble in water, capable of resisting the greater number of chemical agents, and not susceptible of putrifaction. It resembles exactly overtanned leather. The precipitate is soluble in the solution of gelatin, as Davy first observed. Neither is the whole tan thrown down, unless the solutions both of tannin and gelatin be somewhat concentrated. Tremulous gelatin, as was first observed by the same chemist, does not precipitate tannin; but if we

* Partly in the state of persulphate.   † Dissolved in alcohol.
‡ With excess of acid.

employ a solution of gelatin so strong that it gelatinizes when cold, and heat it till it becomes quite liquid, it answers best of all for throwing down tannin. It is by this property of forming a white precipitate with tannin that gelatin is usually detected in animal fluids. It is not, however, a perfectly decisive test, as *albumen* is also thrown down by tannin. Dr. Bostock has pointed out a very ingenious method of detecting and ascertaining the quantity of gelatin contained in an animal fluid. If corrosive sublimate produce no precipitate, we may be certain of the absence of albumen. Then the infusion of galls being mixed with the liquid, in such a proportion that the filtered liquid will neither precipitate infusion of galls, or the animal liquid under examination, a precipitate falls, composed of about two parts tannin and three parts gelatin. Hence this precipitate, dried on a steam bath, and multiplied by 0·6, gives us the weight of gelatin in the liquid examined very nearly.*

Gelatin does not, properly speaking, combine with oils, but it renders them miscible with water, and forms a kind of emulsion.

4. From the effects of different reagents on gelatin, and from the decomposition which it undergoes when heated, we see that it contains carbon, hydrogen, azote, and oxygen. It was subjected to an analysis by Gay-Lussac and Thenard, who burnt it, when mixed, with chlorate of potash, and ascertained the products. According to their experiments, its constituents are as follows : Composition.

Carbon . . . . 47·881
Oxygen . . . . 27·207
Hydrogen . . . . . . 7·914
Azote . . . . 16·998
_____
100·000 †

Not being possessed of any definite compound of gelatin and any other substance with the weight of which we

* Bostock, Nicholson's Jour. xiv. 144. From the latter experiments of Dr. Bostock, it appears that the compound of tannin and gelatin differs in the proportion of its constituents according to circumstances. It does not, therefore, furnish us with a method of detecting the quantity of gelatin in solution. Nicholson's Jour. xxi. 1.

† Recherches Physico-chimiques, ii. 336.

are already acquainted, it is not in our power, from this analysis, to determine the constitution of gelatin. But the smallest number of atoms which correspond nearly with the preceding numbers, is the following:

15 atoms carbon	= 11·25	50·00
6 atoms oxygen	= 6·00	26·67
14 atoms hydrogen ..	= 1·75	7·78
2 atoms azote	= 3·50	15·55
	22·5	100·00

Species.   5. Gelatin, like all other constituents of animal bodies, is susceptible of numerous shades of variations in its properties, and of course is divisible into an indefinite number of species. Several of these have been long known and manufactured for different purposes: and many curious varieties have been pointed out by Hatchett in his admirable Dissertations on Shell, Bone, and Zoophytes, published in the Philosophical Transactions for 1797 and 1800. The most important species are the following:

Glue.   (1.) *Glue.* This well known substance has been long manufactured in most countries, and employed to cement pieces of wood together. It is extracted by water from animal substances, and differs in its qualities according to the substances employed. Bones, muscles, tendons, ligaments, membranes, and skins, all yield it; but the quality is best when skins are employed; and those of old animals yield a much stronger glue than those of young animals. English glue is considered as the best, owing to the care with which it is made. The parings of hides, pelts from furriers, the hoofs and ears of horses, oxen, calves, sheep, &c. are the substances from which it is extracted in Britain, and quantities of these substances are imported for the purpose. They are first digested in lime-water to clean them, then steeped in clean water, laid in a heap till the water runs off, and then boiled in brass caldrons with pure water. The impurities are skimmed off as they rise; and when the whole is dissolved, a little alum or finely powdered lime is thrown in. The skimming having been continued for some time, the whole is strained through baskets, and allowed to settle. The clear liquid is gently poured back into the kettle, boiled a second time, and skimmed till it is reduced to the proper consistency. It is then poured into

large frames, where it concretes on cooling into a jelly. It is cut by a spade into square cakes, which are again cut by means of a wire into thin slices ; these slices are put into a kind of coarse net work, and dried in the open air.* The blest glue is extremely hard and brittle ; it has a dark brown colour, and an equal degree of transparency without black spots. When put into cold water, it swells very much, and becomes gelatinous, but does not dissolve. When glue is soluble in cold water, it is a proof that it wants strength. Dry glue, according to Dr. Bostock, contains $10\frac{1}{2}$ *per cent.* of water. He thinks also that it contains albumen. But from the method of preparing it this can hardly be supposed.†

(2.) *Size.* This substance differs from glue in being colourless and more transparent. It is manufactured in the same way, but with more care ; eel skins, vellum, parchment, some kinds of white leather, and the skins of horses, cats, rabbits, are the substances from which it is procured. It is commonly inferior to glue in strength. It is employed by paper-makers to give strength to that article, and likewise by linen manufacturers, gilders, polishers, painters, &c. ‡

(3.) *Isinglass.* This substance agrees with size in being transparent, but it is much finer, and is therefore sometimes employed as an article of food. It is prepared in Russia from the air-bladders and sounds of different kinds of fish which occur in the mouths of large rivers; chiefly different species of *accipenser,* as the *sturio stellatus, huso ruthenus,* and likewise the *siluris glanis.* The bladder is taken from the fish, clean washed, the exterior membrane separated, cut lengthwise and formed into rolls, and then dried in the open air. When good, isinglass is of a white colour, semi-transparent, and dry. It dissolves in water with more difficulty than glue, probably because it is not formed originally by solution. From the analysis of isinglass by Hatchett, we learn that it is almost completely convertible into gelatin by solution and boiling. Five hundred grains of it left by incineration $1\cdot5$ grains of phosphate of soda, mixed with a little phosphate of lime.

* Clennel. See Johnson's History of Animal Chemistry, i. 315.
† Nicholson's Jour. xxiv. 7.
‡ Clennel. See Johnson's History of Animal Chemistry, i. 315.

A coarse kind of isinglass is prepared from sea wolves, porpoises, sharks, cuttle fish, whales, and all fish without scales. The head, tail, fins, &c. of these are boiled in water, the liquid skimmed and filtered, and then concentrated by evaporation till it gelatinizes on cooling. At that degree of concentration it is cast on flat slabs and cut into tablets. This species is used for clarifying, stiffening silk, making sticking-plaster, and other purposes.*

Substances containing it.

6. Gelatin exists in great abundance in animals, forming a constituent part of their solid parts. It forms an essential part of bones, ligaments, tendons, membranes, skin, muscles, hair, &c.

Uses.

7. Its uses are very numerous. In the state of jelly it constitutes one of the most nourishing and palatable species of food. It constitutes the basis of soups. The great variety of purposes to which it is applied in the state of glue, size, and isinglass, are well known.

SECT. II.

OF ALBUMEN.

Contained in eggs.

THE eggs of fowls contain two very different substances: a yellow oily-like matter, called the *yolk ;* and a colourless glossy viscid liquid, distinguished by the name of *white.* This last is the substance which chemists have agreed to denominate *albumen.*† The white of an egg, however, is not pure albumen. It contains also some mucus, soda, and sulphur: but as albumen is never found perfectly pure, and as no method is known of separating it without at the same time altering the properties of the albumen, chemists are obliged to examine it while in combination with these bodies.

Albumen dissolves readily in water, and the solution has the property of giving a green colour to vegetable blues, in

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* Fabricius de Ichthyocolla, Jackson on British Isinglass, Phil. Trans. lxiii. and Johnson's Animal Chemistry, i. 231.

† This is merely the Latin term for the white of an egg. It was first introduced into chemistry by the physiologists.

consequence of the soda which it contains. When albumen is heated to the temperature of 165°,* it *coagulates* into a white solid mass; the consistency of which, when other things are equal, depends, in some measure, on the time during which the heat was applied. The coagulated mass has precisely the same weight that it had while fluid. This property of coagulating when heated is characteristic of albumen, and distinguishes it from other bodies.

The taste of coagulated albumen is quite different from that of liquid albumen: its appearance, too, and its properties, are entirely changed; for it is no longer soluble, as before, either in hot or in cold water.

The coagulation of albumen takes place even though air be completely excluded; and even when air is present there is no absorption of it, nor does albumen in coagulating change its volume.† Acids have the property of coagulating albumen, as Scheele ascertained.‡ Alcohol also produces, in some measure, the same effect. *Heat*, then, *acids*, and *alcohol*, are the agents which may be employed to coagulate albumen.

It is remarkable, that if albumen be diluted with a sufficient quantity of water, it can no longer be coagulated by any of these agents. Scheele mixed the white of an egg with ten times its weight of water, and then, though he even *boiled* the liquid, no coagulum appeared. Acids, indeed, and alcohol, even then coagulated it; but they also lose their power if the albumen be diluted with a much greater quantity of water, as has been ascertained by many experiments. Now, when water is poured into albumen, its integrant particles must be farther separated from each other, and their distance must increase with the quantity of water with which they are diluted. We see, therefore, that albumen ceases to coagulate whenever its particles are separated from each other beyond a certain distance. That no other change is produced, appears evident from this circumstance, that whenever the watery solution of albumen is sufficiently concentrated by evaporation, coagulation takes place, upon the application of the proper agents, precisely as formerly.

* Cullen.   † Carradori, Ann. de Chim. xxix. 98.
‡ Scheele, ii. 58.

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It does not appear that the distance of the particles of albumen is changed by coagulation; for coagulated albumen occupies precisely the same sensible space as liquid albumen.*

Inquiry into the cause.

Now, to what is the coagulation of albumen owing? We can conceive no change to take place from a state of liquidity to that of solidity, without some change in the figure of the particles of the body which has undergone that change. Now such a change may take place three ways: 1. The figure may be changed by the addition of some new molecules to each of the molecules of the body. 2. Some molecules may be abstracted from every integrant particle of the body. 3. Or the molecules, of which the integrant particles are composed, may enter into new combinations, and form new integrant particles, whose form is different from that of the old integrant particles. Some one or other of these three things must take place during the coagulation of albumen.

1. Scheele and Fourcroy have ascribed the coagulation of albumen to the first of these causes, namely, to the addition of a new substance. According to Scheele, *caloric* is the substance which is added. Fourcroy, on the contrary, affirms that it is *oxygen*.

Ascribed to caloric ;

Scheele supported his opinion with that wonderful ingenuity which shone so eminently in every thing which he did. He mixed together one part of white of egg and four parts of water, added a little pure alkali, and then dropped in as much muriatic acid as was sufficient to saturate the alkali. The albumen coagulated. But when he repeated the experiment, and used carbonate of alkali instead of pure alkali, no coagulation ensued. In the first case, says he, there was a double decomposition: the muriatic acid separated from a quantity of caloric with which it was combined, and united with the alkali; while, at the same instant, the caloric of the acid united with the albumen, and caused it to coagulate. The same combination could not take place when the alkaline carbonate was used, because the carbonic acid gas carried off the caloric, for which it has a strong affinity.†

To oxygen.

Fourcroy observes, in support of his opinion, that the

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* Carradori.   † Scheele, ii. 58.

white of an egg is not at first capable of forming a hard coagulum, and that it only acquires that property by exposure to the atmosphere. It is well known that the white of a new laid egg is milky after boiling; and that if the shell be covered over with grease to exclude the external air, it continues long in that state; whereas the white of an old egg, which has not been preserved in that manner, forms a very hard tough coagulum. These facts are undoubted; and they render it exceedingly probable, that albumen acquires the property of forming a hard coagulum only by absorbing oxygen: but they by no means prove that coagulation itself is owing to such an absorption. And since coagulation takes place without the presence of air, and since no air, even when it is present, is absorbed, this opinion cannot be maintained without inconsistency.

2. The only substance which can be supposed to leave albumen during coagulation, since it does not lose its weight, *is caloric*. We know that in most cases where a fluid is converted into a solid, caloric is actually disengaged. It is extremely probable, then, that the same disengagement takes place here. But the opinion has not been confirmed by any proof. Fourcroy indeed says, that in an experiment made by him, the thermometer rose a great number of degrees. But as no other person has ever been able to observe any such thing, it cannot be doubted that this philosopher has been misled by some circumstance or other to which he did not attend.*

3. The coagulation of albumen resembles exactly what takes place when concentrated silicated potash is exactly saturated with muriatic acid. The mass slowly assumes an opal colour, and at last concretes into a solid gelatinous mass. Now this jelly consists of the particles of silica combined with each other, and with a certain portion of water. These particles were formerly held in solution by the potash; that is to say, the affinity of silica for potash was superior to the cohesive force which exists between the particles of silica. The muriatic acid, by saturating the potash, diminished the force of its affinity for the silica. The cohesive force of the silica, now superior, causes it to combine in masses, consisting of a certain portion of silica

* Thomson's Fourcroy, iii. 271.

and water. These masses, equally diffused through the liquid, and at such small intervals as to cohere together, gives the whole a gelatinous form. Something like this seems to take place with respect to the albumen. Its particles, combined with water and also with soda, are all kept at equal distances in the liquid; because this affinity just balances their cohesive force. But when heat is applied, this affinity is diminished by the additional elasticity, or tendency to separate, given to the water and the soda. The cohesion of the albumen, now superior, causes its particles to combine in sets, forming solid bodies, equally distant from each other, and cohering together. Hence the gelatinous form, and the solidity of the coagulum, always inversely proportional to the quantity of water present. Thus it appears, that whatever diminishes the affinity between the water, and soda, and the albumen, occasions its coagulation, by allowing its cohesive force to act.

Albumen, then, is capable of existing in two states; the one before it has been coagulated, and the other after it has undergone coagulation. Its properties are very different in each. It will be proper therefore to consider them separately.

Uncoagulated albumen.

I. Albumen in its natural state, or uncoagulated, is a glary liquid, having little taste and no smell. When dried spontaneously, or in a low heat, it becomes a brittle transparent glassy-like substance; which, when spread thin upon surfaces, forms a varnish, and is accordingly employed by bookbinders for that purpose. When thus dried it has a considerable resemblance to gum arabic, to which also its taste is similar. The white of an egg loses about $\frac{4}{5}$ths of its weight in drying. It is still soluble in water, and forms the same glary liquid as before.

From the experiments of Dr. Bostock, it appears, that when one part of this dry albumen is dissolved in nine parts of water, the solution becomes perfectly solid when coagulated by heat; but if the albumen amounts only to $\frac{1}{13}$th of the liquid, then, though coagulation takes place, the liquid does not become perfectly solid, but may be poured from one vessel to another.[*]

* Nicholson's Jour. xiv. 141.

When one grain of albumen is dissolved in 1000 grains of water, the solution becomes cloudy when heated.*

Uncoagulated albumen soon putrifies unless it be dried; in which state it does not undergo any change. It putrifies more readily when dissolved in a large quantity of water than when concentrated. The smell of white of egg, allowed to run into putrifaction, resembles that of *pus*.†

It is insoluble in alcohol and ether, which immediately coagulate it, unless it be mixed with a very great proportion of water; in which case even acids have no effect.

When acids are poured upon it, coagulation takes place equally; but several of them have the property of dissolving it again when assisted by heat. This at least is the case with sulphuric acid. The solution is of a green colour, and does not soon blacken even when boiled. It is the case also with nitric acid, and probably also with muriatic acid. Nitric acid first disengages some azotic gas; then the albumen is gradually dissolved, nitrous gas emitted, oxalic and malic acids formed, and a thick oily matter makes its appearance on the surface.‡

I tried the effect of different acids upon a solution consisting of the albumen of a common-sized hen's-egg in about a pint of water, and filtered. The results may be seen in the following table:

Acids.	Effects.
1. Sulphuric acid	A white coagulum, which appears at the bottom first.
2. Muriatic acid	Becomes at once very milky, flakes fall slowly.
3. Nitric acid	A very copious precipitate of yellow flakes soon falls to the bottom, and a slight effervescence is perceptible.
4. Chlorine	Assumes a beautiful white colour, and fine white flakes slowly separate.
5. Sulphurous acid	No change.§ Coagulates in 12 hours.
6. A weak fluoric acid	No change.
7. Acetic acid	No change.
8. Distilled vinegar	No change.

* Bostock, Nicholson's Jour. xi. 247.   † Ibid. xiv. 143.
‡ Scheele, Crell's Annals, ii. 17. Eng. Trans.
§ The water was saturated with the acid.

It may be proper to mention, that the solution was co-agulated by alcohol but not by heat.

When alkalies are mixed with the solution of albumen in water, no apparent change takes place; but if a concentrated solution of pure potash be triturated with albumen for some time, and then allowed to remain at rest, the albumen gradually coagulates or rather gelatinizes; for the coagulum has a striking resemblance to jelly. It gradually hardens; and at a particular period of its drying it resembles very exactly the lense of the eye. When quite dry it is brittle and transparent.

The effect of the different earthy bodies on the solutions of albumen in water may be seen from the following table. The solution consisted of one white of egg dissolved in about a pint of water, and filtered to separate the opaque white films which are always mixed in the white of egg.

Substances.	Effects.
Barytes water	No change.
Strontian water	No change.
Lime water	No change.
Sulphate of magnesia	No change.
Alum	No change.
Silicated potash...........	No change.
Aluminated potash	No change.

Thus it appears that none of the earths form insoluble compounds with albumen; in this respect they resemble the alkalies.

The case is very different with the metallic oxides. The following table exhibits the effects of the metallic salts on the same solution of albumen, as far as my experiments go.

Metallic Salts.	Effects.
1. Nitromuriate of gold.	A copious yellow flaky precipitate, redissolved by ammonia.*
2. Muriate of platinum ..	A yellowish-white precipitate.
3. Nitrate of silver	A copious reddish-brown precipitate, not redissolved by ammonia.
4. Nitrate of mercury ...	A white precipitate.

* The salt had a slight excess of acid.

Metallic Salts.	Effects.	Chap. I.
5. Corrosive sublimate . . .	A light white precipitate.	
6. Supersulph. of do	A white precipitate.	
7. Prussiate of do.	No change.	
8. Pernitrate of copper . .	A green coagulum, redissolved by adding more of the copper, then the mixture becomes opaque.	
9. Muriate of copper	A copious white precipitate.	
10. Persulphate of copper .	A greenish white precipitate.	
11. Cuprate of ammonia.	No change. Muriatic acid renders the mixture colourless, but no precipitate falls.	
12. Sulphate of iron.	Brown flakes precipitate.	
13. Persulphate of ditto in alcohol	A copious dirty white precipitate.	
14. Permuriate of iron. . . .	No change.	
15. Pernitrate of iron	No precipitate. Becomes green.	
16. Permuriate of tin	Becomes slowly milky.	
17. Chlorate of lead.	A copious white precipitate.	
18. Acetate of lead	The same.	
19. Nitrate of lead	The same.	
20. Plumbate of potash . .	No change; but muriatic acid throws down a copious white precipitate.	
21. Plumbate of lime	No change.	
22. Muriate of zinc	Becomes slowly very milky.	
23. Nitrate of bismuth . . .	A white precipitate, which does not appear immediately unless there be an excess of acid.	
24. Nitrate of antimony . . .	A white precipitate.	
25. Muriate of arsenic	Becomes slowly milky.	
26. Arseniate of potash . . .	No change.	
27. Arseniate of cobalt . . .	No change.	
28. Prussiate of potash . . .	No change.	
29. Oxalate of ammonia. .	A slight white precipitate appears after standing an hour.	

Thus we see that every metal tried, except cobalt, occasioned a precipitate; but no precipitate ever appeared when the oxide was held in solution by an alkali or earth. The effect of the metallic salts on albumen forms a striking contrast with their effect on gelatin.

Book V.   From the experiments of Dr. Bostock, it appears that a drop of the saturated solution of corrosive sublimate, let fall into water containing $\frac{1}{2000}$th part of its weight of albumen, produces an evident milkiness, and a curdy precipitate falls.* It is therefore a very delicate test of the presence of albumen in animal fluids. Dr. Bostock has proposed the following ingenious method of estimating the quantity of albumen contained in an animal fluid : Add to the fluid a quantity of corrosive sublimate, more than sufficient to saturate the albumen, then heat the mixture. By this double action a coagulum is formed, which may be separated by the filter. This precipitate, when dry, contains about $\frac{5}{7}$ths of its weight of albumen.†

Of tan.   If a solution of tannin be poured into an aqueous solution of uncoagulated albumen, it forms with it a very copious yellow precipitate of the consistence of pitch, and insoluble in water. This precipitate is a combination of tannin and albumen. When dry it is brittle, like overtanned leather, and is not susceptible of putrifraction. This property which albumen has of precipitating with tannin was discovered by Seguin.‡

The infusion of galls is by no means so delicate a test of the presence of albumen as of gelatin. When an infusion of galls containing $2\frac{1}{2}$ per cent. of solid matter, and water holding $\frac{1}{1000}$th of albumen in solution, are mixed in equal quantities, no effect is produced at first, but after some time a precipitating matter appears and slowly subsides.§

Coagulated albumen.   II. When albumen is coagulated either by heat, alcohol, or acids, it is an opaque substance of a pearl-white colour, tough, and of a sweetish mucilaginous taste. It is no longer soluble in water, and is not nearly so susceptible of decomposition as uncoagulated albumen. Mr. Hatchett kept it for a month under water, and yet it did not become putrid. It is to the experiments of this ingenious chemist that we are indebted for almost every thing at present known relative to coagulated albumen. By drying it in the temperature of 212°, he converted it into a brittle hard yellow substance, semitransparent like horn.||

Its properties.

* Nicholson's Jour. xi. 247.   † Ibid. xiv. 142.
‡ Ibid. i. 272.   § Bostock, ibid. p. 141.
|| Hatchett, Phil. Trans. 1800.

When this substance was digested for some hours in water, it gradually softened, and became white and opaque like newly coagulated albumen. When water is made to act upon it long, a small portion of it is taken up. The watery liquid is not precipitated by the infusion of tan; but nitromuriate of tin occasions a faint cloud.*

According to Scheele, the mineral acids, when greatly diluted with water, dissolve a portion of coagulated albumen, which is thrown down again by the same acids concentrated. †

When coagulated albumen is steeped in diluted nitric acid, the acid in about four weeks begins to acquire a yellow tinge, which becomes gradually deeper; but the albumen, though it becomes more opaque, is not dissolved. The yellow acid, when saturated with ammonia, becomes of a deep orange colour, but does not let fall any precipitate. When the albumen, thus treated, is immersed in ammonia, the liquid assumes a deep orange colour, inclining to blood red. The albumen is slowly dissolved, and the solution has a deep yellowish-brown colour. If the albumen, after being steeped in nitric acid, be washed and then boiled in water, it is dissolved, and forms a pale yellow liquid, which gelatinizes when properly concentrated. If the gelatinous mass be again dissolved in boiling water, the solution is precipitated by tan and by nitro-muriate of tin. Hence we see that nitric acid has the property of converting coagulated albumen into gelatine. For this important fact we are indebted entirely to Mr. Hatchett.‡

Concentrated nitric acid dissolves coagulated albumen with effervescence, especially when assisted by heat. It becomes orange-brown when mixed with ammonia, but no precipitate falls. §

It is readily dissolved by a boiling lixivium of potash, ammonia is disengaged, and an animal soap is formed. This soap, when dissolved in water, and mixed with acetic or muriatic acids, lets fall a precipitate which is of a saponaceous nature. When heated gently some oil flows from it, and a brownish viscid substance remains.|| The alkalies,

* Hatchett, Phil. Trans. 1800.   † Scheele, ii. 57.
‡ Hatchett, Phil. Trans. 1800.   § Ibid. || Ibid.

when diluted, and not assisted by heat, act upon it slowly and imperfectly.

These properties indicate sufficiently that coagulated albumen is a very different substance from uncoagulated albumen. During the coagulation its component parts must arrange themselves differently.

Composition of albumen. III. From the effects of nitric acid on albumen ; and its products, when subjected to destructive distillation, it has been concluded that it consists of carbon, hydrogen, azote, and oxygen. According to the experiments of Gay-Lussac and Thenard, its constituents are as follows:

> Carbon .... 52·883
> Oxygen .... 23·872
> Hydrogen ...... 7·540
> Azote .... 15·705
>
> ----
>
> 100·000 *

The smallest number of atoms that agrees with the preceding analysis nearly, is the following:

> 17 atoms carbon .... = 12·75 .... 53·40
> 6 atoms oxygen .... = 6·00 .... 25·13
> 13 atoms hydrogen .. = 1·625 .... 6·80
> 2 atoms azote ...... = 3·50 .... 14·67
>
> ----
>
> 23·875   100·00

According to this statement it differs from gelatin, by containing two additional atoms of carbon and having one atom fewer of hydrogen.

Species of it. IV. Like all other animal substances, albumen is capable of existing in various states both when coagulated and uncoagulated, forming a number of distinct species; but they have not been characterized with much precision. But if the curdy part of milk be considered as an albumen, as some chemists do, it constitutes a species essentially distinct from the albumen of eggs and blood. Coagulated albumen forms an essential part of bone and muscle; brain perhaps may be considered as a species of it, and so may the lense of the eye. Cartilage, nails, horns, hair, &c. as Hatchett has shown, are almost entirely composed of it; and it forms the

* Recherches Physico-chimiques, ii. 332.

membranous part of many shells, sponges, &c. In short, it is one of the most general and important of the animal substances.

V. The property which albumen has of being coagulated by heat renders it a very useful substance for clarifying liquids. The serum of blood, white of egg, or any liquid containing it, is mixed with the liquid to be clarified, and the whole is then heated. The albumen coagulates, and carries down with it the floating particles which rendered the liquid opaque.

SECT. III.

OF FIBRIN.

IF a quantity of blood, newly drawn from an animal, be allowed to remain at rest for some time, a thick red clot gradually forms in it, and subsides. Separate this clot from the rest of the blood, put it into a linen cloth, and wash it repeatedly in water till it ceases to give out any colour or taste to the liquid; the substance which remains after this process is denominated *fibrin*. It has been long known to physicians under the name of the *fibrous part of the blood*, but has not till lately been accurately described.

It may be procured also from the muscles of animals. Mr. Hatchett, to whom we are indebted for a very interesting set of experiments on this substance, cut a quantity of lean beef into small pieces, and macerated it in water for fifteen days, changing the water every day, and subjecting the beef to pressure at the same time, in order to squeeze out the water. As the weather was cold, it gave no signs of putrifaction during this process. The shreds of muscle, which amounted to about three pounds, were now boiled for five hours every day for three weeks in six quarts of fresh water, which was regularly changed every day. The fibrous part was now pressed, and dried by the heat of a water bath. After this treatment it might be considered as fibrin nearly as pure as it can be obtained.*

2. Fibrin is of a white colour, and has no taste nor smell. Properties.

How obtained.

* Hatchett, Phil. Trans. 1800.

Book V. When newly extracted from blood, it is soft and elastic, and resembles the gluten of vegetables. Its colour deepens very much in drying. That which is extracted from muscle by boiling and maceration has a certain degree of transparency, and is not ductile but brittle. Its colour does not deepen nearly so much as the fibrin from blood.

It undergoes no change though kept exposed to the action of air; neither does it alter speedily though kept covered with water. Mr. Hatchett kept a quantity of the fibrin which he had prepared from beef moistened with water during the whole month of April; it acquired a musty but not a putrid smell, neither were the fibres reduced to a pulpy mass. Even when kept two months under water, it neither became putrid, nor was converted into the fatty matter obtained by macerating recent muscle. *

Action of water,

3. Fibrin is insoluble in cold water. In boiling water it curls up, and after the boiling has continued for some hours, the water becomes milky; but no gas is evolved. When infusion of nutgalls is dropped into the water, white flocks precipitate, which do not adhere together when heated, as those produced by gelatin. The evaporated liquid does not gelatinize, and leaves a white, dry, hard, friable residue, soluble in cold water, and having an agreeable taste similar to that of fresh broth. Fibrin by long boiling in water loses its property of softening and dissolving in acetic acid.†

Of alcohol,

4. In alcohol of the specific gravity 0·81 fibrin undergoes a species of decomposition, and forms an adipocirous substance soluble in alcohol and precipitated by the addition of water. It has often a strong and unpleasant odour. The alcoholic solution leaves when evaporated a fat residue, which did not pre-exist in the fibrin. Fibrin after being heated in alcohol continues soluble in acetic acid.‡

5. Ether acts on fibrin in the same way as alcohol. It forms an adipocirous matter in much greater abundance, and having a stronger and more disagreeable smell.§

Of acid,

6. In concentrated acetic acid fibrin becomes immediately soft and transparent, and with the assistance of heat is converted into a tremulous jelly. By adding water and

* Hatchett, Phil. Trans. 1800.
† Berzelius, Annals of Philosophy, ii. 20.   ‡ Ibid.   § Ibid.

warming it, this jelly is completely dissolved with the evolution of a small quantity of azotic gas. The solution is colourless and has a mawkish and slightly acid taste. During its evaporation a transparent membrane appears on the surface, and after a certain degree of concentration the gelatinous substance is again reproduced. When completely dried it is a transparent mass which reddens litmus paper, but is insoluble in water without a fresh addition of acetic acid. When ferrocyanate of potash, an alkali, or sulphuric, nitric or muriatic acid is dropped into this solution a white precipitate falls. The acid precipitate is a compound of fibrin and the acid. If it be washed, a certain portion of acid holding fibrin in solution is carried off, and the remainder is soluble in water. This solution contains a neutral compound of the acid and fibrin. The addition of a little more of the acid causes it to precipitate again.*

7. In weak muriatic acid fibrin shrinks and gives out a small quantity of azotic gas; but scarcely any portion is dissolved even by boiling; nor does the acid liquid afford any precipitate with ammonia or ferrocyanate of potash. The fibrin thus treated is hard and shrivelled. When repeatedly washed with water it is at last converted into a gelatinous mass, which is perfectly soluble in warm water. The solution reddens litmus paper, and yields a precipitate with acids as well as alkalies. Fibrin, therefore, combines with muriatic acid in two proportions. The one gives a neutral compound soluble in water, the other with an excess of acid is insoluble, but becomes soluble by the action of pure water.†

8. Concentrated sulphuric acid decomposes and carbonizes fibrin. When diluted with six times its weight of water, this acid acquires a red colour if it be digested with fibrin, but dissolves scarcely any thing. The undissolved portion is a compound of fibrin and an excess of sulphuric acid. Water deprives it of this excess, and a neutral combination is obtained which is soluble in water and possesses the same characters as neutral muriate of fibrin.‡

9. Nitric acid of the specific gravity 1·25 digested with fibrin renders it yellow and diminishes its cohesion. The fluid becomes yellow, and the surface of the fibrin is covered

* Berzelius, Annals of Philosophy, ii. 20.   † Ibid.   ‡ Ibid.

with a small quantity of fat formed by the action of the acid. During this operation pure azotic gas is disengaged. After twenty-four hours digestion the fibrin is converted into a pulverulent mass, of a pale-citron colour, which is deposited at the bottom of the liquid. When this pulverulent matter is washed, its colour changes in proportion as the excess of acid is carried off, and it acquires a deep orange colour. This yellow matter was considered by Fourcroy and Vauquelin as a peculiar acid which they distinguished by the name of *yellow acid*. But Berzelius has shown that it is merely fibrin combined with nitric acid. It dissolves in caustic alkali commmunicating a yellow colour. When boiled in alcohol an adipocirous matter is taken up, but deposited again as the liquid cools. If the yellow substance, after being thus deprived of its adipocirous portion, be digested with water and carbonate of lime it slowly decomposes and dissolves the carbonate, and forms a yellow solution. When this solution is concentrated and mixed with alcohol, malate of lime is precipitated. The portion dissolved in alcohol was nitrate and nitrite of lime.*

Of alkalies,   10. In caustic alkali fibrin increases in bulk, becomes transparent and gelatinous, and at length is completely dissolved. The solution is yellow with a shade of green. Acids occasion in it a precipitate which gradually becomes confluent. Alcohol occasions a precipitate in it. Some alteration is produced upon the fibrin by the alkali, but nothing in the least similar to a soap is formed.†

Of heat.   11. When fibrin is exposed to heat, it contracts very suddenly, and moves like a bit of horn, exhaling at the same time the smell of burning feathers. In a stronger heat it melts. When exposed to destructive distillation, it yields water, carbonate of ammonia, a thick heavy fetid oil, traces of acetic acid, carbonic acid, and carbureted hydrogen gas.‡ The charcoal, as Hatchett ascertained, is more copious than that left by gelatin or albumen. It is very difficult to incinerate, owing to the presence of phosphate of soda and some phosphate of lime, which form a glassy coat on the surface. A considerable proportion of carbonate of lime also remains after the incineration of the charcoal. §

* Berzelius, Annals of Philosophy, ii. 20.   † Ibid.
‡ Fourcroy, ix. 158.   § Hatchett, Fourcroy, ix. 158.

12. Fibrin was subjected to an analysis by Gay-Lussac and Thenard, who found its constituents as follows :

Carbon................	53·360
Oxygen	19·685
Hydrogen	7·021
Azote	19·934
	100·000 *

The smallest number of atoms that correspond with this analysis is the following:

18 atoms carbon	=	13·50	....	52·94
5 atoms oxygen	=	5·00	....	19·61
14 atoms hydrogen	=	1·75	....	6·86
3 atoms azote	=	5·25	....	20·59
		25·50		100·00

According to this statement it contains one more atom of carbon, hydrogen, and azote, and one atom less of oxygen, than albumen.

13. Fibrin exists only in the blood and the muscles of animals : but it is a genus which includes as many species as there are varieties in the muscles of animals; and the great diversity of these substances is well known. The muscles of fish, of fowl, and of quadrupeds, bear scarcely any resemblance to each other.

SECT. IV.

OF THE COLOURING MATTER OF BLOOD.

THE blood was very much examined by physiologists during the last century. Leuenhoeck described its colouring matter as consisting of globules of a red colour floating in the serum, and this description was confirmed by the microscopical observations of Hewson and other physiologists. In 1797, Dr. Wells published a paper on the subject in which he showed by very ingenious and satisfactory arguments that this colouring matter was an animal sub-

* Recherches Physico-chimiques, ii. 330.

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stance.* But chemists were prevented from acceding to this opinion by the experiments of Fourcroy and Vauquelin, which were intended to show that blood contains subphosphate of iron in solution, and that it is to the presence of this salt that its red colour is owing.† This opinion was generally acceded to by chemists till Mr. Brande published his Chemical Researches on the Blood in 1812.‡ He demonstrated by decisive experiments that the opinion of Fourcroy and Vauquelin was ill-founded, that the colouring matter of the blood is a peculiar animal substance, which he obtained in a separate state, and the properties of which he investigated.

Towards the end of the year 1812, Berzelius' *General Views of the Composition of Animal Fluids* were published in the third volume of the Medico-chirurgical Transactions. He details the properties of the colouring matter, and shows that it possesses very nearly the same properties as those of fibrin. These experiments had been made long before those published by Mr. Brande, and had been inserted in the second volume of his Djur chemien, printed in 1808, though we only became acquainted with them in this country in consequence of the publication of the paper in question. Mr. Brande's experiments were repeated and confirmed by Vauquelin in 1815. He pointed out a simple process for procuring colouring matter in a state of purity, and examined its properties in detail with his usual precision.§

Colouring matter of blood may be obtained pure by the following process. Let the clot or coagulum of blood, freed as completely as possible from serum, be mixed with four parts of sulphuric acid diluted with eight parts of water. Heat the mixture to the temperature of 158°, and keep it at that temperature for five or six hours. Filter the liquid while hot, and wash the residue with as much hot water as you employed of acid. Evaporate the liquid to one half, and then add ammonia till the excess of acid is almost, but not completely, saturated. The colouring matter precipitates. Decant off the clear liquid and wash the colouring matter with water till that liquid ceases to

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* Phil. Trans. 1797, p. 416.   † Fourcroy, ix. 152.
‡ Phil. Trans. 1812, p. 90.   § Ann. de Chim. et Phys. i. 9.

precipitate nitrate of barytes. Then throw it on a filter, and when well drained scrape it off with an ivory knife, and let it dry in a capsule.*

Colouring matter of blood thus obtained, when dry appears black; but when suspended in water it has a wine-red colour. It is destitute both of taste and smell. It is insoluble in cold water. Boiling water, according to Berzelius, produces nearly the same effects upon it as upon fibrin. And alcohol and ether convert it in part into an adipocirous matter, having a very disagreeable odour.

Vauquelin and Brande found it insoluble in all the acids tried; but Berzelius could not dissolve it in muriatic acid. He obtained an insoluble matter, containing an excess of acid, which became soluble in proportion as the excess of acid was removed by water.

The alkalies dissolve it and the solution has a purple colour. Berzelius found that it formed a brownish jelly in caustic fixed alkali, which was dissolved by a sufficient quantity of water. The alkaline solution is precipitated by alcohol, which however acquires a red tinge by dissolving a small quantity of the compound formed of the colouring matter with the excess of alkali.

Dilute nitric acid dissolves the colouring matter of blood without altering its colour. Muriate of barytes does not occasion any precipitate in its solution in muriatic acid. Neither is any change produced by gallic acid or ferrocyanate of potash. The infusion of nutgalls precipitates it but does not occasion any change of colour. Nitrate of silver does not render its solution in nitric acid turbid; but acetate of lead throws down a brown precipitate.

Mr. Brande tried to form a lake by precipitating its acid solution by means of different earthy and metallic salts. Neither alumina nor oxide of tin answered the purpose well. Corrosive sublimate or nitrate of mercury succeeded best. They gradually precipitated the colouring matter, and formed with it powders of a good red colour, which did not alter by exposure to the air.† Mr. Brande likewise made some attempts to employ it as a pigment in dyeing; but they were not attended with much success. Though,

* Vauquelin, Ann. de Chim. et Phys. i. 9.
† Phil. Trans. 1812, p. 110.

Book V. as blood is an ingredient employed in some dyeing pro-
cesses, it is not unlikely that the colouring matter may be
of some importance even as a dye stuff.

When the colouring matter of blood is heated it neither
alters its form nor colour; but gives out an animal odour
and furnishes carbonate of ammonia and a purple oil ; but
scarcely any gas. The charry residuum is as bulky as the
original substance.*

No analysis of the colouring matter of the blood has yet
been made. It is obvious, however, from the observations
of Berzelius, that its properties approach very nearly those
of fibrin. Hence it is probable that its constitution is
nearly similar. It contains however a considerable porpor-
tion of iron in some unknown state.

SECT. V.

OF MUCUS.

No word in chemistry has been used with less precision
than *mucus*. Too many experimenters have made it serve
as a common name for every animal substance which can-
not be referred to any other class. Dr. Bostock, in his
excellent Papers on the Analysis of Animal Fluids, has
endeavoured to fix the meaning of the word by ascertain-
ing the properties of pure mucus. Fourcroy and Vau-
quelin have published an elaborate paper on the same sub-
ject.†

From Bostock's experiments it appears, that if the solid
matter obtained by evaporating saliva to dryness be redis-
solved in water and filtered, the solution will contain very
little except mucus. He obtained mucus, also, by mace-
rating an oyster in water and evaporating the liquid.‡
Mucus, thus obtained, possesses the following properties :

Properties.   1. It has much the appearance of gum arabic, excepting
that, in general, it is rather more opaque ; like it, it has
little taste, dissolves readily in water, and forms an adhe-
sive solution.

* Vauquelin.   † Ann. du Mus. d'Hist. Nat. xii. 61.
‡ Nicholson's Jour. xi. 251.

2. When evaporated to dryness it is transparent, in- elastic, and has much the appearance of gum. It is inso- luble in water, but dissolves readily in all the acids though very much diluted.

3. It does not dissolve in alcohol nor in ether.

4. It does not coagulate when heated; nor when con- centrated by evaporation does its solution assume the form of a jelly.

5. It is not precipitated by corrosive sublimate, nor by the infusion of galls.*

6. The subacetate of lead occasions a copious white pre- cipitate when dropped into solutions containing mucus; the acetate produces a much less striking effect.†

7. Nitrate of silver likewise occasions a precipitate in solutions containing mucus.

8. When heated it assumes the appearance of horn, and when distilled it yields the common products of animal sub- stances. According to Fourcroy and Vauquelin, horn, nails, hair, feathers, the epidermis, and the scales which form on the skin, consist chiefly of mucus.

Many of the substances called *mucus* have the property of absorbing oxygen, and of becoming by that means in- soluble in water. They resemble vegetable extractive in this respect.

The mucilaginous substances will be pointed out in the next Chapter. In the present state of our knowledge, any account of them here would merely be a repetition of the properties just mentioned.

SECT. VI.

OF OSMAZOME.‡

THIS substance was first noticed by Rouelle. The name was applied to it by Thenard. It seems doubtful, whether osmazome be any thing else than fibrin slightly altered by being boiled in water and dissolved in that liquid. But as it is a substance which is often met with in the analysis of animal substances, and as its identity with fibrin, though

* Bostock, Nicholson's Jour. xi. 251. † Ibid.
‡ Derived, I presume, from οσμη *smell*, and ζωμος *broth*.

probable, is not fully made out, I think it better, at least for the present, to give it a particular place.

Osmazome may be obtained by the following process. Divide the muscle of beef into small fragments, and leave it in contact with twice or thrice its weight of cold water for an hour or two, taking care to squeeze it occasionally. Decant off the first portion of water, and add an additional quantity. Repeat the digestion a third time. These portions of water will dissolve the salts, the albumen, and the osmazome. Mix them all together and evaporate them in a porselain vessel till the whole albumen has coagulated and separated. Then filter the liquor, which will now be reduced to a small quantity, and of a deep colour. Evaporate it by means of a very gentle heat to the consistence of a syrup. It consists of osmazome mixed with the salts of the muscle. Alcohol digested with it takes up the osmazome and leaves the salts. By evaporating the alcohol we obtain the osmazome nearly in a state of purity.*

Osmazome thus obtained has a brownish-yellow colour, and the taste and smell of broth.

It is soluble both in water and alcohol. The aqueous solution does not gelatinize: but when evaporated leaves the osmazome behind it in the state of a brown matter.

The aqueous solution of it is precipitated by infusion of nutgalls, nitrate of mercury, and by the acetate and nitrate of lead.

When heated it melts, swells, and is decomposed, giving out subcarbonate of ammonia, and leaving a bulky charcoal which contains carbonate of soda, showing clearly that it was not in a state of complete purity.

SECT. VII.

OF PICROMEL.

THIS is a name given by Thenard to the peculiar substance which characterizes bile.† It may be obtained pure

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* Thenard's Traité de Chimie, iii. 447.

† The name picromel is derived, I presume, from πικρος *bitter*, and μελι *honey*. It is a very unfortunate name. *Cholin* (from χολη *bile*) would be much better.

by the following process. Mix fresh bile with sulphuric acid, diluted with three or four times its weight of water. A yellow precipitate falls which must be allowed to subside, then separated. Then continue to add fresh acid as long as any precipitate appears. Heat the mixture gently for some hours, and afterwards decant off the fluid part. A green matter remains, which chemists have been in the habit of denominating *resin of bile*. This green matter is to be thoroughly edulcorated with water. In this state it is a compound of picromel and sulphuric acid. Digest it with carbonate of barytes and water; the acid combines with the barytes, while the picromel dissolves in the water and forms a solution exactly similar in appearance to bile. Or the green matter may be dissolved in alcohol, and the liquid digested over carbonate of potash or carbonate of lime till it no longer reddens litmus. It is then to be filtered and evaporated to dryness. The substance thus obtained is picromel.

Picromel when pure resembles entirely inspissated bile. It has a green or greenish-yellow colour, and an intensely bitter taste, followed by some sweetness.

It is soluble in water, and likewise in alcohol in all proportions. Ether does not dissolve it, but converts it into an adipocirous substance, having an exceedingly disagreeable smell.

Like the albumen of blood it unites with acids, and forms compounds soluble when neutral, but insoluble, or only sparingly soluble, when there is an excess of acid. It is this last compound of picromel, and a mineral acid, which has been hitherto mistaken by chemists for the *resin* of bile.

Picromel combines likewise with many metallic oxides into a pulverulent mass.

It is not precipitated by infusion of nutgalls; but the nitrate of mercury, the subacetate of lead, and the salts of iron, occasion a precipitate when dropped into its aqueous solution.

When picromel is subjected to destructive distillation it gives out no ammonia. Hence it would seem that it contains no azote. A difference in composition sufficient to distinguish picromel from albumen and fibrin, with which it possesses many analogous properties.*

* Berzelius, Annals of Philosophy, ii. 377.

SECT. VIII.

OF UREA.

How ob-
tained.

UREA may be obtained by the following process : evapo-
rate by a gentle heat a quantity of human urine, voided six
or eight hours after a meal, till it be reduced to the consis-
tence of a thick syrup.   In this state, when put by to cool,
it concretes into a crystalline mass.   Pour at different times
upon this mass four times its weight of alcohol, and apply
a gentle heat; a great part of the mass will be dissolved,
and there will remain only a number of saline substances.
Pour the alcohol solution into a retort, and distil by the
heat of a sand-bath till the liquid, after boiling some time, is
reduced to the consistence of a thick syrup.   The whole of
the alcohol is now separated, and what remains in the
retort crystallizes as it cools.   These crystals consist of the
substance known by the name of *urea.**

Discovery.

It was first described by Rouelle, junior, in 1773, under
the name of the *saponaceous extract of urine.* He mentioned
several of its properties; but very little was known con-
cerning its nature till Fourcroy and Vauquelin published
their experiments on it in 1799.   These celebrated che-
mists have given it the name of *urea,* which has been gene-
rally adopted.

Properties.

Urea, obtained in this manner, has the form of crystal-
line plates crossing each other in different directions.   Its
colour is yellowish-white; but when perfectly pure it is
white, semitransparent, and crystallized in four-sided and
six-sided prisms.

It has a fetid smell, somewhat resembling that of garlic
or arsenic; its taste is strong and acrid, resembling that of
ammoniacal salts; it is very viscid and difficult to cut, and
has a good deal of resemblance to thick honey.†   When ex-
posed to the open air, it very soon attracts moisture, and is
converted into a thick brown liquid.   It is extremely solu-
ble in water; and during its solution a considerable degree

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* Fourcroy and Vauquelin, Ann. de Chim. xxxii. 86.

† Fourcroy and Vauquelin, Ann. de Chim. xxxii. 88.   According to
Proust, when obtained by the above processes, the urea is saturated with
ammonia.   Jour. de Phys. lvi. 113.

of cold is produced.* Alcohol dissolves it with facility, but scarcely in so large a proportion as water. The alcohol solution yields crystals much more readily on evaporation than the solution in water.

When nitric acid is dropped into a concentrated solution of urea in water, a great number of bright pearl-coloured crystals are deposited, composed of urea and nitric acid. No other acid produces this singular effect. The concentrated solution of urea in water is brown, but it becomes yellow when diluted with a large quantity of water. The infusion of nutgalls gives it a yellowish-brown colour, but causes no precipitate; neither does the infusion of tan produce any precipitate.†

Crystal- lizes with nitric acid.

When heat is applied to urea, it very soon melts, swells up, and evaporates with an insupportably fetid odour. When distilled, there comes over first benzoic acid, then carbonate of ammonia in crystals, some carbureted hydrogen gas, with traces of prussic acid and oil; and there remains behind a large residuum, composed of charcoal, muriate of ammonia, and muriate of soda. The distillation is accompanied with an almost insupportably fetid alliaceous odour. Two hundred and eighty-eight parts of urea yield by distillation 200 parts of carbonate of ammonia, 10 parts of carbureted hydrogen gas, seven parts of charcoal, and 68 parts of benzoic acid, muriate of soda, and muriate of ammonia. These three last ingredients Fourcroy and Vauquelin consider as foreign substances, separated from the urine by the alcohol at the same time with the urea. Hence it follows that 100 parts of urea, when distilled, yield

Action of heat.

Carbonate of ammonia .... 92·027
Carbureted hydrogen gas .. 4·608
Charcoal .... 3·225
————
99·860

Now 200 parts of carbonate of ammonia, according to Fourcroy and Vauquelin, are composed of 86 of ammonia, 90 carbonic acid gas, and 24 water. Hence it follows that 100 parts of urea are composed of

* Fourcroy and Vauquelin, Ann. de Chim. xxxii. 88.
† Ibid.

Oxygen .... 39·5
Azote .... 32·5
Carbon ...... 14·7
Hydrogen .... 13·3
—————
100·0

But it can scarcely be doubted that the water which was found in the carbonate of ammonia existed ready formed in the urea before the distillation.*

When the solution of urea in water is kept in a boiling heat, and new water is added as it evaporates, the urea is gradually decomposed, a very great quantity of carbonate of ammonia is disengaged, and at the same time acetic acid is formed, and some charcoal precipitates.†

Putrifaction. When a solution of urea in water is left to itself for some time, it is gradually decomposed. A froth collects on its surface; air bubbles are emitted which have a strong disagreeable smell, in which ammonia and acetic acid are distinguishable. The liquid contains a quantity of acetic acid. The decomposition is much more rapid if a little gelatin be added to the solution. In that case more ammonia is disengaged, and the proportion of acetic acid is not so great.‡

Action of sulphuric acid, When the solution of urea is mixed with one-fourth of its weight of diluted sulphuric acid, no effervescence takes place; but, on the application of heat, a quantity of oil appears on the surface, which concretes upon cooling; the liquid which comes over into the receiver contains acetic acid, and a quantity of sulphate of ammonia remains in the retort dissolved in the undistilled mass. By repeated distillations, the whole of the urea is converted into acetic acid and ammonia.§

Nitric acid, When nitric acid is poured upon crystallized urea, a violent effervescence takes place, the mixture froths, assumes the form of a dark-red liquid, great quantities of nitrous gas, azotic gas, and carbonic acid gas, are disengaged. When the effervescence is over, there remains

* Ann. de Chim. xxxii. 88. It would be useless to calculate the constitution of urea from this analysis; because several of the data upon which it is founded being obviously inaccurate, the proportions assigned in it cannot be correct.   † Ibid. p. 96.   ‡ Ibid.
§ Ibid. p. 104.

only a concrete white matter, with some drops of reddish liquid. When heat is applied to this residuum, it detonates like nitrate of ammonia. Into a solution of urea, formed by its attracting moisture from the atmosphere, an equal quantity of nitric acid, of the specific gravity 1·460, diluted with twice its weight of water, was added; a gentle effervescence ensued: a very small heat was applied, which supported the effervescence one or two days. There was disengaged the first day a great quantity of azotic gas and carbonic acid gas; the second day, carbonic acid gas, and at last nitrous gas. At the same time with the nitrous gas the smell of the oxyprussic acid of Berthollet was perceptible. At the end of the second day, the matter in the retort, which was become thick, took fire, and burnt with a violent explosion. The residuum contained traces of prussic acid and ammonia. The receiver contained a yellowish acid liquor, on the surface of which some drops of oil swam.[*]

Muriatic acid dissolves urea, but does not alter it. Chlorine gas is absorbed very rapidly by a diluted solution of Muriatic acid and chlorine. urea; small whitish flakes appear, which soon become brown, and adhere to the sides of the vessel like a concrete oil. After a considerable quantity of this gas had been absorbed, the solution, left to itself, continued to effervesce exceeding slowly, and to emit carbonic acid and azotic gas. After this effervescence was over, the liquid contained muriate and carbonate of ammonia.

Urea is dissolved very rapidly by a solution of potash or Action of alkalies. soda, and at the same time a quantity of ammonia is disengaged; the same substance is disengaged when urea is treated with barytes, lime, or even magnesia. Hence it is evident, that this appearance must be ascribed to the muriate of ammonia, with which it is constantly mixed. When pure solid potash is triturated with urea, heat is produced, a great quantity of ammonia is disengaged; the mixture becomes brown, and a substance is deposited, having the appearance of an empyreumatic oil. One part of urea and two of potash, dissolved in four times its weight of water, when distilled, give out a great quantity of ammoniacal water; the residuum contains acetate and carbonate of potash.[†]

* Ann. de Chim. xxxii. 107.　　　　† Ibid.

When muriate of soda is dissolved in a solution of urea in water, it is obtained by evaporation, not in cubic crystals, its usual form, but in regular octahedrons. Muriate of ammonia, on the contrary, which crystallizes naturally in octahedrons, is converted into cubes, by dissolving and crystallizing it in the solution of urea.

Such are the properties of this singular substance, as far as they have been ascertained by the experiments of Fourcroy and Vauquelin. It differs from all animal substances hitherto examined, in the great proportion of azote which enters into its composition, and in the facility with which it is decomposed, even by the heat of boiling water.

SECT. IX.

OF SACCHARINE MATTER.

THE species of saccharine matter hitherto found in the animal kingdom are the following:

  1. Sugar of milk.
  2. Honey.
  3. Sugar of diabetic urine.

How obtained. 1. Sugar of milk may be obtained by the following process: let fresh whey be evaporated to the consistence of honey, and then allowed to cool; it concretes into a solid mass. Dissolve this mass in water, clarify it with the white of eggs, filter and evaporate to the consistence of a syrup; it deposits on cooling a number of brilliant white cubic crystals, which are *sugar of milk*. Fabricius Bartholdi, an Italian, was the first European who mentioned this sugar. He described it in his *Encyclopædia Hermetico-Dogmatica*, published at Boulognia in 1619; but it seems to have been known in India long before that period. For the best account of its properties we are indebted to Mr. Lichtenstein.

Properties. When pure it has a white colour, a sweetish taste, and no smell. Its crystals are semitransparent regular parellelopipeds, terminated by four-sided pyramids. Its specific gravity, at the temperature of 55°, is 1·543. At the tem-

perature of 59°, it is soluble in five times its weight of water, and in two and a half times its weight of boiling water. It is perfecly insoluble in alcohol, but the addition of a little sulphuric acid makes it soluble in that liquid. When burnt it emits the odour of caromel, and exhibits precisely the appearance of burning sugar. When distilled, it yields the same products as sugar, only the empyreumatic oil obtained has the odour of benzoic acid.* When treated with nitric acid it yields *saclactic* acid. From the experiments of Vogel and Bouillon La Grange, we learn that sugar of milk is soluble in muriatic and acetic acid. Chlorine decomposes it into water and carbonic acid. Strong potash ley decomposes it in the cold, and converts it into water, carbonic acid, acetic acid, and a colouring matter. Neither alcohol nor ether dissolves it.† From the experiment of Bucholz, it appears that sugar of milk is not susceptible of the vinous fermentation.‡

Sugar of milk combines with protoxide of lead in various proportions. The neutral compound has a mucous appearance when moist, but becomes yellow and semitransparent when dry. Its constituents, according to the analysis of Berzelius, are as follows :

<div style="margin-left:2em">Saccolate of lead.</div>

| Sugar of milk... | 36·471 | .... 100 | .... 8·039 |
| Oxide of lead... | 63·529 | .... 174·15 | .... 14 |

$$100 \cdot 000$$

Oxide of lead digested with sugar of milk appears at first not in the least altered. It is however converted into a sabsaccolate of lead, which when well washed and dried is a yellow powder composed of

| Sugar of milk... | 12·8 | .... 100 | .... 2·055 |
| Oxide of lead... | 87·2 | .... 681 | .... 14 |

$$100 \cdot 0 §$$

From these analyses we see that the equivalent number for sugar of milk is 8·22. We may take 8·25 as sufficiently near.

It has been analysed both by Gay-Lussac and Thenard,

* Scheele, ii. 70.   † Schweigger's Jour. ii. 342.
‡ Schweigger's Jour. ii. 359.   § Annals of Philosophy, v. 267.

Book V. and by Berzelius. According to Gay-Lussac and Thenard, its constituents are,

Composition.

Oxygen	53·834
Carbon	38·825
Hydrogen	7·341
	100·000*

Berzelius' numbers approach very nearly to these. According to him the constituents of sugar of milk are,

Oxygen	53·359
Carbon	39·474
Hydrogen	7·167
	100·000†

These analyses do not correspond well with the equivalent number for the weight of sugar of milk deduced from analysis. Were we to suppose it composed of 4 atoms oxygen, 5 atoms carbon, and 4 atoms hydrogen, its composition would be as follows :

4 Atoms oxygen ..	= 4	....	48·4
5 Atoms carbon ..	= 3·75	....	45·4
4 Atoms hydrogen	= 0·5	....	6·2
	8·25		100·0

Numbers quite irreconsileable with the analyses above given. The subject therefore requires farther investigation. ‡

Honey. 2. Honey is prepared by bees, and perhaps rather belongs to the vegetable than the animal kingdom. It has a white or yellowish colour, a soft and grained consistence, a saccharine and aromatic smell. By distillation it affords an acid phlegm and an oil, and its coal is light and spongy like that of the mucilages of plants. Nitric acid extracts

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* Recherches Physico-chimiques, ii. 295.
† Annals of Philosophy, v. 266.
‡ If the reader wishes a more detailed account of sugar of milk, he may consult Litchtenstein's Abbandlung, published separately in 1772, and Rouelle's dissertation in the 39th volume of the Jour. de Medicine. An abridged view of the whole has been given by Morveau in the first volume of the Encycl. Methodique, which has been published in an English dress by Mr. Johnson in his History of Animal Chemistry, i. 128.

from it oxalic acid, precisely as it does from sugar. It is very soluble in water, with which it forms a syrup, and like sugar passes to the vinous fermentation. Mr. Cavezzali has affirmed that honey is composed of sugar, mucilage, and an acid. The sugar may be separated by melting the honey, adding carbonate of lime in powder as long as any effervescence appears, and scumming the solution while hot. The liquid thus treated gradually deposits crytals of sugar when allowed to remain in a glass vessel.* Its crytals, as far as I have observed, are quite analogous to those of sugar of grapes.

According to Proust, there are two kinds of honey; one always liquid, and the other solid and not deliquescent. They may be separated, he says, by means of alcohol.†

3. The urine of persons labouring under the disease known to physicians by the name of *diabetes*, yields, when evaporated, a considerable quantity of matter which possesses properties analogous to sugar. This seems to have been first observed by Willis. Afterwards the subject was carried somewhat farther by subsequent physicians. But it is to Mr. Cruikshanks that we are indebted for the most valuable set of experiments on the subject. In this case he extracted frome urine about $\frac{1}{12}$th of its weight of a sweet-tasted extract like honey. When treated with nitric acid, it yielded the same proportion of oxalic acid as an equal quantity of common sugar would have done, making allowance for the saline substances present. No saclactic acid was formed. Hence it follows that this substance is not analogous to sugar of milk, but nearer common sugar in its properties. It crystallizes nearly in the same manner as sugar of grapes. I have seen it prepared by Dr. Wollaston in small grains having almost exactly the appearance of common white sugar. Nicolas affirms that when treated with lime it is decomposed.‡ If so, it certainly differs essentially from common sugar, which Cruikshanks first proved to be capable of uniting to lime without decomposition.

Sugar of diabetic urine.

* Ann. de Chim. xxxix. 110.   † Jour. de Phys. lix. 428.
‡ Ann de Chim. xliv. 64.

SECT. X.

OF CANTHARIDIN.

I GIVE this name to the substance in cantharides or Spanish flies, (*meloé vesicatorius*) which occasions a blister when applied to the skin. It was obtained in a separate state, and its properties were examined by M. Robiquet in 1810.* It may be obtained by the following process.

Prepara-
tion.

Boil cantharides in water till every thing soluble in that liquid be taken up. Concentrate the solution by evaporation, and when reduced to a thick syrup boil it repeatedly in alcohol till that liquid ceases to act upon it. Evaporate the alcoholic solution gently to dryness, and put the dry residue into a phial with sulphuric ether, and agitate the mixture for a considerable time. At first the ether will seem to have no effect upon it, but after some hours it assumes a yellow colour. Decant it off and allow it to evaporate spontaneously in the open air. It deposits small crystalline plates mixed with a yellow matter. Alcohol takes up the yellow matter; but leaves the crystalline plates. These plates when dried between folds of blotting paper are cantharidin in a state of considerable purity.

Properties.

Cantharidin thus obtained is in small plates, having a shining micaceous appearance. It is insoluble in water and in cold alcohol. Boiling alcohol dissolves it, but lets it fall again in crystals as the solution cools. Ether dissolves it but not very powerfully. It dissolves very readily in oils, and when applied to the skin it acts as a vesicatory with great energy. The solution of it in oils is equally efficaceous.†

SECTION XI.

OF COCHENILIN.

THE cocheneal is an insect which inhabits different species of cactus, and which is propagated in Mexico and

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* Ann. de Chim. lxxvi. 302.
† Robiquet, Ann. de Chim. lxxvi. 308.

some other countries in order to be employed as a dye stuff. By it the scarlet, the most splendid of all colours, is given to cloth. It is to the red colouring matter of the insect that Dr. John has given the name of cochenilin. He has examined this colouring matter, and established it as a peculiar animal principle. According to him the constituents of the cocheneal insect, are the following:

Cochenilin	50·0
Jelly	10·5
Waxy fat	10·0
Gelatinous mucus	14·0
Shining matter	14·0
Alkaline phosphate	
Alkaline muriate	
Phosphate of lime }	1·5
Phosphate of iron	
Phosphate of ammonia	

100·0*

Cochenilin has a fine carmine red colour, permanent in dry air, but converted into a glutinous matter when kept in a moist place. It is soluble in water, alcohol, and ether. When the aqueous solution of it is evaporated in the open air it undergoes the same alteration as happens to extractive in the same circumstances. It is soluble in caustic alkalies and likewise in acids. It is not precipitated by the infusion of nutgalls. The strong affinity which it has for alumina, oxide of tin, and some other oxides, is well known.

Properties.

SECT. XII.

OF OILS.

THE oily substances found in animals belong all to the class of fixed oils. They differ very much in their consistence, being found in every intermediate state from spermaceti, which is perfectly solid, to train oil, which is com-

* John's Tabellen des Thier reichs, p. 127.

pletely liquid. The most important of them are the following :

Fat.   1. *Fat.*—This substance is found abundantly in different parts of animals. When pure it possesses the properties of the fixed oils. Its consistence varies from *tallow* or *suet*, which is brittle, to *hog's lard*, which is soft and semifluid. To obtain fat pure, it is cut in small pieces, well washed in water, and the membranous parts and vessels separated. It is then melted in a shallow vessel along with some water, and kept melted till the water is completely evaporated. Thus purified it is white, tasteless, and nearly insipid.

Properties.   Different kinds of it liquify at different temperatures. Lard melts at 97°; but the fat extracted from meat by boiling requires, according to Nicholson, a heat of 127°. When heated to about 400°, it begins to emit a white smoke, which becomes more copious and more disagreeable as the heat increases; at the same time it becomes blackish, owing doubtless to the decomposition of a portion of it and the evolution of some charcoal. If it be now cooled it becomes more brittle and solid than at first. When hog's lard is distilled in a retort, we obtain first a portion of water, and then a white oil, which concretes in the receiver into small round globules, and a black mass remains in the retort. During the whole process abundance of carbureted hydrogen and carbonic acid come over, which have a most abominable odour. When the vessels are unluted, they emit an odour so detestable and powerful that it is absolutely impossible to endure it. It was formerly snpposed that this odour was exhaled by the sebacic acid formed during the process; but Thenard has shown this to be a mistake. We must therefore ascribe it to an empyreumatic oil. The smell does not suddenly disappear. During this distillation acetic acid is disengaged, and likewise some sebacic acid, which is found in solution in the receiver mixed with the oil.

Nature.   These products demonstrate the peculiar nature of fat; at the same time its analogy to fixed oil is so strong that we cannot but consider it as belonging to the same genus of bodies. Its constituents are undoubtedly oxygen, hydrogen, and carbon, in unknown proportions. It has been supposed also to contain an acid. The opinion originated from the older chemists, that all the solid oily bodies were

indebted to an acid for their solidity. The experiments of Crell were supposed to demonstrate the truth of this opinion; but Thenard has lately shown that these experiments were erroneous, and that the results obtained are to be ascribed to the impurity of the substances employed. The sebacic acid is evolved by the action of heat upon the fat.

Fat is insoluble in water, alcohol, and ether. The strong acids dissolve and gradually decompose it. With the alkalies it combines and forms soap.

When a little nitric acid is poured on fat, and a moderate heat applied, the acid deposits its oxygen, and converts the fat into a yellow-coloured ointment, which Fourcroy considers as an oxide of fat, and which is said to have been employed with great success in France in external venereal affections. A portion of saclactic acid is formed by the action of the nitric acid. Fat dissolves a little sulphur and phosphorus. The phosphorus is speedily converted into phosphorous acid. According to Vogel the mercury in the medicinal preparations made by triturating mercury and fat is in the metallic state.[*]

The rancidity of fat is to be ascribed to the same cause as the rancidity of the fixed oils.

2. *Train oil.*—This liquid is extracted from the blubber of the whale, and from other fish. It forms a very important article of commerce, being employed for combustion in lamps, and for other purposes. It is at first thick; but on standing, a white mucilaginous matter is deposited, and the oil becomes transparent. It is then of a reddish brown colour, and has a disagreeable smell. If it be agitated with a little sulphuric acid, and then mixed with water, the oil, when allowed to settle, swims on the surface, of a much lighter colour than before, the water continues milky, and a curdy matter is observed swimming between the oil and water. This method has been employed for purifying the oil, to make it more proper for burning in lamps. Various other methods have been employed. The most important are those recommended by Mr. Dossie.[†]

3. *Spermaceti oil.*—This is the oil which separates from

Marginal notes: Chap. . / Train oil. / Spermaceti oil.

[*] Ann. de Chim. lviii. 154.

[†] See Phil. Mag. xv. 105 ; and the Transactions of the Society for the Encouragement of the Arts, vol. xx.

Book V.   spermaceti during the purification of it. It is much purer than train oil, and therefore answers better for burning in lamps.

Butter.   4. *Butter* possesses all the characters of a fixed oil; but as it is not found ready formed in any animal substance, the detail of its properties belongs to the next Chapter.

Oil of ants.   5. *Oil of ants.*—Margraff obtained this oil by macerating the *formica rufa* in water, and distilling off one-half of the liquid. The oil was found swimming upon the surface of the water in the receiver. It is liquid, and dissolves completely in alcohol. Its taste is not hot, but it has a peculiar smell. It appears to be intermediate between fixed and volatile oils in its properties.*

Animal oil of Dippel.   6. Though all the oily bodies found in animal substances belong to the class of fixed oils, yet there is a peculiar volatile oil which makes its appearance, and which is doubtless formed during the distillation of different animal bodies. Though this oil has now lost that celebrity which drew the attention of the older chemists to it, yet as its properties are peculiar, a short account of it will not be improper. It is usually called the *animal oil of Dippel*, because that chemist first drew the attention of chemists to it. It is commonly obtained from the gelatinous and albuminous parts of animals. The horns are said to answer best. The product of the first distillation is to be mixed with water, and distilled with a moderate heat : the oil which is first obtained is the animal oil of Dippel.

It is colourless and transparent; its smell is strong and rather aromatic; it is almost as light and as volatile as ether; water dissolves a portion of it; and it changes syrup of violets green, owing, as is supposed, to its containing a little ammonia. The acids all dissolve it, and form with it a kind of imperfect soap. Nitrous acid sets it on fire. It forms with alkalies a soap. Alcohol, ether, and oils unite with it. When exposed to the air it becomes brown, and loses its transparency. It was formerly used as a specific in fevers.†

* Margraff, Opusc. i. 291.
† See the experiments of Model and Dehne.

SECT. XIII.

OF ANIMAL RESINS.

SUBSTANCES resembling resins are found in different animal bodies; and which, for that reason, may be called *animal resins*. Their properties are somewhat different from the vegetable resins, but they have not been all examined with precision. The following are the most remarkable of these substances:

1. *Ambergris.*—This substance is found floating on the sea, near the coasts of India, Africa, and Brazil, usually in small pieces, but sometimes in masses of 50 or 100 pounds weight. Various opinions have been entertained concerning its origin. Some affirmed that it was the concrete juice of a tree; * others thought it a bitumen; but it is now considered as pretty well established, that it is a concretion formed in the stomach or intestines of the *physeter macrocephalus,* or spermaceti whale.†

Ambergris when pure is a light soft substance which swims on water. Its specific gravity varies from 0·78 to 0·92, according to Brisson; Bouillon La Grange, who has published an analysis of it, found its specific gravity from 0·849 to 0·844.‡ Its colour is ash grey, with brownish yellow and white streaks. It has an agreeable smell, which improves by keeping. Its taste is insipid.

When heated to 122° it melts without frothing; if the heat be increased to 212°, it is volatilized completely in a white smoke, leaving only a trace of charcoal. When distilled, we obtain a whitish acid liquid and a light volatile oil; a bulky charcoal remains behind.§

It is insoluble in water. Acids have little action on it. Weak sulphuric acid occasions no change; but when concentrated it developes a little charcoal. Nitric acid dissolves it, giving out at the same time nitrous gas, carbonic acid, and azotic gas. A brownish liquid is formed, which leaves, when evaporated to dryness, a brittle brown substance, possessing the properties of a resin. The alkalies dissolve it

Ambergris.

Properties.

* See the New Abridgement of the Phil. Trans. ii. 89.
† See Phil. Trans. vols. xxxiii. xxxviii. and xc.
‡ Ann. de Chim. xlvii. 73.
§ Bouillon La Grange, Ann. de Chim. xlvii. 73.

by the assistance of heat, and form a soap soluble in water. Both the fixed and volatile oils dissolve ambergris. It is soluble also in ether and alcohol.*

Analysis.   When 100 parts of ambergris are macerated for 24 hours in 16 parts of alcohol, the liquid assumes a deep yellow colour. By repeating the process, the alcohol takes up the whole that is soluble. Hot alcohol dissolves the rest, except a little charry matter easily separated by filtration. It weighs 5·4 parts. The cold infusions of alcohol being evaporated to dryness, there remains a brown brilliant substance, which is readily melted by heat, and which volatilizes completely when put upon hot charcoal. This substance possesses the properties of a resin. It amounts to 30·8 parts. It is precipitated from alcohol by water, leaving a portion of benzoic acid, which may be likewise separated from ambergris by heat, and by the usual process by which it is extracted from benzoin. It amounts to 11·1 parts. When the hot alcohol infusion is allowed to cool, it lets fall the portion of ambergris which it held in solution. This substance is of a pale yellow colour, and easily softens by heat. When slowly cooled, it assumes a lamellar form. It possesses the properties of the fatty matter into which the muscles are converted by nitric acid, and which makes its appearance when dead bodies are allowed to putrify in great numbers together. This substance has been distinguished by the name of *adipocire*, from its resemblance both to fat and wax. The quantity of it in ambergris amounts to 52·8 parts. Such is the analysis of ambergris made by Bouillon La Grange. This substance, then, according to that chemist, is composed of

Constituents.

52·7 adipocire

30·8 resin

11·1 benzoic acid

5·4 charcoal
———
100·0†

But Bucholz who subjected ambergris to a late examination was unable to extract any benzoic acid from it. He considers it as a peculiar substance.‡

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* Bouillon La Grange, Ann. de Chim. xlvii. 75.

† Ann. de Chim. xlvii. 80.   ‡ Ibid. lxxiii. 95.

2. *Propolis.* This is a substance collected by bees newly placed in a hive. They employ it to cover the bottom of the hive, and to coat over all foreign substances which are too heavy to be removed. The bees bring it on their legs and feet; to which it adheres so strongly that the insect cannot extricate itself; but its associates pull it off with their jaws, and apply it to immediate use. It is probably a vegetable production; but as this is not known for certain, and as it is prepared by animals, I have reserved an account of its properties for this place. Vauquelin has subjected it to a chemical analysis.

It is at first soft and ductile, but it gradually hardens and becomes solid. In large masses it appears blackish; but in thin pieces it is semitransparent. The heat of the fingers is sufficient to soften it, and give it the ductility of wax; but it is more ropy and tenacious. It is tasteless, but has an aromatic odour similar to that of the balsam of Peru. When macerated in alcohol, it tinges the liquid of a deep red colour; and by repeating the maceration, the portion soluble is separated. Boiling alcohol dissolved another portion of it; and by repeated decoctions 100 parts of propolis were reduced to 14, which consisted of extraneous bodies. All the alcoholic solutions were mixed and passed through a fine strainer, which separated the portion that precipitated as the decoction cooled. This substance, when properly dried, possessed the properties of wax. The alcohol was now concentrated by distillation, then mixed with water, and boiled. A resinous mass was obtained of a red brown colour, semitransparent, and very brittle. It weighed 57 parts. The water in which it had been boiled contained an acid, probably the benzoic. By distillation the resinous matter yielded a volatile oil, and became harder. This resin is soluble in fixed and volatile oils, and very similar in its properties to the resin of balsam of Peru. Thus 100 parts of propolis contain

57 resin
14 wax
14 impurities
15 acid and loss

———

100*

* Nicholson's Jour. v. 48.

Book V.   3. *Castor.* This substance is obtained from the beaver.
In each of the inguinal regions of that animal there are

Castor.   two bags, a large and a small. The large one contains the
true castor; the small one a substance which has some re-
semblance to it, but which is in much less estimation. We
are indebted to Bouillon La Grange for a set of experi-
ments on it.*

Properties.   Castor is of a yellow colour; and when newly taken from
the animal it is nearly fluid. But by exposure to the at-
mosphere it gradually hardens, becomes darker coloured,
and assumes a resinous appearance. Its taste is bitter and
acrid, and its odour strong and aromatic. In water it
softens, and tinges the liquid of a pale yellow colour. The
infusion gives a green colour to vegetable blues, and con-
tains an alkali. By long continued maceration a deeper
coloured infusion is obtained, which yields a dry extract of
a tortoise-shell colour, soluble in ether and alcohol. Water
precipitates a resinous substance from the alcohol. From
the analysis of Bouillon La Grange, we learn that castor
contains the following ingredients :

Constitu-
ents.
1. Carbonate of potash.
2. Carbonate of lime.
3. Carbonate of ammonia.
4. Iron.
5. Resin.
6. A mucilaginous extractive matter.
7. A volatile oil.

The properties of the resin are analogous to those of the
resin of bile.

Civet.   4. *Civet.*—This substance, like the last, is obtained from
the inguinal region of the *civet-cat.* It is squeezed out of
the cavity where it is secreted every other day. It is em-
ployed as a perfume, but has not hitherto engaged the at-
tention of chemists. Its colour is yellow; its consistence
that of butter; its smell so strong as to be agreeable only
when much reduced by mixture with other bodies. It
unites readily with oils, but is said not to dissolve in alco-
hol. In that case it ought to be excluded from the class of
resinous bodies.

Musk.   5. *Musk.*—This substance is secreted into a kind of bag

* Jour. de Phys. xlii.

situated in the umbilical region of the quadruped called *moschus moschifer*. Its colour is brownish-red; it feels unctuous; its taste bitter; and its smell aromatic and intensely strong. It is partially soluble in water, which acquires its smell; and in alcohol, but that liquid does not retain the odour of musk. Nitric and sulphuric acids dissolve it, but destroy the odour. Fixed alkalies develope the odour of ammonia. Oils do not act on it. At a red heat it has the same fetid smell as urine.* Its component parts have not been ascertained.

6. The *formica rufa*, or red ant, contains also a peculiar resin, as has been proved by Fourcroy and Vauquelin.†

SECT. XIV.

OF SULPHUR AND PHOSPHORUS.

THESE two simple combustibles constitute a part of many animal substances; but in what state of combination they exist in them has not been ascertained. All that can be done therefore at present is to mention some of the bodies from which they may be separated.

1. Sulphur seems to be a never-failing attendant on al- Sulphur. bumen, in whatever part of the body that substance exists as a constituent. Scheele ascertained its presence in the white of an egg and in milk; ‡ Parmentier and Deyeux in the blood; § Proust in urine and fæces, in the muscles, in hair, &c. and he has made it probable that sulphur is mixed with the matter which is transpired from the body.‖ This chemist informs us, that in the blood it is combined with ammonia in the state of hydrosulphuret of ammonia; but whether it be in the same state in other parts of the body is not known.

2. Phosphorus exhales from different animal bodies during Phosphorus. putrifaction in the state of phosphureted hydrogen gas, and of course must have been a constituent part of these bodies. The luminous appearance which some animals exhibit

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* Neumann. † Phil. Mag. xv. 148
‡ Scheele, ii. 57. § Jour. de Phys. xliv. 437.
‖ Ann. de Chim. xxxvi. 258.

Book V. seems, in several instances, to be owing to the presence of this very combustible substance: but the experiments hitherto made upon these animals are not sufficiently decisive.

SECT. XV.

OF ACIDS.

Acids.   THE acids which have been discovered ready formed, and constituting a part of animal bodies, are the following:

1. Phosphoric.	8. Amniotic.
2. Sulphuric.	9. Oxalic.
3. Muriatic.	10. Formic.
4. Carbonic.	11. Acetic.
5. Benzoic.	12. Malic.
6. Uric.	13. Lactic.
7. Rosacic.	14. Silica.

Phosphoric.   1. The phosphoric acid is by far the most abundant of all the acids found in animals. Combined with lime, it constitutes the basis of bone; and the phosphate of lime is found in the muscles and almost all the solid parts of animals; neither are there many of the fluids from which it is absent. In the blood, phosphoric acid is found combined with oxide of iron; and in the urine it exists in excess, holding phosphate of lime in solution.

Sulphuric.   2. Sulphuric acid has been shown by Berzelius to be a constant ingredient of urine. It is a very common constituent of the liquid contents of the inferior animals. Thus sulphate of soda is found in the liquor of the amnios of cows, and sulphate of lime occurs usually in the urine of quadrupeds.

Muriatic.   3. Muriatic acid occurs in most of the fluid animal substances, and is almost always combined with soda, constituting common salt.

Carbonic.   4. Carbonic acid has been detected in fresh human urine by Proust, and it occurs in the urine of horses and cows abundantly, partly combined with lime.

Benzoic.   5. Benzoic acid was first discovered in human urine by Scheele; and Fourcroy and Vauquelin have found it abundantly in the urine of cows. Proust has detected it in the

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blood, the albumen of an egg, in glue, silk, and wool, in the
sponge, different species of algæ, and even in mushrooms.
This chemist even thinks it probable that it is a constituent
of all substances which contain azote.* Or more pro-
bably it is formed during the action of reagents on these
substances.

6. Uric or lithic acid was discovered by Scheele in 1776. Uric.
It is the most common constituent of urinary calculi, and
exists also in human urine. That species of calculus which
resembles wood in its colour and appearance is composed
entirely of this substance. It was called at first lithic acid;
but this name, in consequence of the remarks made by Dr.
Pearson on its impropriety, has been laid aside, and that of
uric acid substituted in its place.† .

7. Rosacic. During intermittent fevers urine deposits Rosacic.
a very copious precipitate, which has been long known to
physicians under the name of *lateritious sediment*. This
sediment always makes its appearance at the crisis of fevers.
In gouty people, the same sediment appears in equal abun-
dance towards the end of a paroxysm of the disease; and
if this sediment suddenly disappears after it has begun to
be deposited, a fresh attack may be expected.‡ Scheele
considered this sediment as uric acid mixed with some phos-
phate of lime; and the same opinion has been entertained
by other chemists: but Proust affirms that it consists chiefly
of a different substance, to which he has given the name of
rosacic acid from its colour, mixed with a certain propor-
tion of uric acid and phosphate of lime. This rosacic acid,
he informs us, is distinguished from the uric by the facility
with which it dissolves in hot water, the violet precipitate
which it occasions in muriate of gold, and by the little ten-
dency which it has to crystallize.

8. Amniotic acid has been discovered by Vauquelin and Amniotic.
Buniva in the liquor of the amnios of the cow, and may be
obtained in white crystals by evaporating that liquid slowly.
Hence they have given it the name of *amniotic acid*. It is
of a white and brilliant colour; its taste has a very slight
degree of sourness; it reddens the tincture of turnsole; it

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* Ann. de Chim. xxxvi. 272.
† Dr. Pearson rather chooses to call it *uric oxide*.
‡ Cruickshanks, Phil. Mag. ii. 249.   § Ann. de Chim. xxxvi. 265.

Book V.   is scarcely soluble in cold water, but very readily in hot water, from which it separates in long needles as the solution cools. It is soluble also in alcohol, especially when assisted by heat. It combines readily with pure alkalies, and forms a substance which is very soluble in water. The other acids decompose this compound; and the acid of the liquor of the amnios is precipitated in a white crystalline powder. This acid does not decompose the alkaline carbonates at the temperature of the atmosphere, but it does so when assisted by heat. It does not alter solutions of silver, lead, or mercury, in nitric acid. When exposed to a strong heat it froths, and exhales an odour of ammonia and of prussic acid. These properties are sufficient to show that it is different from every other acid. It approaches nearest to the saclactic and the uric acids; but the first of these does not furnish ammonia by distillation like the amniotic; the uric acid is not so soluble in hot water as the amniotic; it does not crystallize in white brilliant needles, and it is insoluble in boiling alcohol: in both which respects it differs completely from amniotic acid.*

Oxalic.   9. Oxalic acid has been found only in a species of urinary calculi first analysed by Dr. Wollaston.

10. Formic acid has been hitherto found only in the *formica rufa*, or red ant. The details have been already given in a preceding part of this work.

Acetic.   11. Acetic. This acid exists in the *formica rufa*, or red ant, as has been demonstrated by the experiments of Fourcroy and Vauquelin.

Malic.   12. Malic acid. This acid has been detected by Fourcroy and Vauquelin in the acid liquid obtained from the *formica rufa*. When this liquid is saturated with lime, if acetate of lead be dropped into the solution, a copious precipitate falls, which is soluble in acetic acid. Fourcroy and Vauquelin exposed the precipitate to the proper trials, and ascertained that it was malate of lead.

Lactic.   13. Lactic acid has been shown by Berzelius to exist in urine, milk, and all the fluids of the animal body.

Silica.   14. Silica has not hither been detected in any of the component parts of animals, except hair; but Fourcroy and Vauquelin found it in urinary calculi.

* Ann. de Chim. xxxiii. 279.

Besides the acids enumerated above, several others have been mentioned by chemical writers. The truth is, that a variety of acid liquors have been observed in animals; but Other a-cids. as these have not been examined, we do not know whether they are peculiar substances, or merely some of those already enumerated. Chaussier, in 1781, pointed out an acid in the silk worm, which has been called *bombic acid*.[*] But the list of its properties which he has given is altogether insufficient to constitute it a peculiar substance; and all subsequent accounts of it which I have seen are mere repetitions of the original paper. Dehne obtained an acid from the insects called *meloe proscarabæus* and *majalis*. Chaussier obtained an acid from the grasshopper and the bug. In short, acids are obtained from many of the insect tribe; and from the experiments published, it is extremely probable that in most of these insects the acid is the acetic.

SECT. XVI.

OF ALKALIES, EARTHS, AND METALS.

I. ALL the alkalies have been found in the fluids of animals.

1. Potash is rather uncommon in the human fluids; but Potash. it has been detected in the milk of cows, and it has been found abundantly in the urine of quadrupeds.

2. Soda exists in all the fluids, and seems always to be Soda. combined with albumen. Phosphate and muriate of soda are also found. It is this alkali which gives animal fluids the property of tinging vegetable blues green.

3. Ammonia has been detected by Proust in urine; and Ammonia. it is formed in abundance during the putrifaction of most animal bodies.

II. The only earths hitherto found in animals are lime and magnesia.

1. Lime exists in great abundance in all the larger ani- Lime. mals. Combined with phosphoric acid, it constitutes the basis of bones, while shells are composed of carbonate of

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[*] Mem. Dijon, 1783, ii. 70.

Book V. lime. Phosphate of lime is found also in the muscles and other solid parts, and it is held in solution by almost all the fluids.

Magnesia. 2. Magnesia has been detected in human urine by Fourcroy and Vauquelin, combined with phosphoric acid and ammonia. It constitutes also sometimes a component part of urinary calculi.

The metals found in animals are two; namely, iron and manganese.

Iron. 1. Iron combined with phosphoric acid is a constituent part of the blood. Its presence was first ascertained by Manghini, who proved at the same time that it does not exist in the solid parts of animals. It is said to exist also in bile.

Manganese. 2. Manganese has been found in human hair, but scarcely in any other animal substance.

SECT. XVII.

OF ANIMAL PRINCIPLES IN GENERAL.

Such are the properties of all the animal substances hitherto detected and accurately examined. They are by no means so numerous as the vegetable principles, owing in all probability to the chemical examination of animals having been hitherto confined to a small number, while a much more extensive range has been taken in the vegetable kingdom. The inferior animals, if we except a few insects, have Substances attracted but little of the attention of chemists. I confess, omitted. too, that I have omitted on purpose an account of several principles which are well known to exist in the animal kingdom, merely because we know nothing so precise about their chemical properties as to enable us to class them properly. I may mention, as an example, the colouring matter of the shell-fish with which the ancients dyed their purple. The reader will find a very full and interesting account of all that we know respecting this substance in Dr. Bancroft's *Philosophy of Permanent Colours.* I may mention also the liquor emitted by the ink fish.

Almost the whole of the soft parts of animal bodies con-

sist of albumen, fibrin, and oil; while the bases of the hard parts is either phosphate or carbonate of lime. The other animal principles occur only in small quantities, and particular parts of the animal. The oils seldom enter into the structure of the organs of animals: they serve rather to lubricate the different parts, and to fill up interstices. Gelatin is insoluble in cold water, albumen insoluble in hot, and fibrin insoluble both in cold and hot. The constituents of these three bodies, according to the best analyses of them hitherto made, are as follows:

	Atoms of		
Carbon.	Oxygen.	Hydrogen.	Azote.
Gelatin 15	 6	 14	 2
Albumen .. 17	 6	 13	 2
Fibrin 18	 5	 14	 3

The colouring matter of blood approaches albumen in many of its properties; but it seems entirely destitute of azote.

The simple bodies of which the animal principles consist are the following:

Simple substances found in animals.

1. Azote.	8. Soda.
2. Carbon.	9. Potash.
3. Hydrogen.	10. Muriatic acid.
4. Oxygen.	11. Magnesia.
5. Phosphorus.	12. Silica.
6. Lime.	13. Iron.
7. Sulphur.	14. Manganese.

Of these, magnesia and silica may in a great measure be considered as foreign bodies: for they are only found in exceedingly minute quantities. The principal elementary ingredients are the first six: animal substances may be considered as in a great measure composed of them. The first four constitute almost entirely the soft parts, and the other two form the basis of the hard parts. But we shall be able to judge of this much better after we have taken a view of the various parts of animals as they exist ready formed in the body. This shall be the subject of the next Chapter.

CHAP. II.

OF THE PARTS OF ANIMALS.

Solids.

THE different substances which compose the bodies of animals may be arranged under the following heads:

1. Bones and shells.
2. Horns and nails.
3. Muscles.
4. Skin.
5. Membranes.
6. Tendons and ligaments.
7. Glands.
8. Brain and nerves.
9. Marrow.
10. Hair and feathers.
11. Silk and similar bodies.

Besides these substances, which constitute the solid parts of the bodies of animals, there are a number of fluids, the most important of which are the *chyme* and *chyle*, liquids separated from the food in the stomach and intestines for the purpose of nourishing the animal and the *blood* into which these liquids are finally converted. The rest are known by the name of *secretions*, because they are formed or *secreted*, as the anatomists term it, from the blood. The principal animal secretions are the following:

Fluids.

1. Milk.
2. Eggs.
3. Saliva.
4. Pancreatic juice.
5. Bile.
6. Cerumen.
7. Tears.
8. Liquor of the pericardium.
9. Humours of the eye.
10. Mucus of the nose, &c.
11. Sinovia.
12. Semen.
13. Liquor of the amnios.
14. Poisonous secretions.
15. Air.

Various substances are separated either from the blood or the food, on purpose to be afterwards thrown out of the body as useless or hurtful. These are called *excretions*. The most important of them are,

1. Sweat.   2. Urine.   3. Fæces.

Besides the liquids which are secreted for the different purposes of healthy animals, there are others which make their appearance only during disease, and which may therefore be called *morbid secretions*. The most important of these are the following:

    1. Pus.
    2. The liquor of dropsy.
    3. The liquor of blisters.

To these we must add several solid bodies, which are occasionally formed in different cavities in consequence of the diseased action of the parts. They may be called *morbid concretions*. The most remarkable of them are the following :

    1. Salivary calculi.
    2. Concretions in the lungs, liver, brain, &c.
    3. Intestinal calculi.
    4. Biliary calculi.
    5. Urinary calculi.
    6. Gouty calculi.

These different substances shall form the subjects of the following sections :

SECT. I.

OF BONES, SHELLS, AND CRUSTS.

By *bones* are meant those hard, solid, well-known substances, to which the firmness, shape, and strength of animal bodies are owing; which, in the larger animals, form as it were the ground work upon which all the rest is built. In man, in quadrupeds, and many other animals, the bones are situated below the other parts, and scarcely any of them are exposed to view; but shell-fish and snails have a hard covering on the outside of their bodies, evidently intended for defence. As these coverings, though known by the name of *shells*, are undoubtedly of a bony matter, I shall include them in this Section. For the very same reason, it would be improper to exclude *egg-shells*, and those coverings of certain animals, the lobster for instance, known by the name of *crusts*. The solid substances belonging to that class of bodies usually distinguished by the name *zoophites*, may be included likewise without impropriety in this Section. As these different substances, though they belong to the same genus, are notwithstanding distinguished by peculiar properties, I shall consider each set separately.

2

I. BONES.

The bones are the most solid part of animals. Their texture is sometimes dense, at other times cellular and porous, according to the situation of the bone. They are white, of a lamellar structure, and not flexible nor softened by heat. Their specific gravity differs in different parts. That of adults' teeth is 2·2727; the specific gravity of children's teeth is 2·0833.* It must have been always known that bones are combustible, and that when sufficiently burnt, they leave behind them a white porous substance, which is tasteless, absorbs water, and has the form of the

original bone. The nature of this substance embarrassed the earlier chemists. Beccher observed, that in a very violent heat it underwent a kind of fusion, and assumed an appearance analogous to that of porcelain. It was afterwards considered as a peculiar earth, and distinguished by the name of *animal earth* or *earth of bones*. Some chemists considered it as the same with lime; but the difference between it and that earth was too well marked to allow that opinion to gain ground. It had been long known that bones yielded a gelatinous substance when boiled in water; they had even been employed in the manufacture of glue. Hence it was obvious that they contained gelatin. It had been observed, that all acids had the property of softening them by dissolving their earthy and gelatinous constituents; and that when thus softened they resembled cartilage. These facts must have been known at a very early period, and afforded chemists some data for estimating their constituents.

In 1771, Scheele mentioned, in his dissertation on fluor spar, that the earthy part of bones is *phosphate of lime.*† This discovery was the first and the great step towards a chemical knowledge of the composition of bones. Afterwards some new facts were made known by Berniard, Bouillon, and Rouelle: but for by far the most complete analyses which have hitherto appeared we are indebted to Mr. Hatchett,‡ to Fourcroy and Vauquelin,§ and to Berzelius.‖

* Pepys, Fox on the Teeth, p. 99.
† The discoverer of this fact was Assessor Gahn of Fahlun, who however never published it himself.   ‡ Phil. Trans. 1799.
§ Ann. de Chim. xlvii. 244.   ‖ Afhandlingar, i. 195.

The component parts of bones are chiefly four; namely, the *earthy salts, fat, gelatin,* and *cartilage.*

1. The earthy salts may be obtained either by calcining the bone to whiteness, or by steeping it for a sufficient length of time in acids. In the first case, the salts remain in the state of a brittle white substance; in the second, they are dissolved, and may be thrown down by the proper precipitants. These earthy salts are four in number: 1. Phosphate of lime, which constitutes by far the greatest part of the whole. 2. Carbonate of lime. 3. Phosphate of magnesia, discovered by Fourcroy and Vauquelin. It occurs in the bones of all the inferior animals examined by these indefatigable chemists, but could not be detected by them in human bones. Berzelius however announces its existence in human bones also. 4. Sulphate of lime, detected by Mr. Hatchett in a very minute proportion, and shown by Berzelius to be formed during the calcination.

To estimate these substances, calcined bones may be dissolved in nitric or muriatic acid. During the solution carbonic acid gas makes its escape.* Pure ammonia dropped into the solution throws down the phosphate of lime and phosphate of magnesia in the state of a fine powder, readily soluble without effervescence in nitric and muriatic acids. Nitrate of barytes afterwards causes a small precitate insoluble in muriatic acid, and therefore consisting of sulphate of barytes. Its weight indicates the quantity of sulphuric acid in bones, from which the sulphate of lime which they contain may be estimated.† Carbonate of ammonia now throws down pure carbonate of lime.‡ These three constituents were found by Hatchett in all the bones of quadrupeds and fish which he examined. The carbonate scarcely exceeds the fifth part of the phosphate, and the proportion of sulphate is still smaller. As the proportion of phosphate of lime varies not only in different animals, but even in different bones of the same animal, and even in the same bone of different ages, no precise numbers can be given. To detect and estimate the phosphate of magnesia, Fourcroy and Vauquelin employed the following simple method: the bone, previously calcined and reduced to powder, was treated with its own weight of sulphuric acid, and

* Hatchett, Phil. Trans. 1799, p. 327.   † Ibid.   ‡ Ibid.

Book V. the mixture left to macerate for five or six days. It was then diluted with water, edulcorated, and filtered. The filtered liquid was mixed with an excess of ammonia, which threw down a mixture of phosphate of lime and ammonio-phosphate of magnesia. This precipitate is boiled in potash, which decomposes the magnesian salt, and leaves a mixture of magnesia and phosphate of lime. This mixture is treated with boiling acetous acid, which dissolves the magnesia, and leaves the phosphate of lime. The acetate of magnesia is decomposed by carbonate of soda, and the carbonate of magnesia obtained is dissolved in sulphuric acid.*

2. Fat.   2. The proportion of fat contained in bones is various. By breaking bones in small pieces, and boiling them for some time in water, Mr. Proust obtained their fat swimming on the surface of the liquid. It weighed, he says, one-fourth of the weight of the bones employed.† This proportion appears excessive, and can scarcely be accounted for without supposing that the fat still retained water.

3. Gelatin.   3. The gelatin is separated by the same means as the fat, by breaking the bones in pieces and boiling them long enough in water. The water dissolves the gelatin, and gelatinizes when sufficiently concentrated. Hence the importance of bones in making portable soups, the basis of which is concrete gelatin; and likewise in making glue. By this process Proust obtained from powdered bones about $\frac{1}{10}$th of their weight of gelatin. This celebrated chemist has been at considerable pains to point out the advantage of employing powdered bones in the preparation of soups and broths; and Cadet de Vaux has published a set of experiments to show, that from bones thus powdered as much good soup may be obtained as from five times their weight of meat.‡ But when Dr. Young repeated this improbable experiment it did not succeed.§

4. Carti-   4. When bones are deprived of their gelatin by boiling
lage.   them in water, and of their earthy salts by steeping them in diluted acids, there remains a soft white elastic substance, possessing the figure of the bones, and known by the name of *cartilage*. From the experiments of Hatchett, it appears that this substance has the properties of coagulated

* Ann. de Chim. xlvii. 247.   † Jour. de Phys. lii. 257.
‡ Jour. de Chim. iv. 95.   Jour. of the Royal Institut. ii. 18.
§ Ibid. p. 25.

albumen. Like that substance, it becomes brittle and semi-transparent when dried, is readily soluble in hot nitric acid, is converted into gelatin by the action of diluted nitric acid; for it is soluble in hot water, and gelatinises on cooling, and ammonia dissolves it and assumes a deep orange colour. Like coagulated albumen, it forms an animal soap with fixed alkalies.* Berzelius found its weight about one-third of the whole bone.

This cartilaginous substance is the portion of the bone first formed. Hence the softness of these parts at first. The phosphate of lime is afterwards gradually deposited, and gives the bone the requisite firmness. The gelatin and fat, especially the first, give the bone the requisite degree of toughness and strength; for when they are removed the bone becomes brittle. The relative proportion of phosphate of lime and cartilage differs exceedingly in different bones and in different animals.

Merat-Guillot † a good many years ago published a comparative analysis of the bones of a great number of animals. But Berzelius found these results quite inaccurate. The differences between the composition of the bones of different animals are much smaller than indicated by the table of Merat-Guillot. The following table exhibits the composition of calcined human bones according to the analysis of Berzelius.

Phosphate of lime	81·9
Fluate of lime	3·0
Lime	10·0
Phosphate of magnesia	1·1
Soda	2·0
Carbonic acid	2·0
	100·0 ‡

One hundred parts of fresh bones are reduced by calcination to 63 parts.

Ox bones, according to the analysis of Fourcroy and Vauquelin, are composed of

* Phil. Trans. 1800.   † Ann. de Chim xxxiv. 71.
‡ Gehlen's Jour. Second Series, iii. 1.

Solid gelatin	51·0
Phosphate of lime....	37·7
Carbonate of lime....	10·0
Phosphate of magnesia	1·3
	100·0*

According to the analysis of Berzelius, ox bones are composed of

Cartilage	33·30
Phosphate of lime.............	55·35
Fluate of lime	3·00
Carbonate of lime..........	3·85
Phosphate of magnesia........	2·05
Soda with a little common salt..	2·45
	100·00†

From the calcined bones of horses and sheep, fowls, and fishes, Fourcroy and Vauquelin extracted about $\frac{1}{30}$th part of phosphate of magnesia.

Enamel.   The only bone hitherto observed altogether destitute of cartilage is the enamel of the teeth. When the raspings of bones are steeped in diluted acids, the cartilage alone remains undissolved. Now, when the raspings of enamel are treated in this manner, Mr. Hatchett observed that the whole was dissolved without any residuum whatever.‡ If we believe Fourcroy and Vauquelin, the enamel of the teeth is composed of

Phosphate of lime	72·9
Gelatin and water	27·1
	100·0§

But the most complete analysis of teeth has been made by Mr. Pepys, and his results agree exactly with those of Hatchett. He found the enamel of the teeth composed of

* Ann. de Chim. xlvii. 258.   † Djur kemien, ii. 128.
‡ Phil. Trans, 1799, p. 328.   § Mem. de l' Instit. ii. 284.

Phosphate of lime 78
Carbonate of lime 6
Loss and water 16

——

100*

Berzelius however could not find two per cent. of combustible matter in the enamel of the teeth.†

From the analysis of Mr. Pepys, we learn that the teeth are composed as follows: ‡

	Roots of the Teeth.		Teeth of Adults.		First Teeth of Children.
Phosphate of lime	58	..	64	..	62
Carbonate of lime	4	..	6	..	6
Cartilage	28	..	20	..	20
Loss	10	..	10	..	12
	——		——		——
	100		100		100

Analysis of teeth.

From this analysis, we see that teeth contain more phosphate and less cartilage than bone, and enamel more phosphate than teeth.

Mr. Hatchett examined likewise *fossil bones* from the rock of Gibraltar. He found them to consist of phosphate of lime without any cartilage or soft animal part. Their interstices were filled with carbonate of lime. Hence they resemble exactly bones that have been burnt. They must, then, have been acted on by some foreign agent; for putrifaction, or lying in the earth, does not soon destroy the cartilaginous part of bones. On putting a human os humeri, brought from Hythe in Kent, and said to have been taken from a Saxon tomb, into muriatic acid, he found the cartilaginous residuum nearly as complete as in a recent bone. From the recent experiments of Morichini,§ Klaproth, ‖ and Fourcroy and Vauquelin, ** we learn that fossil ivory and teeth of animals frequently contain a portion of fluate of lime. Morichini and Gay-Lussac endeavoured to prove that this salt existed even in recent ivory, and that the enamel of the teeth was almost entirely composed of it.†† But the experiments of Wol-

Fossil bones.

* Fox on the Teeth, p. 96.　† View of Animal Chemistry, p. 78.
‡ Ibid.　　　　　　　　　§ Phil. Mag. xxiii. 265.
‖ Gehlen's Jour. iii. 625.　** Phil. Mag. xxv. 265.
†† Phil. Mag. xxiii. 265.

laston, Brande,* Fourcroy and Vauquelin, † have shown that there does not exist any sensible portion of fluoric acid in these substances while recent. Berzelius, however, has announced that he separated 3 *per cent.* of fluate of lime from fresh teeth, and that he has detected it also in bones, nearly in the same proportion. He even affirms that it exists in urine.‡ And as his experiments appear to have been made with considerable care, it is probable that the results which he obtained are correct.§

II. SHELLS.

Under the name of *shells* I include all the bony coverings of the different species of shell fish. For almost all the knowledge of these substances that we possess we are indebted to the important dissertations of Mr. Hatchett. A few detached facts, indeed, had been observed by other chemists; but his experiments gave us a systematic view of the constituents of the whole class.

Shells, like bones, consist of calcareous salts united to a soft animal matter; but in them the lime is united chiefly to carbonic acid, whereas in bones it is united to phosphoric acid. In shells the predominating ingredient is carbonate of lime; whereas in bones it is phosphate of lime. This constitutes the characteristic difference in their composition.

Divided into two classes.

Mr. Hatchett has divided shells into two classes. The first are usually of a compact texture, resemble porcelain, and have an enamelled surface, often finely variegated. The shells belonging to this class have been distinguished by the name of *porcelaneous shells.* To this class belong the various species of *voluta, cypræa,* &c. The shells belonging to the second class are usually covered with a strong epidermis, below which lies the shell in layers, and composed entirely of the substance well known by the name of *mother-of-pearl.*|| They have been distinguished by the name of *mother-of-pearl shells.* The *shell* of the *fresh water muscle,*

* Nicholson's Jour. xiii. 216.   † Phil. Mag. xxv. 266.
‡ Gehlen's Jour. vi. 591.
§ His experiments will be found in Gehlen's Jour. Second Series, iii.
2. There is an abstract of them in Ann. de Chim. lxi. 256.
|| Herissant, Mem. Par. 1766, p. 22. Hatchett, Phil. Trans. 1799, p. 317.

the *haliotis iris*, the *turbo olearius*, are examples of such shells. The shells of the first of these classes contain a very small portion of soft animal matter; those of the second contain a very large proportion. Hence we see that they are extremely different in their composition.

1. Porcelaneous shells, when exposed to a red heat, crackle and lose the colour of their enamelled surface. They emit no smoke or smell; their figure continues unaltered, their colour becomes opaque white, tinged partially with pale-grey. They dissolve when fresh with effervescence in acids, and without leaving any residue; but if they have been burnt there remains always a little charcoal. The solution is transparent, gives no precipitate with ammonia or acetate of lead; of course it contains no sensible portion of phosphate or sulphate of lime. Carbonate of ammonia throws down an abundant precipitate of carbonate of lime. Porcelaneous shells, then, consist of carbonate of lime cemented together by a small portion of an animal matter, which is soluble in acids, and therefore resembles gelatin.*

1. Porcelaneous.

Composed of carbonate of lime and a little jelly.

Patellæ from Madeira, examined by Mr. Hatchett, were found, like the porcelaneous shells, to consist of carbonate of lime; but when exposed to a red heat they emitted a smell like horn; and when dissolved in acids a semiliquid gelatinous matter was left behind. They contain therefore less carbonate of lime and more gelatin, which is of a more viscid nature than that of porcelaneous shells.

Patellæ.

2. Mother-of-pearl shells when exposed to a red heat crackle, blacken, and emit a strong fetid odour. They exfoliate, and become partly dark-grey, partly a fine white. When immersed in acids they effervesce at first strongly; but gradually more and more feebly, till at last the emission of air-bubbles is scarcely perceptible. The acids take up only lime, and leave a number of thin membranous substances, which still retain the form of the shell. From Mr. Hatchett's experiments, we learn that these membranes have the properties of coagulated albumen. Mother-of-pearl shells, then, are composed of alternate layers of coagulated albumen and carbonate of lime, beginning with the epidermis, and ending with the last-formed membrane.

2. Mother-of-pearl.

Of membrane and carbonate of lime.

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* Hatchett, Phil. Trans. 1799, p. 317.

Book V. The animals which inhabit these shells increase their habitation by the addition of a stratum of carbonate of lime, secured by a new membrane; and as every additional stratum exceeds in extent that which was previously formed, the shell becomes stronger as it becomes larger.*

Though this in general is the structure of the mother-of-pearl shells, yet there is a considerable difference between the proportion of the component parts and the consistency of the albuminous part. Some of them, as the common oyster-shell, approach nearly to the patellæ, the albuminous portion being small, and its consistence nearly gelatinous; while in others, as the *haliotis iris*, the *turbo olearius*, the real mother-of-pearl, and a species of fresh water muscle analysed by Hatchett, the membranes are distinct, thin, compact, and semitransparent.† Mother-of-pearl contains

Carbonate of lime. 66
Membrane. 24
                        ———
                        100‡

Pearl.   *Pearl*, a well known globular concretion which is formed in some of these shells, resembles them exactly in its structure and composition. It is a beautiful substance of a bluish-white colour, iridescent, and brilliant. It is composed of concentric and alternate coats of thin membrane and carbonate of lime. The iridescence is obviously the consequence of the lamellated structure. §

Bone of the   Mr. Hatchett found that what is called the *bone* of the
cuttle fish. *cuttle fish* is exactly similar to mother-of-pearl shells in its composition.

From the comparative analysis of shells and bones, Mr. Hatchett was induced to compare them together, and has shown that porcelaneous shells bear a striking resemblance to enamel of teeth; while mother-of-pearl shells bear the same resemblance to the substance of teeth or bone : with this difference, that in enamel and bone the earthy salt is phosphate of lime, whereas in shells it is pure carbonate of lime.

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* Hatchett, Phil. Trans. 1799, p. 317.   † Ibid.
‡ Merat-Guillot, Ann. de Chim. xxiv. 71.
§ Hatchett, Phil. Trans. 1799.

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III. CRUSTS.

By crusts we understand those bony coverings of which the whole external surface of crabs, lobsters, and other similar sea animals are composed. Mr. Hatchett found them composed of three ingredients: 1. A cartilaginous substance, possessing the properties of coagulated albumen; 2. Carbonate of lime; 3. Phosphate of lime. By the presence of this last substance they are essentially distinguished from shells, and by the great excess of carbonate of lime above the phosphate they are equally distinguished from bones. Thus the crusts lie intermediate between bones and shells, partaking of the properties and constitution of each. The shells of the eggs of fowls must be referred likewise to the class of crusts, since they contain both phosphate and carbonate of lime. The animal cement in them, however, is much smaller in quantity. From the experiments of Berniard and Hatchett, it is extremely probable that the shells of snails are composed likewise of the same ingredients, phosphate of lime having been detected in them by these chemists.

Constituents.

Between shells and bones.

Mr. Hatchett examined the crusts of crabs, lobsters, prawns, and cray fish. When immersed in diluted nitric acid these crusts effervesced a little, and gradually assumed the form of a yellowish-white soft elastic cartilage, retaining the form of the crust. The solution yielded a precipitate to acetate of lead, and ammonia threw down phosphate of lime. Carbonate of ammonia threw down a much more copious precipitate of carbonate of lime. On examining the crust which covers different species of *echini*, Mr. Hatchett found it to correspond with the other crusts in its composition. Some species of star-fish yielded a phosphate of lime, others none: hence the covering of that genus of animals seems to be intermediate between shell and crust.

With these observations of Mr. Hatchett the analysis of Merat-Guillot corresponds. From lobster crust he obtained

Analysis.

Carbonate of lime. 60
Phosphate of lime 14
Cartilage 26
_____
100*

* Ann. de Chim. xxxiv. 71.

One hundred parts of cray fish crust contain

> Carbonate of lime 60
> Phosphate of lime 12
> Cartilage 28
> ────
> 100*

Egg-shells. One hundred parts of hen's egg-shells contain

> Carbonate of lime . . . . . 89·6
> Phosphate of lime . . . . . 5·7
> Animal matter . . . . 4·7
> ──────
> 100·0†

IV. ZOOPHITES.

Many of the substances called *zoophites* have the hardness and appearance of shell or bone, and may therefore be included among them without impropriety. Others, indeed, are soft, and belong rather to the class of membrane or horn; but of these very few only have been examined. Indeed scarcely any chemical experiments have been published on these interesting subjects, if we except the admirable dissertation by Hatchett, in the Philosophical Transactions for 1800, which has been so often quoted. From this dissertation, and from a few experiments of Merat-Guillot, we learn that the hard zoophites are composed chiefly of three ingredients: 1. An animal substance of the nature of coagulated albumen, varying in consistency; sometimes being gelatinous and almost liquid, at others of the consistency of cartilage. 2. Carbonate of lime. 3. Phosphate of lime.

Composition.

Divided into four classes.

In some zoophites the animal matter is very scanty, and phosphate of lime wanting altogether; in others the animal matter is abundant, and the earthy salt pure carbonate of lime; while in others the animal matter is abundant, and the hardening salt a mixture of carbonate of lime and phosphate of lime; and there is a fourth class almost destitute of earthy salts altogether. Thus there are four classes of zoophites; the first resemble porcelaneous shells, the second

* Merat-Guillot, Ann. de Chim. xxxiv. 71.
† Vauquelin, ibid. xxix. 6.

resemble mother-of-pearl shell, the third resemble crusts,
and the fourth horn.

1. When the *madrepora virginea* is immersed in diluted 1. Compo-
nitric acid it effervesces strongly, and is soon dissolved. A sed of car
bonate of
few gelatinous particles float in the solution, which is other- lime and
wise transparent and colourless. Ammonia precipitates jelly.
nothing; but its carbonate throws down abundance of car-
bonate of lime. It is composed, then, of carbonate of
lime and a little animal matter. The following zoophites
yield nearly the same results:

> Madrepora muricata.
> ————— labyrinthica.
> Millepora cerulea.
> ————— alcicornis.
> Tubipora musica.

2. When the *madrepora ramea* is plunged into weak 2. Of car-
nitric acid, an effervescence is equally produced; but after lime and
all the soluble part is taken up, there remains a membrane membrane.
which retains completely the original shape of the madre-
pore. The substance taken up is pure lime. Hence this
madrepore is composed of carbonate of lime, and a mem-
branaceous substance which, as in mother-of-pearl shells,
retains the figure of the madrepore. The following zoo-
phites yield nearly the same results:

> Madrepora fascicularis.
> Millepora cellulosa.
> ————— fascialis.
> ————— truncata.
> Iris hippuris.

The following substances, analysed by Merat-Guillot,
belong to this class from their composition, though it is
difficult to say what are the species of zoophites which were
analysed. By *red coral* he probably meant the *gorgonia
nobilis*, though that substance is known, from Hatchett's
analysis, to contain also some phosphate.

	White Coral.	Red Coral.	Articulated Coraline.
Carbonate of lime	50	53·5	49
Animal matter	50	46·5	51
	100	100·0	100*

3. Of mem-
brane, car-
bonate, and
phosphate.

3. When the *madrepora polymorpha* is steeped in weak nitric acid, its shape continues unchanged; there remaining a tough membranaceous substance of a white colour and opaque, filled with a transparent jelly. The acid solution yields a slight precipitate of phosphate of lime when treated with ammonia, and carbonate of ammonia throws down a copious precipitate of carbonate of lime. It is composed therefore of animal substance, partly in the state of jelly, partly in that of membrane, and hardened by carbonate of lime together with a little phosphate of lime.

Flustra foliacea, treated in the same manner, left a finely reticulated membrane, which possessed the properties of coagulated albumen. The solution contained a little phosphate of lime, and yielded abundance of carbonate of lime when treated with the alkaline carbonates. The *coralina opuntia*, treated in the same manner, yielded the same constituents; with this difference, that no phosphate of lime could be detected in the fresh coraline, but the solution of burnt coraline yielded traces of it. The *iris ochracea* exhibits the same phenomena, and is formed of the same constituents. When dissolved in weak nitric acid, its colouring matter falls in the state of a fine red powder, neither soluble in nitric nor muriatic acid, nor changed by them: whereas the tinging matter of the *tubipora musica* is destroyed by these acids. The branches of this iris are divided by a series of knots. These knots are cartilaginous bodies connected together by a membranous coat. Within this coat there is a conical cavity filled with the earthy or coraline matter; so that, in the recent state, the branches of the iris are capable of considerable motion, the knots answering the purpose of joints.

When the *gorgonia nobilis*, or red coral, is immersed in weak nitric acid, its colouring matter is destroyed, an effer-

* Merat-Guillot, Ann. de Chim. xxxiv. 71.

vescence takes place, and the calcareous part is dissolved. There remains an external tubulated membrane of a yellow colour, inclosing a transparent gelatinous substance. The solution yields only carbonate of lime: but when red coral is heated to redness, and then dissolved, the solution yields a little phosphate of lime also. Red coral is composed of two parts: an internal stem, composed of gelatinous matter and carbonate of lime; and an external covering or cortex, consisting of membrane hardened by the calcareous salts, and both coloured by some unknown substance.

The *gorgonia ceratophyta* likewise consists of a stem and cortex. The stem is composed of cartilage, hardened chiefly by phosphate of lime; and containing little carbonate of lime; but the cortex consists of membrane, hardened almost entirely by carbonate of lime. The *gorgonia flabellum* is almost exactly similar. The cortex of the *gorgonia suberosa* yielded gelatine to boiling water; when steeped in acids, it left a soft yellowish membrane, and the acid had taken up a little phosphate and a large portion of carbonate of lime. The stem contained scarcely any earthy salt. When burnt, it left a little phosphate of lime. To water it yielded a little gelatin; but it consisted chiefly of a horny substance, analogous to coagulated albumen. The *gorgonia setosa* and *pectinata* exhibited the same phenomena.

4. *Gorgonia antiphates*, like the other species of gorgonia, has a horny stem, but it is destitute of a cortex. To boiling water it gives out some gelatin. When steeped in nitric acid it becomes soft, and exhibits concentric coats of thin opaque brown membranes, of a ligneous aspect. It contains no earthy salt. With potash it forms an animal soap, and possesses nearly the properties of horn.

The stems of the *gorgonia umbraculum* and *verrucosa* resemble that of the gorgonia antiphates; but these are both provided with a cortex composed of membrane and carbonate of lime.

The *antiphates ulex* and *myriophyla* resemble almost exactly the horny stem of the gorgonia antiphates.

Mr. Hatchett analysed many species of sponges, but found them all similar in their composition. The *spongia cancellata, oculata, infundibuliformis, palmata,* and *officinalis,* may be mentioned as specimens. They consist of gelatin, which they gradually give out to water, and a thin brittle

Book V. membranous substance, which possesses the properties of coagulated albumen. Hence the effect of acids and alkalies on them.

The *alcyonium ficus*, *asbestinum*, and *arboreum*, resemble very much the cortex of the gorgonia suberosa in their composition. They yield a little gelatin to water. In nitric acid they soften, and appear membranous. The acid takes up the carbonate of lime, and likewise a little phosphate, at least when the substance has been previously heated to redness.

Such is an abstract of Mr. Hatchett's instructive analysis of the zoophites.

SECT. II.

OF HORNS, NAILS, AND SCALES.

In the last Section I treated of those hard parts of animals which were inflexible and incapable of being softened by heat, and which contained a great portion of calcareous salts; but there is another set of hard parts which possess considerable elasticity, which are softened by heat, and which contain but a very small portion of calcareous matter. This set comprehends the substances well known under the names of *horn, nails,* and *scales.* The fourth class of zoophites ought, in strict propriety, to be joined to them; but in the present state of our knowledge I thought it better to give a view of all that is known of the zoophites in one place.

Almost all that we know of these bodies has been discovered by Mr. Hatchett. Many experiments, indeed, had been made by preceding chemists; but not of such a nature as to throw much light upon their composition.

Horns. 1. *Horns* are well known substances that are attached to the foreheads of oxen, sheep, and various other animals. They are not very hard, as they may be easily cut with a knife or rasped with a file; but they are so tough as not to be capable of being pounded in a mortar. When in thin plates, they have a degree of transparency, and have been sometimes substituted for glass in windows. When heated

sufficiently they become very soft and flexible, so that their shape may be altered considerably. Hence they may be gradually squeezed into a mould, and wrought into various forms, as is well known. When strongly heated in a Papin's digester, they are said to be converted into a gelatinous mass, which possesses the properties of gelatin.

The quantity of earthy matter which they contain is exceedingly small. Mr. Hatchett burnt 500 grains of ox horn. The residuum was only 1·5 grain, and not the half of this was phosphate of lime. Seventy-eight grains of the horn of the chamois left only 0·5 of residue, of which less than the half was phosphate of lime.* They consist chiefly of a membranous substance, which possesses the properties of coagulated albumen; and probably they contain also a little gelatin. Hence we see the reason of the products that are obtained when these substances are subjected to distillation.

The horns of the buck and hart must, however, be excepted. From the experiments of Scheele and Rouelle, together with those of Hatchett, we know that these substances possess exactly the properties of bone, and are composed of the same constituents, excepting only that the proportion of cartilage is greater. They are intermediate, then, between bone and horn. The same remarks apply to a fossil horn found in France, and lately analysed by Braconnot. He found it composed of

Composed of membrane.

Siliceous sand	4·0
Gelatin	4·6
Bitumen	4·4
Oxide of iron	0·5
Alumina	0·7
Phosphate of magnesia	1·0
Water	11·0
Carbonate of lime	4·5
Phosphate of lime	69·3
	100·0†

2. The *nails*, which cover the extremities of the fingers, are attached to the epidermis, and come off along with it.

Nails.

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* Phil. Trans. 1799, p. 332.   † Gehlen's Jour. Second Series, iii. 49.

Book V. Mr. Hatchett has ascertained that they are composed chiefly of a membranous substance, which possesses the properties of coagulated albumen. They seem to contain also a little phosphate of lime. Water softens but does not dissolve them; but they are readily dissolved and decomposed by concentrated acids and alkalies. Hence it appears that nails agree with horn in their nature and composition. Under the head of nails must be comprehended the talons and claws of the inferior animals, and likewise their hoofs, which differ in no respect from horn.

Tortoise-shell. The substance called tortoise-shell is very different from shells in its composition, and approaches much nearer to the nature of *nail*; for that reason I have placed it here. When long macerated in nitric acid, it softens, and appears to be composed of membranes laid over each other, and possessing the properties of coagulated albumen. When burnt, 500 grains of it yield three of earthy matter, consisting of phosphate of lime and soda, with a little iron.*

Scales 3. The *scales* of animals are of two kinds; some, as those of serpents and other amphibious animals, have a striking resemblance to horn; while those of fish bear a greater resemblance to mother-of-pearl. The composition of these two kinds of shells is very different.

1. Of fish. The scales of fish, as had been observed by Lewenhoeck, Composed of membrane and brane and phosphate. are composed of different membranous laminæ. When immersed for four or five hours in nitric acid, they become transparent and perfectly membranaceous. The acid, when saturated with ammonia, gives a copious precipitate of phosphate of lime.† Hence they are composed of alternate layers of membrane and phosphate of lime. To this structure they owe their brilliancy. Mr. Hatchett found the spicula of the shark's skin to be similar in its composition, but the skin itself yielded no phosphate of lime.

2. Of serpents. The horny scales of serpents, on the other hand, are composed alone of a horny membrane, and are destitute of phosphate of lime. They yield, when boiled, but slight Like horn. traces of gelatin; the horn-like crusts which cover certain insects and other animals appear, from Mr. Hatchett's experiments, to be nearly similar in their composition and nature.

* Hatchett, Phil. Trans. 1799, p. 332.   † Ibid.

Thus it appears that these substances bear a striking resemblance to each other, being composed of a membrane which Hatchett considers as coagulated albumen. Vauquelin, however, who affirms that they dissolve in water, provided the temperature be raised sufficiently in a digester above the boiling point, considers them, on that account, rather as a species of concrete mucus than as coagulated albumen:*

SECT. III.

OF THE MUSCLES OF ANIMALS.

AFTER the hard parts of animals have been examined, it remains for us to consider the composition of the *soft* parts. Of these, the muscles naturally claim our attention, in the first place, as being the most important.

The muscular parts of animals are known in common language by the name of *flesh*. They constitute a considerable portion of the food of man.

Muscular flesh is composed of a great number of fibres or threads, commonly of a reddish or whitish colour; but its appearance is too well known to require any description. Hitherto it has not been subjected to any accurate chemical History. analysis. Mr. Thouvenel, indeed, has published a valuable dissertation on the subject; and it is to to him that we are indebted for almost all the facts known concerning the composition of muscle. Some curious experiments have also been made by Fourcroy and Vauquelin; Mr. Hatchett has not neglected this part of the subject in his interesting dissertations on animal substances; and Berzelius has examined muscles as well as every other part of the animal body.

It is scarcely possible to separate the muscle from all the other bodies with which it is mixed. A quantity of fat often adheres to it closely; blood pervades the whole of it: and every fibre is enveloped in a particular thin membranous

* Nicholson's Jour. xv. 147.

matter, which anatomists distinguish by the name of *cellular* substance. The analysis of the muscle, then, cannot be supposed to exhibit an accurate view of the composition of pure muscular fibres, but only of muscular fibre not perfectly separated from other substances.

Action of cold water. 1. When a muscle is cut in small pieces, and well washed with water, the blood and other liquids contained in it are separated, and part of the muscular substance also is dissolved. The muscle, by this process, is converted into a white fibrous substance, still retaining the form of the original body. The water assumes the colour which results from mixing water with some blood. When heated it coagulates; brown flakes swim on the surface, consisting of albumen combined with the colouring matter of the blood: some fibrin likewise precipitates. If the evaporation be continued, more albumen precipitates, and at last the whole assumes the form of a jelly. When evaporated to dryness, and treated with alcohol, the gelatin, thus formed, together with a little phosphate of soda and ammonia, remains undissolved; but the alcohol dissolves a peculiar *extractive* matter, first observed by Thouvenel. This matter may be obtained by evaporating the alcohol to dryness. It has a reddish-brown colour, a strong acrid taste, and aromatic odour. It is soluble both in water and alcohol; and when its watery solution is very much concentrated, it assumes an acid and bitter taste. It swells upon hot coals and melts, emitting an acid and penetrating smell. It attracts moisture from the air, and forms a saline efflorescence. In a hot atmosphere it becomes sour and putrifies. When distilled, it yields an acid, partly combined with ammonia. According to Berzelius, it consists of lactic acid and lactate of soda.

Of hot water. 2. If the muscle, after being thus treated with cold water, be boiled for a sufficient time in water, an additional portion of the same substances are separated from it. Some albumen collects on the surface in the form of scum, accompanied with some melted fat. The water, when sufficiently concentrated by evaporation, assumes the form of a jelly. When evaporated to dryness, and treated with alcohol, the gelatin and phosphoric salts remain, while the extractive matter of Thouvenel is dissolved, and may be obtained by

evaporating to dryness. It is by this process that it is pro-
cured in a sufficient quantity for examination, cold water
abstracting only a very small portion from the muscle.

3. The muscle, thus treated with water, is left in the
state of grey fibres, insoluble in water, and becoming
brittle when dry. This substance possesses all the proper-
ties of *fibrin.*

4. From these facts, ascertained by Thouvenel and Four-
croy,* it appears that the muscles are composed chiefly of
fibrin, to which they owe their fibrous structure and their
form, and that they contain also

2. Albumen. 5. Phosphate of soda.
3. Gelatin. 6. Phosphate of ammonia.
4. Extractive. 7. Phosph. of lime and carb. of do.

For the discovery of the last ingredients we are indebted to
Mr. Hatchett, who found that 500 parts of beef muscle
left, after combustion, a residuum of 25·6 parts, consisting
chiefly of these salts. When muscles are long boiled in water,
Mr. Hatchett found that the greater part of the phosphate of
lime, as well as of the alkaline phosphates, was dissolved ;
for the muscle, after this treatment, when dissolved in nitric
acid, yielded scarcely any phosphate of lime; whereas if it
was dissolved directly in nitric acid, a precipitate of phos-
phate of lime was thrown down by ammonia. Hence it
would appear, either that the phosphate of lime is united
to gelatin, or that it is rendered soluble by means of it.
The carbonate of lime still remains after the action of water,
and is converted into oxalate when the muscle is treated
with nitric acid.

Fourcroy and Vauquelin have likewise detected the pre-
sence of potash and sulphuric acid in muscle. To these
chemists we are indebted for a very curious set of experi-
ments on the action of nitric acid on muscular fibres. They
found that 4·826 ounces of muscular fibre, mixed with its
own weight of nitric acid, of the specific gravity 1·284, and
heated till it boiled gently, gave 116 cubic inches of gas,
composed of nine parts by bulk of azote and one part of
carbonic acid. What remained in the retort consisted of
three distinct substances : 1. A greasy substance of a yellow
colour, which floated on the surface; 2. A yellow liquid;

* Fourcroy, ix. 242.

Book V. 3. A solid matter which still retained its fibrous appearance. This last was separated by means of alcohol into two distinct substances; namely, a fatty matter taken up by the alcohol, and a yellow substance insoluble in that liquid, which possessed the properties of an acid, and to which they gave the name of *yellow acid,* and of which the properties have been detailed in the last Chapter when treating of fibrin. The yellow liquid contained oxalic and malic acid, probably formed from the cellular substance, a portion of yellow acid somewhat altered, and some bitter principle.[*]

5. Berthollet boiled the muscle of beef in water till the liquid ceased to be precipitated by infusion of nut-galls. He then suspended the beef in a glass cylinder filled with common air, and inverted over water. The oxygen of the air was changed into carbonic acid, the beef became putrid, and, when boiled again in water, gave out gelatin. By repeating this process a number of times the beef acquired the taste and smell of old cheese. Very little ammonia was given out during the process.[†]

Constituents of muscle.

6. Berzelius subjected a portion of muscle to an elaborate analysis. About three fourths of it were liquids. The following were the constituents which he obtained.

I. Solid matters.

Fibrin, vessels and nerves .... 15·8
Cellular matter dissolved by boiling   1·9
_____
17·7 .. 17·7

II. Liquid bodies.

Muriate and lactate of soda ..... 1·80
Albumen and colouring matter of
    the blood .... 2·20
Phosphate of soda .... 0·90
Extract .... 0·15
Albumen holding in solution phos-
    phate of lime .... 0·08
Water and loss................ 77·17
_____
82·30 .. 82·3
_____
100·0[‡]

[*] Nicholson's Jour. xiii. 240.   [†] Mem. d'Arcueil, i. 333.
[‡] Djurkemien, ii. 174.

7. The muscles of different animals differ exceedingly from each other in their appearance and properties, at least as articles of food; but we know little of their chemical differences. The observations of Thouvenel alone were directed to that object, and they are imperfect. The flesh of the *ox* contains, according to him, the greatest quantity of insoluble matter, and leaves the greatest residuum when dried; the flesh of the *calf* is more aqueous and mucous: the land and water *turtle* yields more matter to water than the muscle of the ox; but Thouvenel ascribes the difference to foreign bodies, as ligaments, &c. mixed with the muscle of the turtle: *snails* yield to water a quantity of matter intermediate between that given by beef and veal: with them the muscles of *frogs*, *cray fish*, and *vipers*, agree nearly in this respect; but the muscles of fresh water fish, notwithstanding their softness, yield a considerably smaller proportion.*

8. When meat is boiled, it is obvious that the gelatin, the extractive, and a portion of the salts, will be separated, while the coagulated albumen and fibrin will remain in a solid state. Hence the flavour and the nourishing nature of soups derived from the extractive and gelatin. When meat is roasted, on the other hand, all these substances continue in it, and the taste and odour of the extractive is greatly heightened by the action of the fire. Hence the superior flavour of roasted meat. Fourcroy supposes that the brown crust which forms on roasted meat is composed entirely of the extractive.

SECT. IV.

OF THE SKIN.

THE skin is that strong thick covering which envelopes the whole external surface of animals. It is composed chiefly of two parts: a thin white elastic layer on the outside, which is called *epidermis* or *cuticle*; and a much thicker

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* Some experiments on the gizzards or muscular stomachs of fowls have been published by Bouillon La Grange. See Nicholson's Journal, xiii. 206.

layer, composed of a great many fibres closely interwoven, and disposed in different directions; this is called the *cutis*, or *true skin*. The *epidermis* is that part of the skin which is raised in blisters.

1. The epidermis is easily separated from the cutis by maceration in hot water. It possesses a very great degree of elasticity.

It is totally insoluble in water and in alcohol. Pure fixed alkalies dissolve it completely, as does lime likewise, though slowly.* Sulphuric and muriatic acids do not dissolve it, at least they have no sensible action on it for a considerable time; but nitric acid soon deprives it of its elasticity, and causes it to fall to pieces.† It is well known that the living epidermis is tinged yellow almost instantaneously by nitric acid; but this effect does not take place, at least so speedily, when the dead cuticle is plunged in nitric acid altogether.‡

If the cuticle be tinged with nitric acid, the application of ammonia to it is well known to give it instantaneously a deep-orange colour. Now, as Hatchett has shown that this change is also produced upon coagulated albumen in the same circumstances, and as the epidermis resembles that substance in all the properties above detailed, it can scarcely be doubted that it is any thing else than a peculiar modification of coagulated albumen.

2. The cutis is a thick dense membrane, composed of fibres interwoven like the texture of a hat. When it is macerated for some hours in water, and agitation and pressure employed to accelerate the effect, the blood, and all the extraneous matter with which it was loaded, are separated from it, but its texture remains unaltered. On evaporating the water employed, a small quantity of gelatin may be obtained. No subsequent maceration in cold water has any farther effect. When distilled it yields the same products as fibrin. The concentrated alkalies dissolve it, converting it into oil and ammonia. Weak acids soften it, render it transparent, and at last dissolve it. Nitric acid converts it into oxalic acid and fat, while, at the same time, azotic gas and prussic acid are emitted.§ When heated it

* Chaptal, Ann. de Chim. xxii. 221. But Davy could obtain no solution.

† Cruikshanks on Insensible Perspiration, p. 32.

‡ Ibid.   § Fourcroy, ix. 254.

contracts, and then swells, exhales a fetid odour, and leaves a dense charcoal, difficult to incinerate. By spontaneous decomposition in water or moist earth, it is converted into a fatty matter and into ammonia, which compose a kind of soap.* When allowed to remain long in water, it softens and putrifies, being converted into a kind of jelly. When long boiled in water it becomes gelatinous, and dissolves completely, constituting a viscid liquor, which, by proper evaporation, is converted into glue. Hence the cutis of animals is commonly employed in the manufacture of glue.

From these facts the cutis appears to be a peculiar mo- A species of dification of gelatin enabled to resist the action of water, gelatin. partly by the compactness of its texture, and partly by the viscidity of the gelatin of which it is formed; for those skins which dissolve most readily in boiling water afford the worst glue. Mr. Hatchett has observed that the viscidity of the gelatin obtained from skins is nearly inversely as their flexibility, the supplest hides always yielding the weakest glue; but this glue is very soon obtained from them by hot water. The skin of the eel is very flexible, and affords very readily a great proportion of gelatin. The skin of the shark also readily yields abundance of gelatin; and the same remark applies to the skins of the hare, rabbit, calf, and ox; the difficulty of obtaining the glue and its goodness always increasing with the toughness of the hide. The hide of the rhinoceros, which is exceedingly strong and tough, far surpasses the rest in the difficulty of solution and in the goodness of its glue. When skins are boiled, they gradually swell and assume the appearance of horn : then they dissolve slowly.

3. It is from the skin or cutis of animals that leather is Leather. formed; and the goodness of the leather, or at least its strength, depends in some measure on the toughness of the hides. Those easily soluble, as seal-skins, afford a weaker leather than those which are more difficultly soluble in water. The process by which the skins of animals are converted into leather is called *tanning*. It seems to have been known and practised in the earliest ages; but its nature was totally unknown till after the discovery of the *tanning principle* by Seguin. That chemist ascertained that

* Fourcroy, ix. 254.

leather is a compound of *tannin* and *skin* ; that it is to the tannin that leather owes its insolubility and its power of resisting putrifaction. The subject engaged the attention of Davy, who examined it with his usual ingenuity, and added several important facts to our former knowledge.

When skins are to be tanned, the first step of the process is to deprive them of their hair and cuticle. This is either done by steeping them in water till they begin to putrify, or by steeping them in lime and water. The lime seems to combine with the cuticle, and to render it brittle and easily detachable from the hide. It produces the same effect upon the hair and the matter at its root.* When the hides have been steeped for a sufficient time, they are taken out, the hair, cuticle, &c. scraped off, and then they are washed in water.

After this preliminary process, the skins are subjected to different treatment according to the kind of leather which is to be made.

The large and thick hides are introduced for a short time into a strong infusion of bark. They are then said to be *coloured*. After this they are put into water slightly impregnated with sulphuric acid, or with the acid evolved during the fermentation of barley and rye. This renders them harder and denser than they were before, and fits them for forming sole leather. Davy thinks, that by this process a triple compound is formed of the *skin*, *tan*, and *acid*.†

The light skins of cows, those of calves, and all small skins, are steeped for some days in a lixivium made by the infusion of pigeons' dung in water. This lixivium is called the *grainer*. By this process they are rendered thinner and softer, and more proper for making flexible leather. Davy considers the effect of this lixivium to depend upon the fermentation which it undergoes ; for dung that has undergone fermentation does not answer the purpose.‡

After these preliminary processes, the skins are exposed to the action of the infusion of bark till they are converted into leather.

The infusion of oak bark contains two ingredients,

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* Davy, Journal of the Royal Instit. ii. 30.   † Ibid. p. 31.
‡ Ibid. p. 32.

namely, *tannin* and an *extractive.* The first is more solu-
ble than the second. Hence, in saturated infusions, there
is a much greater proportion of tannin than of extractive;
whereas in weak infusions the extractive bears a greater
proportion to the tannin. Davy considers it as doubtful
whether the infusion of oak bark contains any gallic acid.
This chemist has ascertained, that the hides extract both
the tannin and extractive from the infusion, and leave
nothing behind but pure water, provided they be employed
in sufficient quantity. Hence it is obvious, that both the
tannin and extractive must enter into the composition of
leather. The extractive gives the hide a brown colour,
but does not render it insoluble in boiling water; the tannin
renders it insoluble, but its colour continues whitish. Hence
it is likely that the lightest kinds of leather contain little
else than tannin, while the brown kinds contain both tan-
nin and extractive, and the new compound is leather.
Hence the reason of the increase of its weight.

Calf-skins, and those hides which are prepared by the
grainer, are first steeped in weak infusions of oak bark, and
gradually removed to stronger and stronger, till they are
completely impregnated, which takes up from two to four
months. As the weak infusions contain a greater propor-
tion of extractive, the consequence of this process is, that
the skin combines in the first place with a portion of it,
and afterwards with the tannin. When saturated solutions
of tannin are employed, the leather is formed in a much
shorter time. This was the process recommended by
Seguin; but it has been observed, that leather tanned in
this way is more rigid and more liable to crack than leather
tanned in the usual way. Hence it is likely, as Davy has
observed, that the union of the extractive is requisite to
form pliable and tough leather. Leather rapidly tanned
must be less equable in its texture than leather slowly
tanned, as the surface must be saturated with tannin before
the liquid has time to penetrate deep. Davy has ascertained
that skins, while tanning, seldom absorb more than $\frac{1}{3}$ of
their weight of vegetable matter.

Skins intended for sole leather are generally kept from
the first in an infusion preserved nearly saturated by means
of the strata of bark with which they alternate. The full
impregnation requires from ten to eighteen months. It is

Book V. likely, from this process, that sole leather contains a greater proportion of tannin than soft leather. While drying, it is smoothed with a rolling-pin, and beat with a mallet, which must add considerably to its density.*

Rete muco-
sum.

4. As to the *rete mucosum*, or the mucous substance, situated between the cutis vera and epidermis, its composition cannot be determined with precision, because its quantity is too small to admit of examination. It is known that the black colour of negroes depends upon a black pigment, situated in this substance. Chlorine deprives it of its black colour, and renders it yellow. A negro, by keeping his foot for some time in water impregnated with that gas, deprived it of its colour, and rendered it nearly white; but in a few days the black colour returned again with its former intensity.† This experiment was first made by Dr. Beddoes on the fingers of a negro. ‡

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SECT. V.

OF MEMBRANES, TENDONS, LIGAMENTS, AND GLANDS.

THESE substances have not hitherto been subjected to a rigid chemical analysis. But from the properties which have been observed, they appear to have a closer resemblance to the skin than to any other animal substance.

Mem-
branes.

1. The membranes are thin semitransparent bodies which envelope certain parts of the body, especially the viscera; such as, the dura and pia mater, the pleura, the peritoneum, the periosteum, &c. These substances are soft and pliable; when macerated in water, they swell, and become somewhat pulpy; and by continued decoction in hot water they are almost completely dissolved, and the solution concretes into gelatin. They are convertible of course into the same substance as the cutis by decoction; hence we

Resemble
skin.

must consider their composition as similar. Like hides they may also be tanned and converted into leather. From the experiments of Mr. Hatchett, it appears that

* See Davy on the Preparation of Skin for Tanning. Royal Instit. ii. 30.

† Fourcroy, ix. p. 259. ‡ Beddoes on Factitious Airs, p. 45.

they contain no phosphate of lime as a constituent part, Chap. II. and scarcely any saline ingredients; for when calcined they leave but a very inconsiderable residuum. Thus 250 grains of hog's bladder left only 0·02 grain of residuum.*

2. The tendons are strong, pearl-coloured, brilliant Tendons. bodies, which terminate the muscles, and attach them to the bones, and are known in common language by the name of *sinews*. When boiled they assume the form of a semitransparent gelatinous substance, of a pleasant taste, well known in boiled meat. If the decoction be continued they dissolve completely, and are converted into gelatin. From these facts we are authorized to conclude, that the composition of the tendons is similar to that of the membranes and cutis.

3. The ligaments are strong bands which bind the bones Ligaments. together at the different joints: they are fibrous substances, very dense and strong, and somewhat elastic. When boiled they yield a portion of gelatine, but they resist the action of water with great obstinacy, and after a great deal of boiling retain their form, and even their strength. The ligaments, then, differ essentially from the two last species. How far they resemble coagulated albumen remains to be ascertained. It is not unlikely that they will form a genus apart.

4. The glands are a set of bodies employed to form or to Glands. alter the different liquids which are employed for different purposes in the animal body. There are two sets of them: the *conglobate*, which are small, scattered in the course of the lymphatics; and the *conglomerate*, such as the liver, kidneys, &c. Fourcroy supposes the first of these to be composed of gelatin; but this is not very probable. The structure of the large glands has been examined by anatomists with great care; but we are still ignorant of their composition. Indeed the present state of chemistry scarcely admits of an accurate analysis of these complicated bodies.

* Phil. Trans. 1799, p. 333.

SECT. VI.

OF THE BRAIN AND NERVES.

THE brain and nerves are the instruments of sensation, and even of motion; for an animal loses the power of moving a part the instant that the nerves which enter it are cut.

The brain and nerves have a strong resemblance to each other; and it is probable that they agree also in their composition. But hitherto no attempt has been made to analyse the nerves. The only chemists who have examined the nature of *brain* are Mr. Thouret,* Mr. Fourcroy,† and M. Vauquelin.‡

Properties
of brain.

The brain consists of two substances, which differ from each other somewhat in colour, but which, in other respects, seem to be of the same nature. The outermost matter, having some small resemblance in colour to wood-ashes, has been called the *cineritious* part; the innermost has been called the *medullary* part.

Brain has a soft feel, not unlike that of soap; its texture appears to be very close; its specific gravity is greater than that of water.

When brain is kept in close vessels so that the external air is excluded, it remains for a long time unaltered. Fourcroy filled a glass vessel almost completely with pieces of brain, and attached it to a pneumatic apparatus; a few bubbles of carbonic acid gas appeared at first, but it remained above a year without undergoing any farther change.§

This is very far from being the case with brain exposed to the atmosphere. In a few days (at the temperature of 60°) it exhales a most detestable odour, becomes acid, assumes a green colour, and very soon a great quantity of ammonia makes its appearance in it.

Action of
cold water,

Cold water does not dissolve any part of the brain; but by trituration in a mortar it forms, with water, a whitish-coloured emulsion, which appears homogeneous, may be passed through a filter, and the brain does not precipitate

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* Jour. de Phys. xxxviii. 329.   † Ann. de Chim. xvi. 282.
‡ Annals of Philosophy, i. 332.   § Ann. de Chim. xvi. 297.

by rest. When this emulsion is heated to 145°, a white coagulum is formed. The addition of a great quantity of water also causes a coagulum to appear, which swims on the surface, but the water still retains a milky colour. When sulphuric acid is dropped into the watery emulsion of brain, white flakes separate and swim on the surface, and the liquid becomes red. Nitric acid produces the same effects, only the liquid becomes yellow. Alcohol also separates a white coagulum from the emulsion, after it has been mixed with it for some hours. When nitric acid is added to the emulsion till it becomes slightly acid, a coagulum is also separated. This coagulum is of a white colour; it is insoluble in water and in alcohol. Heat softens, but does not melt it. When dried it becomes transparent, and breaks with a glassy fracture. It is therefore *albumen*.*

When brain is triturated in a mortar with diluted sulphuric acid, part is dissolved; the rest may be separated, by filtration, in the form of a coagulum. The acid liquor is colourless. By evaporation, the liquid becomes black, sulphurous acid is exhaled, and crystals appear; and when evaporated to dryness, a black mass remains behind. When this mass is diluted with water, a quantity of charcoal separates, and the water remains clear. This brain is completely decomposed, a quantity of ammonia combines with the acid and forms sulphate of ammonia, while charcoal is precipitated. The water, by evaporation and treatment with alcohol, yields sulphates of ammonia and lime, phosphoric acid, and phosphates of soda and ammonia. Brain therefore contains

> Of sulphuric acid,

Phosphate of lime
———————— soda
———————— ammonia.

Traces also of sulphate of lime can be discovered in it. The quantity of these salts is very small; altogether they do not amount to $\frac{1}{300}$th part.†

Diluted nitric acid, when triturated with brain, likewise dissolves a part, and coagulates the rest. The solution is transparent. When evaporated till the acid becomes concentrated, carbonic acid gas and nitrous gas are disengaged; an effervescence takes place, white fumes appear,

> Of nitric acid,

* Ann. de Chim. xvi. p. 288.   † Ibid.

an immense quantity of ammonia is disengaged, a bulky charcoal remains mixed with a considerable quantity of oxalic acid.*

When brain is gradually evaporated to dryness by the heat of a water bath, a portion of transparent liquid separates at first from the rest, and the residuum, when nearly dry, acquires a brown colour; its weight amounts to about one-fourth of the fresh brain. It may still be formed into an emulsion with water, but very soon separates again spontaneously.

Of alcohol,   When alcohol is repeatedly boiled upon this dried residuum till it ceases to have any more action, it dissolves about five-eighths of the whole. When this alcohol cools, it deposits a yellowish white substance, composed of brilliant plates. When kneaded together by the fingers, it assumes the appearance of a ductile paste; at the temperature of boiling water it becomes soft, and when the heat is increased it blackens, exhales empyreumatic and ammoniacal fumes, and leaves behind it a charry matter.† When the alcohol is evaporated, it deposits a yellowish black matter, which reddens paper tinged with turnsole, and readily diffuses itself through water.‡

Of potash.   Pure concentrated potash dissolves brain, disengaging a great quantity of ammonia.

The result of an elaborate analysis of brain by Vauquelin gave him the following constituents:

Constituents.

Water	80·00
White fatty matter	4·53
Reddish fatty matter	0·70
Albumen	7·00
Osmazome	1·12
Phosphorus	1·50
Acids, salts, and sulphur	5·15
	100·00

From the experiments of Vauquelin we learn that the medulla oblongata and the nerves are composed of the same materials as the brain.

Vauquelin's analysis of the brain though far more com-

* Ann. de Chim. xvi. 307.   † Ibid. 313.   ‡ Ibid. 317.

plete and satisfactory than that of any of his predecessors, throws no light upon the way in which the constituents are combined or on what it is that gives to the brain its very peculiar appearance.

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SECT. VII.

OF MARROW.

THE hollows of the long bones are, in living animals, filled with a peculiar species of fat matter, to which the name of *marrow* has been given. In some bones this matter is a good deal mixed with blood, and has a red colour; in others, as the thigh bones, it is purer, and has a yellow colour. Various experiments on this matter were made by the older chemists, showing it to be analogous to animal fats,* and pointing out some of its peculiarities. Berzelius has examined it in detail, and published the results of his experiments.† The marrow on which his trials were made was obtained from the thigh bone of an ox.

1. When marrow is digested in cold water it becomes lighter coloured, while the water acquires the colour which it would have received had it been digested on blood. When this water is boiled it becomes muddy, and a dark-brown matter precipitates. This matter consists of coagulated albumen mixed with some phosphate of lime, and phosphate of iron. A small portion of a yellow-coloured salt is dissolved by the action of alcohol or water. This matter separated from marrow by water, is obviously owing to the blood with which it was mixed. The quantity which Berzelius obtained from marrow amounted to $\frac{1}{100}$th part of the whole. The portion of it dissolved by water and alcohol consisted partly of gelatin and common salt, and partly of the peculiar extractive matter obtained by Thouvenel from the muscles of animals, and described in the Third Section of this Chapter. The proportion of these substances obtained by Berzelius from marrow amounted to about $\frac{1}{300}$th part of the whole.

Action of cold water,

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* Neumann's Chemistry, p. 560.
† Gehlen's Jour. Second Series, ii. 287.

2. When marrow is boiled in water, the greatest part of
it melts and swims upon the surface of the liquid. The
water is at first muddy and milky, but becomes transparent
on standing. When passed through the filter a substance
is separated, which becomes greyish-green, and semitrans-
parent when dry. More of this matter precipitates when
the liquid is evaporated. When the water is evaporated to
dryness, a substance is obtained of a sharp aromatic taste
like the marrow of roasted meat. These two substances
consist chiefly of extractive, gelatin, and a peculiar sub-
stance which approaches the nature of albumen in its pro-
perties.

3. When marrow, thus purified, is melted in water and
passed through a cloth, a quantity of blood vessels and skins
remain upon the cloth, amounting to about $\frac{1}{100}$th part of
the whole.

4. Marrow, thus freed from its impurities, has a white
colour with a shade of blue; its taste is insipid and rather
sweetish. It softens by the heat of the hand, and melts
when heated to 113°.* When cooled slowly it crystallizes
in sphericles like olive oil. It burns with a flame like tal-
low. When distilled it gives first a transparent fluid yel-
lowish-oil, accompanied by carbonic acid gas, water, and
heavy inflammable air. Afterwards there comes over a
white solid oil, accompanied by a less copious evolution of
gaseous bodies, and which does not become dark-coloured,
as happens when tallow is distilled. This had already been
observed by Neumann. This solid oil has a disagreeable
smell, amounts to 0·3 of the marrow distilled, reddens
vegetable blues, and when boiled in water gives out a por-
tion of sebacic acid, which Berzelius considers as benzoic
acid.

The empyreumatic oil combines readily with alkalies and
their carbonates. With the latter it forms a snow-white
soap, insoluble in water, though it increases in bulk when
placed in contact with that liquid. It combines also with
the earths, and forms soaps, likewise insoluble in water.

The water which comes over during the distillation of
marrow is colourless, has a fetid and sour smell, and an

* Berzelius says at 45°. This is 113° Fahrenheit, if Celsius' thermo-
meter be meant, as is probable. If it be Reaumur's, the melting point
of marrow is 133° Fahrenheit.

empyreumatic taste. It contains a little acetic acid, empy- reumatic oil, and probably benzoic acid; but exhibits no traces of ammonia.

The gaseous products amount to $\frac{1}{10}$th of the marrow distilled. They contain no sulphur nor phosphorus, and consist of carbonic acid and heavy inflammable air, which burns with a white flame, and seems to contain oil in solution.

The charry matter in the retort amounts to 0·05 of the marrow distilled. It is dark-brown, heavy and brilliant. It is incinerated with difficulty, and leaves an ash consisting of phosphate of lime, carbonate of lime, and some soda.

5. Concentrated sulphuric acid dissolves marrow without the assistance of heat. The solution has the appearance of a brown syrup; and when the acid is diluted with water the marrow separates unaltered. When heat is applied, the acid decomposes the marrow and forms a resinous coal.

Diluted nitric acid digested on marrow, in a moderate heat, renders it yellow, and gives it more consistence, and the smell of old bones. Concentrated nitric acid dissolves marrow without the assistance of heat, and the marrow is not precipitated by the addition of water.

6. Marrow combines with alkalies and forms soap. Boiling alcohol and ether dissolve a small portion of it, which precipitates again as the solution cools.

Marrow, from the thigh bone of an ox, was found by Berzelius to be composed of the following substances:

Pure marrow............ 0·96
Skins and blood vessels ... 0·01
Albumen ⎫
Gelatin ⎪
Extractive ⎬ .... 0·03
Peculiar matter ⎪
Water ⎭

———

1·00

From the preceding detail it appears, that pure marrow is a species of fixed oil, possessing peculiar properties, and approaching somewhat to butter in its nature. But it differs considerably in its appearance in different parts of the body, owing chiefly, in all probability, to a greater or smaller mixture of blood.

SECT. VIII.

OF HAIR AND FEATHERS.

THESE substances cover different parts of animals, and are obviously intended by Nature to protect them from the cold. For this, their softness and pliability, and the slowness with which they conduct heat, render them peculiarly proper.

Varieties. 1. *Hair* is usually distinguished into various kinds, according to its size and appearance. The strongest and stiffest of all is called *bristle:* of this kind is the hair on the backs of hogs. When remarkably fine, soft, and pliable, it is called *wool;* and the finest of all is known by the name of *down.* But all these varieties resemble one another very closely in their composition.

Properties. Hair appears to be a kind of tube covered with a cuticle. Its surface is not smooth, but either covered with scales or consisting of imbricated cones. Hence the roughness of its feel, and the disposition which it has to entangle itself, which has given origin to the processes of *felting* and *fulling.* It is constantly increasing in length, being protruded from the roots, and seems at first to be soft or nearly gelatinous. From the experiments which have been made on hair by Achard and Hatchett, it follows that it contains gelatin, to which it owes its suppleness and toughness. This substance may be separated by boiling the hair in water. When thus treated it becomes much more brittle than before. Indeed, if the process be continued long enough, the hair crumbles to pieces between the fingers. The portion insoluble in water possesses the properties of coagulated albumen.

Mr. Hatchett has concluded from his experiments, that the hair which loses its curl in moist weather, and which is the softest and most flexible, is that which yields its gelatin most easily; whereas strong and elastic hair yields it with the greatest difficulty, and in the smallest proportion. This conclusion has been confirmed by a very considerable hair-merchant in London, who assured him that the first kind of hair was much more injured by boiling than the second.

Analysis. Vauquelin has published a curious set of experiments on

the analysis of human hair of various colours. Though hair is insoluble in boiling water, he obtained a solution by raising the temperature of the liquid in a Papin's digester. If the heat thus produced was too great, the hair was decomposed, and ammonia, carbonic acid, and an empyreumatic oil formed. Sulphureted hydrogen is always evolved, and its quantity increases with the heat. When hair is thus dissolved in water heated above the boiling point, the solution contains a kind of bituminous oil, which is deposited very slowly. This oil was black when the hair dissolved was black, but yellowish-red when red hair was employed.

When the solution is filtered to get rid of this oil, the liquid which passes through is nearly colourless. Copious precipitates are formed in it by the infusion of nutgalls and chlorine. Silver is blackened by it, and acetate of lead precipitated brown. Acids render it turbid, but the precipitate is redissolved by adding these liquids in excess. Though very much concentrated by evaporation, it does not concrete into a jelly.

Water containing only four per cent. of potash dissolves hair, while hydrosulphuret of ammonia is evolved. If the hair be black, a thick dark-coloured oil, with some sulphur and iron, remains undissolved; if the hair be red there remains a yellow oil, with some sulphur and an atom or two of iron. When acids are dropped into this solution, they throw down a white matter soluble in an excess of acid.

Sulphuric and muriatic acids become red when first poured on hair, and gradually dissolve it. Nitric acid turns hair yellow and dissolves it, while an oil separates, which is red or black according to the colour of the hair dissolved. The solution yields a great deal of oxalic acid, and contains, besides, bitter principle, iron, and sulphuric acid. Chlorine first whitens hair, and then reduces it to a substance of the consistence of turpentine, and partly soluble in alcohol.

When alcohol is digested on black hair, it extracts from it two kinds of oil. The first, which is white, subsides in white shining scales as the liquor cools; the second is obtained by evaporating the alcohol. It has a greyish-green colour, and at last becomes solid. From red hair alcohol

Colouring matter.

Book V. likewise separates two oils: the first white as from black hair, and the other as red as blood. When the red hair is deprived of this oil, it becomes of a chesnut colour. Hence its red colour is obviously owing to the red oil.

When hair is incinerated, it yields iron and manganese, phosphate, sulphate, and carbonate of lime, muriate of soda, and a considerable portion of silica. The ashes of red hair contain less iron and manganese: those of white hair still less; but in them we find magnesia, which is wanting in the other varieties of hair. The ashes of hair do not exceed 0·015 of the hair.

From the preceding experiments of Vauquelin, we learn that black hair is composed of the nine following substances:

Constitu-
ents.

1. An animal matter constituting the greatest part.
2. A white solid oil, small in quantity.
3. A greyish-green oil, more abundant.
4. Iron; state unknown.
5. Oxide of manganese.
6. Phosphate of lime.
7. Carbonate of lime, very scanty.
8. Silica.
9. Sulphur.

The colouring matter of hair appears from Vauquelin's experiments to be an oil. The oil is blackish-green in black hair, red in red hair, and white in white hair. Vauquelin supposes that sulphureted iron contributes to the colour of dark hair; and ascribes to the presence of an excess of sulphur the property which white and red hair have of becoming black with the oxides of the white metals. The sudden change of colour in hair from grief, he thinks, is owing to the evolution of an acid.*

Vauquelin considers the animal matter of which hair is chiefly composed as a variety of inspissated mucus; but some of its properties, especially its copious precipitation by tannin, do not well agree with that supposition. It seems to approach more closely to coagulated albumen, as Hatchett has shown.

Wool.   Wool has not yet been subjected to a rigid examination; but from the experiments made on it by Berthollet, there

* Nicholson's Jour. xv. 141.

is reason to conclude that its chemical qualities do not differ much from those of hair. When growing upon the sheep it is enveloped in a kind of soapy matter, which protects it from the attack of insects, and which is afterwards removed by scouring. Vauquelin has examined this matter, and found it to consist of the following ingredients: 1. A soap of potash; 2. Carbonate of potash; 3. A little acetate of potash; 4. Lime; 5. A very little muriate of potash; and, 6. An animal matter.*

2. *Feathers* seem to possess very nearly the same properties with hair. Mr. Hatchett has ascertained that the quill is composed chiefly of coagulated albumen. Though feathers were boiled for a long time in water, Mr. Hatchett could observe no traces of gelatin.

Feathers.

SECT. IX.

OF SILK.

Silk is the production of different species of caterpillars. The *phalena bombyx* is most commonly propagated for that purpose in Europe; but the *phalena atlas* yields a greater quantity. A similar substance indeed is yielded by the greater number of the tribe of caterpillars. It is found inclosed in two small bags, from which it it is protruded in fine threads to serve the insect for a covering during its chrysalis state. The webs of spiders are obviously of the same nature with silk; though their fibres, at least in this country, are finer and weaker. Reaumur and other naturalists ascertained, that the larger species of spiders spun cocoons sufficiently strong to be manufactured, and that the produce was neither inferior in beauty nor in strength to the silk of the silk-worm. Attempts were made in consequence to establish a manufactory of this new kind of silk; but it was soon found that the spiders could not be made to work in concert. They attacked and devoured each other without mercy, till the whole colony was exterminated to a single individual.

Origin.

Spiders' webs.

The silkworm is a native of China, and feeds on the

History.

* Ann. de Chim. xlvii. 267.

leaves of the white mulberry. That industrious nation was acquainted with the manufacture of silk from the most remote ages; but it was scarcely known in Europe before the time of Augustus. Its beauty attracted the attention of the luxurious Romans; and after the effeminate reign of Elagabulus, it became a common article of dress. It was brought from China at an enormous expence, manufactured again by the Phenicians, and sold at Rome for its weight of gold. In the reign of Justinian this commerce was interrupted by the conquests of the Scythian tribes, and all attempts to procure it failed, till two Persian monks had the address to convey some of the eggs of the insect from China to Constantinople, concealed in the hollow of a cane. They were hatched and the breed carefully propagated. This happened in 555; and some years after we find that the Greeks understood the art of procuring and manufacturing silk as well as the Orientals. Roger, king of Sicily, brought the manufacture to that island in 1130, forcibly carrying off the weavers from Greece, and settling them in Sicily. From that island the art passed into Italy, and thence into France: and the revocation of the edict of Nantz established the manufactory of silk in Britain.

Silk, as spun by the animal, is in the state of fine threads, varying in colour from white to reddish-yellow. It is very elastic, and has considerable strength, if we consider its small diameter. It is covered with a varnish, to which its Varnish. elasticity is owing. This varnish is soluble in boiling water; but alcohol does not act upon it. Hence it has been compared to a gum, though it approaches much nearer to gelatin; since Berthollet has shown that it is precipitated by tannin and by muriate of tin. It differs, however, from gelatin in several particulars. Alum throws it down of a dirty white, sulphate of copper of a dark brown, and sulphate of iron of a brown colour.* When the water is evaporated, the varnish is obtained of a black colour, brittle, and of a shining fracture. Its weight is nearly one-third of the raw silk from which it was extracted. It may be separated from silk by soap as well as water, and the soap leys containing it soon putrify.† Roard has published a set of experiments on this matter. It amounts to 23 per cent. of

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* Berthollet.   † Ibid.

the silk. It is brittle and hard like resins; when pounded
its colour is reddish-yellow. It has the taste and odour of
extractive. It does not melt when heated. It dissolves in
five times its weight of water. The solution has a brown
colour, but when diluted with water becomes golden-yellow.
When exposed to the air in that state it becomes greenish,
is decomposed, and exhales the odour of putrid animal
matter. The liquid froths like soap leys. Sulphuric and
muriatic acids deepen its colour; nitric acid converts it into
a fine yellow; sulphurous acid brightens the colour, and
makes it greenish-yellow. Alcohol scarcely acts upon it.
Chlorine throws down a copious white precipitate, which
becomes reddish in the air, is no longer soluble in water,
but is very soluble in alcohol. Alkalies produce no effect
upon this substance. Infusion of nutgalls occasions a co-
pious precipitate.* These properties show us that this sub-
stance is of a peculiar nature.

Besides the varnish, silk contains another substance, to Resin.
which it owes its yellow colour. This substance possesses
the properties of *resin*. It is yellow, soluble in alcohol and
in a mixture of alcohol and muriatic acid. Baumé has
ascertained, that by this last mixture it may be separated
completely, and the silk deprived of it assumes a fine white
colour.† This matter melts at 36°. Its colour is reddish-
brown when in lumps, but greenish-yellow when divided.
It has a strong smell, owing to a volatile oil which it con-
tains. When exposed to the light it becomes white. It is
insoluble in water but very soluble in alcohol, in the alka-
line solutions and in soap. ‡

Roard has shown that raw silk contains also a portion of
wax, which is dissolved by boiling alcohol, and by alkaline
or soapy solutions. It is white and precipitates as the alco-
hol cools. Silk contains about $\frac{1}{200}$th of its weight of wax,
while the resinous colouring matter amounts to about $\frac{1}{60}$th
of its weight. §

The properties of silk itself have been but imperfectly Properties
examined. It is not acted on by water or alcohol, has no of silk.
taste, and is but imperfectly combustible; though fire ra-
pidly blackens and decomposes it. When distilled, it yields,

* Ann. de Chim. lxv. 59.   † Ibid. xvii. 156.
‡ Roard, ibid. lxv. 61.   § Ibid.

according to Neumann, an uncommonly great proportion of ammonia.

The fixed alkalies dissolve it by the assistance of heat; and it is not unlikely that they form with it an animal soap. It is dissolved likewise by sulphuric and muriatic acids, and by nitric acid. By the action of this last acid, Berthollet obtained from silk some oxalic acid, and a fatty matter which swam on the surface of the solution. By a similar treatment, Welter obtained fine yellow crystals, very combustible, to which he gave the name of *yellow brittle principle.*

Silk is very little susceptible of putrifaction. Dr. Wilson of Falkirk informs us, that a ribbon was found in the church-yard of that town wrapped round the bone of the arm. It was uninjured though it had lain eight years in the earth.* We know, at the same time, that when silk is kept in a damp place it *rots* (to use the common language) in a much shorter period.

Spiders' webs.

Cadet has published a chemical analysis of spiders' webs, the result of which, as these substances have a considerable analogy to silk, both in their properties and mode of being produced, may be mentioned here. He obtained from spiders' webs, by treating them with water and alcohol, and incineration, the following substances : 1. A brown extract soluble in water, and not altered by exposure to the air; 2. A resinous matter soluble in alcohol, and very deliquescent; 3. Alumina; 4. Sulphate of lime; 5. Carbonate of soda; 6. Muriate of soda; 7. Carbonate of lime; 8. Iron; 9. Silica.† He supposes, however, that some of the fixed matters obtained may have originated from accidental impurities mixed with the webs examined.

Having given the preceding account of the solids which compose animal bodies, I proceed next to the *chyle* and the fluid which circulates through living bodies, namely *blood;* and to the various *secretions* formed from the blood, either in order to answer some important purpose to the animal, or to be evacuated as useless, that the blood thus purified

* Nicholson's Jour. ii. 222.   † Ibid. xi. 294.

may be more proper for answering the ends for which it is destined. Many of these substances have been examined with more care by chemits than the animal solids. Chap. II.

SECT. X.

OF CHYLE.

THE name *chyle* is given to a liquid matter formed during the passage of the food along the intestinal canal. It is taken up by a set of vessels called *lacteals*, carried to the thoracic duct, from which it passes into the blood vessels and is converted into blood. It was occasionally examined and described by the physiologists and anatomists during the course of the last century. But it is only a few years since History. we became acquainted with its chemical properties. A set of experiments on the chyle of the horse was published by M. Emmert in 1811.[*] Vauquelin examined the chyle of different horses in 1812,[†] and during the course of the same year a set of experiments on chyle was published by Mr. Brande.[‡] And in 1815, a comparative examination was made by Dr. Marcet, of the chyle of animals that live on vegetable, and that of those that live on animal food. [§]

Chyle when drawn from the thoracic duct, about five Characters. hours after the animal has taken food is an opaque liquid of a white colour; without smell, and having a slightly acid taste, accompanied by a perceptible sweetness. It restores the blue colour of litmus paper, reddened by acetic acid, indicating the presence of an alkali. About ten minutes after it is drawn from the animal it coagulates into a stiff jelly, which in the course of 24 hours gradually separates into two parts, producing a firm contracted coagulum surrounded by a colourless fluid.

1. The coagulum, as appears from the experiments of Coagulum. Vauquelin, is an intermediate substance, between albumen and fibrin. He considers it as albumen on its way to assume the nature of fibrin. It is not so stiff, nor of so fibrous a texture as fibrin; it is more easily acted on and

[*] Ann. de Chim. lxxx. 81. [†] Ibid. lxxxi. 113.
[‡] Phil. Trans. 1812, p. 91. [§] Annals of Philosophy, vii. 234.

dissolved by caustic alkalies. In potash and soda it forms a brown solution while a little ammonia is evolved. Its solution in ammonia has a reddish hue.

It is insoluble in alcohol and ether; but readily dissolved by diluted sulphuric acid. Very dilute nitric acid gradually converts it into adepocire; when the acid is more concentrated, the coagulum assumes the appearance of gelatin; and when heat is applied oxalic acid and carbonic acid are formed. Muriatic acid does not dissolve it when in a concentrated state, but it dissolves it readily when diluted with water. Acetic and oxalic acids dissolve a small portion of it when boiled on it.

When burnt it leaves a charcoal, which is with difficulty incinerated, and which contains common salt, phosphate of lime, and gives traces of iron.

Liquid portion.   2. The liquid portion of chyle is coagulated by heat, alcohol, and acids, and the coagulated portion that falls possesses the properties of albumen. When hot alcohol is employed to produce the coagulation, it dissolves a little matter which is deposited in white flocks as the alcohol cools. Vauquelin found this matter similar to the fatty substance which he extracted from brain.

Sugar.   3. Mr. Brande, after separating the albumen by heat, evaporated the liquid portion to one half, at a temperature not exceeding 200°. On cooling, small crystals separated which he considered as of the same nature as sugar of milk. They had the shape of oblique six-sided prisms, were soluble in four times their weight of boiling water, and in 16 times their weight of cold water. They are insoluble in cold alcohol, but sparingly soluble in that liquid at the boiling temperature.

4. Dr. Marcet found the same salts in chyle, and in the same proportion as in other animal fluids.

5. The chyle differs so much at different times, that little confidence can be put in the distinctions pointed out by Dr. Marcet between the chyle of herbivorous and carnivorous animals. He found the chyle of the former much less white, it contained less solid matter, and yielded less albumen.

SECT. XI.

OF BLOOD.

BLOOD is a well-known fluid which circulates in the veins and arteries of the more perfect animals. It is of a red colour, has a considerable degree of consistency, and an unctuous feel, as if it contained a quantity of soap. Its taste is slightly saline, and it has a peculiar smell.

Properties of blood.

The specific gravity of human blood is, at a medium, 1·0527.* Mr. Fourcroy found the specific gravity of bullock's blood, at the temperature of 60°, to be 1·056.† The blood does not uniformly retain the same consistence in the same animal, and its consistence in different animals is very various. It is easy to see that its specific gravity must be equally various.

No substance has attracted a greater degree of attention than the blood. The number of philosophers who have devoted their time to develope its nature, and ascertain its properties, is immense. It was not, however, till towards the middle of the eighteenth century that much progress was made in its chemical analysis. ‡ The prussic acid formed during its decomposition had been observed; Hales had measured the gases exhaled during its distillation; Menghini had demonstrated the presence of iron in it; and several curious observations had been made upon its coagulation. But Rouelle junior was the first chemist who published a tolerably precise analysis of it. Since that time much additional information has been acquired by the experiments of Bucquet, Fourcroy, Deyeux, Parmentier, Brande, Berzelius, &c.

When blood, after being drawn from an animal, is allowed to remain for some time at rest, it very soon coagulates into a solid mass of the consistence of curdled milk. This mass gradually separates into two parts; one of which is fluid, and is called *serum;* the other, the coagulum, has been called *cruor,* because it alone retains the red colour

Spontaneous decomposition.

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* Haller's Physiology, ii. 41.   † Ann. de Chim. vii. 147.

‡ A very full account of every thing that had been done before that time may be found in the second volume of Haller's Physiology.

Book V. which distinguishes blood. This separation is very similar to the separation of curdled milk into curds and whey.

The proportion between the cruor and serum of the blood varies much in different animals, and even in the same animal in different circumstances. The most common proportion is about one part of cruor to three parts of serum; but in many cases the cruor exceeds or falls short of this quantity; the limits of the ratios of these substances to each other appear, from a comparison of the conclusions of most of those who have written accurately on the subject, to be 1 : 1 and 1 : 4; but the first case must be very rare indeed.*

The cause of this spontaneous decomposition of blood has not hitherto been ascertained. The coagulation takes place equally in close vessels and in the open air, whether the blood be allowed to cool, or be kept at the temperature at which it is when it issues from the animal; neither is the coagulation prevented by diluting it with water, as has been sufficiently proved by the experiments of Hewson, Hunter, Deyeux, and Parmentier.

Serum.   1. The serum is of a light greenish-yellow colour; it has the taste, smell, and feel of the blood, but its consistence is not so great. Its mean specific gravity is about 1·0287.† It converts syrup of violets to a green, and therefore contains an alkali. On examination, Rouelle found that it owes this property to a portion of soda, ‡ and this has been fully confirmed by Dr. Marcet. § When heated to the temperature of 156°, || the cerum coagulates, as Harvey first discovered. ** It coagulates also when boiling water is mixed with it; but if serum be mixed with six parts of cold water, it does not coagulate by heat. ††
When thus coagulated, it has a greyish-white colour, and is not unlike the boiled white of an egg. ‡‡ If the coagulum be cut into small pieces, a muddy fluid may be squeezed from it, which has been termed the *serosity*. After the se-

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* Haller's Physiology, ii. 47.   † Jurin, ibid. p. 41.

‡ Dr. Pearson considers the alkali in animal fluids as potash, and not soda.

§ Nicholson's Jour. xxxi. 230; xxxiii. 147. || Cullen.

** De Gener. Anim. p. 161.   †† Fourcroy, Ann. de Chim. vii. 157.

‡‡ Fourcroy, Ann. de Chim. vii. 156.

paration of this fluid, if the residuum be carefully washed in boiling water and examined, it will be found to possess all the properties of coagulated *albumen.* The serum, therefore, contains a considerable proportion of albumen. Hence its coagulation by heat, and the other phenomena which albumen usually exhibits.

The only other constituents in the serum, besides water, are soda, lactate of soda, muriate of soda, muriate of potash, and some animal matter, the nature of which has not been precisely determined. The following table exhibits the constituents of 1000 parts of the serum of bullocks blood according to the analysis of Berzelius:

Water	905·00
Albumen	79·99
Lactate of soda and extractive matter	6·175
Muriates of soda and potash	2·565
Soda and animal matter soluble only in water	1·52
Loss	4·75
	1000·000*

The serum of human blood he found composed as follows:

Water	905·0
Albumen	80·0
Muriates of potash and soda	6
Lactate of soda with animal matter	4
Soda, phosphate of soda with animal matter	4·1
Loss	0·9
	1000·0 †

Dr. Marcet found the constituents of serum as follows:

* Djur kemien, ii. 46. ; and Annals of Philosophy, ii. 202.
† Annals of Philosophy, ibid.

Water	900·0
Albumen	86·8
Muriates of potash and soda	6·6
Muco-extractive matter	4
Subcarbonate of soda	1·65
Sulphate of potash	0·35
Earthy phosphates	0·60
	———
	1000·00*

The *muco-extractive* matter was doubtless impure lactate of soda. Berzelius is of opinion that the sulphate of potash and the earthy phosphates which were found by Dr. Marcet in the ashes of serum, were formed during the incineration. For phosphorus, sulphur, and the bases of lime and magnesia exist according to him as constituents of albumen.

Gelatin was considered as a constituent of the serum of blood, in consequence of the observations of De Haen. But Dr. Bostock and Professor Berzelius have shown that the opinion of its existence in blood is not well founded.

Cruor contains fibrin.

2. The cruor, or *clot* as it is sometimes called, is of a red colour, and possesses considerable consistence. Its mean specific gravity is about 1·245.† If this cruor be washed carefully by letting a small jet of water fall upon it till the water runs off colourless, it is partly dissolved, and partly remains upon the searce. Thus it is separated into two portions: namely, 1. A white, solid, elastic substance, which has all the properties of *fibrin*; 2. The portion held in solution by the water, which consists of the colouring matter, not however in a state of purity, for it is impossible to separate the cruor completely from the serum.

Berzelius and Brande have shown that this clot is a compound of fibrin, albumen, and colouring matter of blood. According to the analysis of Berzelius, it consists of

Constituents.

Colouring matter	64
Fibrin and albumen	36
	——
	100

* Medico-chirurgical Transact. ii. 370.
† Jurin, Haller's Physiology, ii. 41.

When the colouring matter is incinerated, about one-third of a per cent. of oxide of iron may be extracted from its ashes. This portion of iron is a constituent of the colouring matter, and perhaps the cause of its red colour. But in what way it is united to the albuminous portion of the colouring matter remains unknown. When incinerated the colouring matter leaves $\frac{1}{80}$th of its weight of ashes, consisting according to the analysis of Berzelius, of the following ingredients:

Oxide of iron .... 50·0
Subphosphate of iron .... 7·5
Phosphate of lime with traces of magnesia .... 6·0
Pure lime .... 20·0
Carbonic acid and loss .... 16·5
                                            ———
                                            100·0

Berzelius is of opinion that none of these bodies existed in the colouring matter; but merely their bases, iron, phosphorus, calcium, &c. &c. that they were formed during the incineration.

The albumen of blood leaves the same quantity of ashes as the colouring matter. But these ashes contain no traces of iron.

The cause of the change of colour which blood undergoes when exposed to oxygen gas or common air, is still inexplicable.

M. Vogel has shown that when blood is placed in the vacuum of an air pump, a considerable quantity of carbonic acid gas separates from it.*

Dr. Gordon has rendered it probable, that during the coagulation of blood a little heat is evolved.†

It would be of great consequence to compare together the blood of different animals, and of the same animal at different ages, and to ascertain in what particulars they differ from each other. This would probably throw light on some of the obscurest parts of the animal economy. Very little progress has hitherto been made in these researches. If we except the labours of Rouelle, who obtained nearly the same ingredients, though in different pro-

* Ann. de Chim. xciii. 71. † Annals of Philosophy, iv. 139.

Book V. portions, from the blood of a great variety of animals, the experiments of Fourcroy on the blood of the human fœtus are almost the only ones of that kind with which we are acquainted.

Blood of the fœtus. He found that it differs from the blood of the adult in three things : 1. Its colouring matter is darker, and seems to be more abundant; 2. It contains no fibrin, but probably a greater proportion of gelatin than blood of adults; 3. It contains no phosphoric acid.*

The examination of diseased blood, too, would be of great consequence; because the difference of its properties from the blood of people in health might throw much light on the nature of the disease.

Deyeux and Parmentier, to whom we are indebted for an excellent analysis of blood, examined that liquid drawn from patients labouring under different diseases; but the result of their examination was not so satisfactory as might have been expected.

Diseased blood. 1. It has been long known, that blood drawn from a person labouring under inflammation is soon covered with a white crust, which is distinguished by physicians by the name of the *buffy coat*, and which characterises blood during inflammation. Deyeux and Parmentier ascertained that this buffy coat consists of the fibrin. The cruor, deprived of this substance, is much softer than usual, and almost totally soluble in water. The albumen of the serum is also altered, for it does not coagulate as usual when heated, but it becomes milky when mixed with hot water.

2. The blood drawn from several patients labouring under sea scurvy afforded scarcely any remarkable properties to these chemists, except a peculiar smell, and an albumen which was not so easily coagulated as usual.

3. The blood drawn from patients afflicted with a putrid fever was also examined by these chemists. Sometimes it exhibited the inflammatory crust, but frequently it did not appear to differ from healthy blood.†

4. During that disease which is known by the name of *diabetes*, in which the urine is excessive in quantity, and contains sugar, the serum of blood often, as appears from

* Fourcroy, Ann. de Chim. vii. 162.   † Jour. de Phys. xliv. 454.

the experiments of Dr. Dobson and Dr. Rollo, assumes the appearance of whey: Dr. Wollaston has shown that it contains no perceptible quantity of sugar, even when the urine is loaded with it.

SECT. XII.

OF MILK.

MILK is a fluid secreted by the female of all those animals denominated *mammalia*, and intended evidently for the nourishment of her offspring.

The milk of every animal has certain peculiarities which distinguish it from every other milk. But the animal whose milk is most made use of by man as an article of food, and with which, consequently, we are best acquainted, is the *cow*. Chemists, therefore, have made choice of cow's milk for their experiments. I shall, at first, confine myself to the properties and analysis of cow's milk, and afterwards point out in what respect the milk of other animals differs from it, as far at least as these differences have hitherto been ascertained.

Milk is an opaque fluid, of a whitish colour, a slight Properties peculiar smell, and a pleasant sweetish taste. When of milk. newly drawn from the cow, it has a taste very different from that which it acquires after it has been kept for some hours. It reddens vegetable blues.

Its boiling and freezing points are nearly the same as those of water; but they vary a few degrees in different milks.* Milk is specifically heavier than water, and lighter than blood; but the precise degree cannot be ascertained, because almost every particular milk has a specific gravity peculiar to itself.

When milk is allowed to remain for some time at rest, Spontane- there collects on its surface a thick unctuous yellowish- ous decom- coloured substance, known by the name of *cream*. position.

After the cream is separated, the milk which remains is

* Jour. de Phys. xxxviii. 362.

Book V. much thinner than before, and it has a bluish-white colour. If it be heated to the temperature of 100°, and a little *rennet*, which is water digested with the inner coat of a calf's stomach and preserved with salt, be poured into it, coagulation ensues; and if the coagulum be broken, the milk very soon separates into two substances; a solid white part, known by the name of *curd*, and a fluid part called *whey*. Thus we see that milk may be easily separated into three parts; namely, *cream*, *curd*, and *whey*.

Cream.   1. Cream is of a yellow colour, and its consistence increases gradually by exposure to the atmosphere. In three or four days it becomes so thick that the vessel which contains it may be inverted without risking any loss. In eight or ten days more, its surface is covered over with mucors and byssi, and it has no longer the flavour of cream, but of very fat cheese.* This is the process for making what in this country is called a *cream cheese*.

Cream possesses many of the properties of an oil. It is specifically lighter than water; it has an unctuous feel, stains clothes precisely in the manner of oil; and if it be kept fluid, it contracts at last a taste which is very analogous to the rancidity of oils.† When kept boiling for some time, a little oil makes its appearance, and floats upon its surface.‡ Cream is neither soluble in alcohol nor oils.§ These properties are sufficient to show us that it contains a quantity of oil; but this oil is combined with a part of the curd, and mixed with some cerum. Cream, then, is composed of a peculiar oil, curd, and cerum. The oil may be Converted into butter. easily obtained separate by agitating the cream for a considerable time. This process, known to every body, is called *churning*. After a certain time, the cream separates into two portions: one fluid, and resembling creamed milk; the the solid, and called *butter*.

Butter is of a yellow colour, possesses the properties of an oil, and mixes readily with other oily bodies. When heated to the temperature of 96° it melts, and becomes transparent; if it be kept for some time melted, some curd, water, or whey, separate from it, and it assumes exactly

* Parmentier and Deyeux, Jour. de Phys. xxxviii. 372.
† Ibid. p. 375.   ‡ Ibid. p. 374.   § Ibid.

the appearance of oil.* But this process deprives it in a
great measure of its peculiar flavour.

When butter is kept for a certain time, it becomes rancid, owing in a good measure to the presence of these foreign ingredients; for if butter be well washed, and a great portion of these matters separated, it does not become rancid nearly so soon as when it is not treated in this manner. It was formerly supposed that this rancidity was owing to the developement of a peculiar acid; but Parmentier and Deyeux have shown that no acid is present in rancid butter.† When butter is distilled, there comes over water, an acid, and an oil, at first fluid, but afterwards concrete. The carbonaceous residuum is but small.

Butter may be obtained by agitating cream newly taken from milk, or even by agitating milk newly drawn from the cow. But it is usual to allow cream to remain for some time before it is churned. Now cream, by standing, acquires a sour taste; butter, therefore, is commonly made from sour cream. Fresh cream requires at least four times as much churning before it yields its butter as sour cream does; ‡ consequently cream acquires, by being kept for some time, new properties, in consequence of which it is more easily converted into butter. When very sour cream is churned, every one who has paid the smallest attention must have perceived, that the butter-milk, after the churning, is not nearly so sour as the cream had been. The butter, in all cases, is perfectly sweet; consequently the acid which had been evolved, has in a great measure disappeared during the progress of churning. It has been ascertained that cream may be churned, and butter obtained, though the contact of atmospheric air be excluded.§ On the other hand, it has been affirmed, that when cream is churned in contact with air it absorbs a considerable quantity of it.||

In many cases there is a considerable extrication of gas during the churning of butter. From the phenomena, it can scarcely be doubted that this gas is carbonic acid. Dr.

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* Fourcroy, Ann. de Chim. vii. 170.   † Ibid. p. 375.
‡ Ibid. p. 169.
§ Young, de Lacte, 15 ; and Thenard, Nicholson's Jour. xii. 518.
|| Mid-Lothian Report for 1795.

Young affirms, that during the churning there is an increase of temperature amounting to four degrees.

The affinity of the oil of cream for the other ingredients is such, that it never separates completely from them. Not only is curd and whey always found in the cream, but some of this oil is constantly found in creamed milk and even in whey: for it has been ascertained, by actual experiment, that butter may be obtained by churning whey. Twenty-seven Scotch pints of whey yield at an average about a pound of butter.* This accounts for a fact well known to those who superintend dairies, that a good deal more butter may be obtained from the same quantity of milk, provided it be churned as drawn from the cow, than when the cream alone is collected and churned.

The butter-milk, as Parmentier and Deyeux ascertained by experiment, possesses precisely the properties of milk deprived of cream.†

Cream, of the specific gravity 1·0244, was analysed by Berzelius, who found it composed of

$$
\begin{array}{ll}
\text{Butter} \dots\dots\dots & 4\cdot5 \\
\text{Cheese} \dots\dots\dots & 3\cdot5 \\
\text{Whey} \dots\dots\dots & 92\cdot0 \\
\hline
& 100\cdot0
\end{array}
$$

Properties of curd.

2. Curd, which may be separated from creamed milk by rennet, has many of the properties of coagulated albumen. It is white and solid; and when all the moisture is squeezed out, it has a good deal of brittleness. It is precipitated by acids, and the precipitate consists of the curd combined with the acid employed to precipitate it. If we digest this precipitate over carbonate of lime, or barytes and water, the acid combines with the earth and remains undissolved (supposing it sulphuric acid), while the curd dissolves in the water. The aqueous solution of curd, thus obtained, is yellowish, and resembles a solution of gum. When evaporated to dryness, it leaves a yellow mass which easily redissolves in water. When the solution is boiled in an open vessel, it becomes covered with a white pellicle, precisely as milk does, and acquires the smell of boiled milk.

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* Mid-Lothian Report for 1795.   † Jour. de Phys. xxxviii. 379.

The membrane is almost insoluble in water, and appears to be a product by the action of air on the dissolved cheese. With the mineral acids curd forms the same compounds as albumen and fibrin do. But the neutral compounds are less soluble. A great excess of acetic acid is required to dissolve curd; and the neutral compound of curd and this acid appear to be insoluble. The alkalies easily dissolve curd. The constituents of curd, according to the analysis of Gay-Lussac and Thenard, are as follows:

$$
\begin{array}{ll}
\text{Carbon} & 59\cdot781 \\
\text{Oxygen} & 11\cdot409 \\
\text{Hydrogen} & 7\cdot429 \\
\text{Azote} & 21\cdot381 \\
\hline
& 100\cdot000\,* \\
\end{array}
$$

As we are ignorant of the equivalent number for curd, we are unable, from the preceding analysis, to determine the constitution of that substance. But the smallest number of atoms which accords with the analysis, is the following:

$$
\begin{array}{lll}
\text{7 atoms carbon} & = 5\cdot25 & 60\cdot87 \\
\text{1 atom oxygen} & = 1\cdot00 & 11\cdot60 \\
\text{5 atoms hydrogen} & = 0\cdot625 & 7\cdot24 \\
\text{1 atom azote} & = 1\cdot75 & 20\cdot29 \\
\hline
& 8\cdot625 & 100\cdot00 \\
\end{array}
$$

If we double the number of atoms, it will be in our power to compare curd with gelatin, albumen, and fibrin. On that supposition its composition will be

$$
\begin{array}{ll}
\text{14 atoms carbon} & = 10\cdot5 \\
\text{2 atoms oxygen} & = 2\cdot0 \\
\text{10 atoms hydrogen} & = 1\cdot25 \\
\text{2 atoms azote} & = 3\cdot5 \\
\hline
& 17\cdot25 \\
\end{array}
$$

This composition approaches nearest to that of gelatin, from which it differs by the absence of 4 atoms water and 1 atom carbon.

* Recherches Physico-chimiques, ii. 334.

Curd, as is well known, is used in making *cheese*; and the cheese is the better the more it contains of cream, or of that oily matter which constitutes cream.   It is well known to cheesemakers, that the goodness of it depends in a great measure on the manner of separating the whey from the curd.   If the milk be much heated, the coagulum broken in pieces, and the whey forcibly separated, as is the practice in many parts of Scotland, the cheese is scarcely good for any thing; but the whey is delicious, especially the last squeezed out whey, and butter may be obtained from it in considerable quantity:—a full proof that nearly the whole creamy part of the milk has been separated with the whey. Whereas if the milk be not too much heated (about 100° is sufficient), if the coagulum be allowed to remain unbroken, and the whey be separated by very slow and gentle pressure, the cheese is excellent; but the whey is almost transparent, and nearly colourless.*

Good cheese melts at a moderate heat; but bad cheese, when heated, dries, curls, and exhibits all the phenomena of burning horn.   From this it is evident, that good cheese contains a quantity of the peculiar oil which constitutes the distinguishing characteristic of cream; hence its flavour and smell.   Proust has found in cheese an acid which he calls the *caseic* acid, to which he ascribes several of the peculiar properties of cheese.†

This resemblance of curd and albumen makes it probable that the coagulation of milk and of albumen depend upon the same cause.   Heat, indeed, does not coagulate milk, because the curd in it is diluted with too large a quantity of water; but if milk be boiled in contact with air, a pellicle soon forms on its surface, which has the properties of curd. If this pellicle be removed, another succeeds; and by continuing the boiling, the whole of the curdy matter may be separated from milk.‡   When this pellicle is allowed to remain, it falls at last to the bottom of the vessel, where, being exposed to a greater heat, it becomes brown, and communicates to milk that disagreeable taste which, in this

* Parmentier and Deyeux, Jour. de Phys. xxxviii. 417.   Fourcroy, ibid. p. 173.   † Jour. de Phys. lxiv. 107.
‡ Parmentier, Jour. de Phys. xxxviii. 415.

country, is called a *singed* taste. It happens more readily when milk is boiled along with rice, flour, &c.

If to boiling milk there be added as much of any neutral salt as it is capable of dissolving, or of sugar, or of gum arabic, the milk coagulates, and the curd separates.* Alcohol also coagulates milk ; † as do all acids, rennet, and the infusion of the flowers of artichoke and of the thistle. ‡ If milk be diluted with ten times its weight of water, it cannot be made to coagulate at all. § From the experiments of Bouillon La Grange it appears that the acid or salt employed to coagulate milk combines with the curd.‖

3. Whey, after being filtered, to separate a quantity of Whey. curd which still continues to float through it, is a thin pellucid fluid, of a yellowish-green colour and pleasant sweetish taste, in which the flavour of milk may be distinguished. It always contains some curd; but nearly the whole may be separated by keeping the whey for some time boiling; a thick white scum gathers on the surface, which in Scotland is known by the name of *float whey*. When this scum, which consists of the curdy part, is carefully separated, the whey, after being allowed to remain at rest for some hours, to give the remainder of the curd time to precipitate, is decanted off almost as colourless as water, and scarcely any of the peculiar taste of milk can be distinguished in it. If it be now slowly evaporated, it deposits at last a number of white-coloured crystals, which are *sugar of milk*. Toward the end of the evaporation, some crystals of muriate of potash and of muriate of soda make their appearance.** According to Scheele, it contains also a little phosphate of lime,†† which may be precipitated by ammonia.

Contains sugar of milk,

Salts.

The recent experiments of Fourcroy and Vauquelin, Thenard, Bouillon La Grange, and Berzelius, have added considerably to our knowledge of the constituents of whey. It always reddens vegetable blues, containing a portion of lactic acid. It contains likewise some phosphate of magnesia and phosphate of iron, as Fourcroy and Vauquelin

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* Scheele, ii. 52. † Parmentier, Jour. de Phys. xxxviii. 416.
‡ Parmentier, Jour. de Phys. xxxviii. 416. § Scheele, ii. 54.
‖ Nicholson's Jour. x. 143.
** Parmentier, Jour. de Phys. xxxviii. 417. †† Scheele, ii. 61.

Book V. have discovered.* Sulphate of potash, likewise, and a peculiar extractive matter, have been separated from it.

From the analysis of Berzelius we learn that 100 parts of milk deprived of its cream is composed of the following ingredients:

Water.	928·75
Curd with a little cream	28·00
Sugar of milk...................	35·00
Muriate of potash	1·70
Phosphate of potash	0·25
Lactic acid, acetate of potash, with a trace of lactate of iron ...... }	6·00
Earthy phosphates...............	0·30
	1000·00

Milk capable of the vinous fermentation. Milk is one of the few animal substances which may be made to undergo the vinous fermentation, and to afford a liquor resembling wine or beer, from which alcohol may be separated by distillation. This singular fact seems to have been first discovered by the Tartars; they obtain all their spirituous liquors from mare's milk. It has been ascertained that milk is incapable of being converted into wine till it has become sour; after this nothing is necessary but to place it in the proper temperature; the fermentation begins of its own accord, and continues till the formation of wine be completed.† Scheele had observed that milk was capable of fermenting, and that a great quantity of carbonic acid gas was extricated from it during this fermentation.‡ But he did not suspect that the result of this fermentation was the formation of an intoxicating liquor similar to wine. The Tartars call the vinous liquid which they prepare *koumiss*. An account of its preparation and medical uses has been published by Dr. Guthrie.§ In Orkney and Shetland also, as I have been informed by Sir John Sinclair, it is prepared nearly in a similar way.

Distillation of milk. When milk is distilled by the heat of a water-bath, there comes over water, having the peculiar odour of milk;

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* Gehlen, Ann. de Chim. l. 272.   Vauquelin, Gehlen's Jour. iii. 456.
† Parmentier, Jour. de Phys. xxxviii. 365.   ‡ Scheele, ii. 65.
§ Edin. Trans. vol. ii.

which putrifies, and consequently contains, besides mere water, some of the other constituent parts of milk. After some time the milk coagulates, * as always happens when hot albumen acquires a certain degree of concentration. There remains behind a thick unctuous yellowish-white substance, to which Hoffman gave the name of *franchipann.* This substance, when the fire is increased, yields at first a transparent liquid, which becomes gradually more coloured; some very fluid oil comes over, then ammonia, an acid, and at last a very thick black oil. Towards the end of the process carbureted hydrogen gas is disengaged.† There remains in the retort a coal, which contains carbonate of potash, muriate of potash, and phosphate of lime, and sometimes magnesia, iron, and muriate of soda.‡

The milk of all other animals, as far as it has hitherto been examined, consists nearly of the same ingredients as cow's milk: but there is a very great difference in their proportion.

Woman's milk has a much sweeter taste than cow's milk. When allowed to remain at rest for a sufficient time, a cream gathers on its surface. This cream is more abundant than in cow's milk, and its colour is usually much whiter. After it is separated, the milk is exceedingly thin, and has the appearance rather of whey, with a bluish-white colour, than of creamed milk.

None of the methods by which cow's milk is coagulated succeed in producing the coagulation of woman's milk.§ It is certain, however, that it contains curd; for if it be boiled, pellicles form on its surface, which have all the properties of curd.‖ Its not coagulating, therefore, must be attributed to the great quantity of water with which the curd is diluted.

Though the cream be churned ever so long, no butter can be obtained from it; but if, after being agitated for some hours, it be allowed to remain at rest for a day or two, it separates into two parts; a fluid which occupies the inferior part of the vessel, pellucid and colourless like water, and a thick white unctuous fluid, which swims on

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* Bouquet.   † Parmentier, Jour. de Phys. xxxvii. 368.
‡ Mem. Med. Par. 1787, p. 607.   § Clarke, Irish Trans. ii. 175.
‖ Parmentier, Jour. de Phys. xxxviii. 419.

the surface. The lowermost fluid contains sugar of milk and some curd; the uppermost does not differ from cream except in consistence. The oily part of the cream, then, cannot be separated by agitation from the curd. * This cream contains a greater portion of curd than the cream of cow's milk. †

When this milk, after the curd is separated from it, is slowly evaporated, it yields crystals of sugar of milk and of muriate of soda. The quantity of sugar is rather greater than in cow's milk. According to Haller, the sugar obtained from cow's milk is to that obtained from an equal quantity of woman's milk as 35 : 58, and sometimes as 37 : 67, and in all the intermediate ratios.

Its peculiarities.　Thus it appears that woman's milk differs from that of cows in three particulars :

1. It contains a much smaller quantity of curd.

2. Its oil is so intimately combined with its curd that it does not yield butter.

3. It contains rather more sugar of milk.

Parmentier and Deyeux ascertained that the quantity of curd in woman's milk increases in proportion to the time after delivery.‡ Nearly the same thing has been observed with respect to cows' milk.

Ass's milk.　Ass's milk has a very strong resemblance to human milk : It has nearly the same colour, smell, and consistence. When left at rest for a sufficient time, a cream forms upon its surface, but by no means in such abundance as in woman's milk. This cream, by very long agitation, yields a butter, which is always soft, white, and tasteless ; and, what is singular, very readily mixes again with the buttermilk ; but it may be again separated by agitation, while the vessel, which contains it, is plunged in cold water. Creamed ass's milk is thin, and has an agreeable sweetish taste. Alcohol and acids separate from it a little curd, which has but a small degree of consistence. The serum yields sugar of milk and muriate of lime.§

Ass's milk therefore differs from cow's milk in three particulars :

1. Its cream is less abundant and more insipid.

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* Parmentier, Jour. de Phys. xxxviii. 419.　　　　† Ibid.

‡ Ibid. p. 422.　　　　　　　　　　　　　　　§ Ibid. p. 423.

5

2. It contains less curd.

3. It contains more sugar of milk: the proportion is 35 : 80.

Goat's milk, if we except its consistence, which is greater, Goat's milk. does not differ much from cow's milk. Like that milk, it throws up abundance of cream, from which butter is easily obtained. The creamed milk coagulates just as cow's milk, and yields a greater quantity of curd. Its whey contains sugar of milk, muriate of lime, and muriate of soda.*

Ewe's milk resembles almost precisely that of the cow. Ewe's milk. Its cream is rather more abundant, and yields a butter which never acquires the consistence of butter from cow's milk. Its curd has a fat and viscid appearance, and is not without difficulty made to assume the consistence of the curd of cow's milk. It makes excellent cheese.†

Mare's milk is thinner than that of the cow, but scarcely Mare's milk. so thin as human milk. Its cream cannot be converted into butter by agitation. The creamed milk coagulates precisely as cow's milk, but the curd is not so abundant. The serum contains sugar of milk, sulphate of lime, and muriate of lime.‡

SECT. XIII.

OF EGGS.

THE eggs of fowls consist of four distinct parts; namely, 1. The the *shell*, a thin *membrane* that lines the shell; and two shell. liquids, the *white* and the *yolk*, which fill the whole internal cavity of the egg.

1. The shell, as is well known, consists chiefly of carbonate of lime cemented together by an animal matter. But Vauquelin has shown that it contains likewise magnesia, probably in the state of carbonate, phosphate of lime, and a notable quantity of oxide of iron. The animal matter which acts as a cement to the calcareous salt contains sulphur as a constituent; for when the shell is calcined,

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* Parmentier, Jour. de Phys. xxxviii. 425.
‡ Ibid. p. 428.   ‡ Ibid. p. 431.

Book V. and then dissolved in an acid, the odour of sulphureted hydrogen gas is perceptible. This odour is mixed with that of hydrocyanic acid, which is also formed during the calcination of egg-shell.*

2. The membrane. 2. The thin membrane which lines the inside of the shell of the egg possesses the characters of albumen. Like that substance it dissolves in caustic potash, and is precipitated by acids in white flakes.†

3. The white. 3. The white is a glary insipid liquid, often used as a kind of varnish, and to clarify turbid liquors. For the most accurate experiments on the composition of this liquid we are indebted to Dr. Bostock. It had been considered as almost pure albumen, but he has shown that it is of a more compound nature. When heated it coagulates; but a small portion remains liquid, which, when evaporated to dryness, leaves a residue possessing the properties of mucus. From the experiments of Bostock, it follows that white of egg is composed of

$$
\begin{aligned}
&\text{Water} \dots \dots \quad 80\text{·}0 \\
&\text{Albumen} \dots \dots \quad 15\text{·}5 \\
&\text{Mucus} \dots \dots \quad 4\text{·}5 \\
&\overline{} \\
& 100\text{·}0 \ddagger
\end{aligned}
$$

Besides some traces of soda, of sulphureted hydrogen gas, and of benzoic acid.

4. The yolk. 4. The yolk has a mild oily taste; when boiled, it becomes solid, and easily separates into small particles. If it be now heated for some time in a pan, it softens; and when squeezed between the fingers, drops of oil exude. If put into linen in this state and pressed, an oil may be forced out. This oil is of a yellow colour and insipid, unless too much heat has been employed in preparing it.

Contains oil, Its properties are those of *fixed* oil, or rather of semifluid fat. Chandelier obtained this oil without the assistance of heat. §

Albumen, The residue, after the separation of the oil, possesses the properties of albumen, though it is still a little coloured by the remains of the oil. Hence, when washed with water,

* Ann. de Chim. lxxxi. 304.   † Vauquelin.   Ibid. p. 309.
‡ Nicholson's Jour. xi. 246; and xiv. 142.
§ Jour. de Med. xvi. 43.

a kind of emulsion is obtained. It is owing to the presence of albumen that the yolk hardens when heated.

Thus it appears that the yolk consists of three constituents:

1. Water.
2. Oil.
3. Albumen.

The knowledge of its component parts enables us, without difficulty, to explain the changes produced upon the yolk by the action of different reagents.

Mr. Hatchett found that when yolk is boiled with potash, it forms a pale olive-coloured concrete animal soap, which, when dissolved in water, and saturated with muriatic acid, is thrown down in the state of fat. When burnt the yolk leaves a small residuum of phosphate of lime and phosphate of soda.* Action of potash.

When agitated with water, the yolk forms a white emulsion like milk. The principal use of the yolk is to serve for food to the chicken before it bursts the shell.

SECT. XIV.

OF SALIVA.

THE fluid secreted in the mouth, which flows in considerable quantity during a repast, is known by the name of *saliva*. All the properties of this liquor which had been observed by philosophers before the middle of the 18th century have been collected by Haller:† but since that time several additional facts have been related by Fourcroy, Du Tennetar, and Brugnatelli; and a very numerous set of experiments have been published by Mr. Siebold in 1797, in his Treatise on the *Salivary System*. Berzelius has subjected saliva, as well as the other secretions, to an accurate analysis.‡ History.

Saliva is a limpid fluid like water; but much more viscid: it has neither smell nor taste. Its specific gravity, according- Properties.

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* Hatchett, Phil. Trans. 1800.   † Haller's Physiology, vol. vi.
‡ Annals of Philosophy, ii. 379.

Book V. ing to Hamberger, is 1·0167; * according to Siebold, 1·080. I found it 1·0038. When agitated, it froths like all other adhesive liquids; indeed it is usually mixed with air, and has the appearance of froth.

It neither mixes readily with water nor oil; † but by trituration in a mortar it may be so mixed with water as to pass through a filter.‡ It is said to have an affinity for oxygen, to absorb it readily from the air, and to give Absorbs it out again to other bodies.§ Hence the reason why gold oxygen. or silver, triturated with saliva in a mortar, is oxidized, as Du Tennetar has observed; and why the killing of mercury by oils is much facilitated by spitting into the mixture.‖ Hence also, in all probability, the reason that saliva is a useful application to sores of the skin. Dogs, and several other animals, have constantly recourse to this remedy, and with much advantage.

Analysis. When mixed with water, a few flakes of mucus precipitate. From the experiments of Dr. Bostock, we learn that this mucus is not in a state of solution. It is separated by the filter, and subsides of its own accord when the liquid is diluted with water. In his analysis, this matter amounted to 0·4 of the solid matter contained in the saliva examined.**

When saliva is evaporated, it swells exceedingly, and leaves behind it a thin brown-coloured crust: but if the evaporation be conducted slowly, small cubic crystals of muriate of soda are formed. The viscidity of saliva, the property which it has of absorbing oxygen, and of being inspissated, announce the presence of a peculiar matter as a component part. This is confirmed by the effect of acetate of lead, which produces a copious precipitate in saliva. Dr. Bostock considers this matter as constituting about ½ of the solid contents of saliva.††

When saliva is distilled in a retort, it froths very much:

* Haller's Physiology, vol. vi. 52.   † Narcessus, ibid. p. 34.
‡ Fordice on Digest. p. 51.
§ Fourcroy, Ann. de Chim. xxviii. 262.
‖ Fourcroy, ibid.—Dr. Saunders ascertained long ago, that mercury soon disappears when triturated with saliva. He found the mucus of the throat still more efficacious, and the mucilage of gum arabic the most efficacious of all.
** Nicholson's Jour. xiv. 148.   †† Ibid. p. 149.

100 parts yield 80 parts of water nearly pure, then a little carbonate of ammonia, some oil, and an acid, which perhaps is the prussic. The residuum amounts to about 1·56 part, and is composed of muriate of soda, phosphate of soda and phosphate of lime.*

The acids and alcohol inspissate saliva; the alkalies disengage ammonia; oxalic acid precipitates lime; and the nitrates of lead, mercury, and silver, precipitate phosphoric and muriatic acids.

The constituents of Saliva according to the analysis of Berzelius are as follows:

Water	992·9
Peculiar animal matter.............	2·9
Mucus	1·4
Alkaline muriates.	1·7
Lactate of soda and animal matter ..	0·9
Pure soda	0·2
	1000·0 †

The peculiar animal matter possesses the characters of mucus as given in the last Chapter of this work. It is soluble in water, insoluble in alcohol, and precipitated by subacetate of lead.

The substance to which Berzelius has thought proper to apply the term *mucus* is in white flakes, and has very much the appearance of coagulated albumen. It has been denominated albumen both by Dr. Bostock and myself. It is quite insoluble in water. It becomes transparent and horny in acetic, muriatic, and sulphuric acids, but does not dissolve in them. It dissolves in caustic potash, and is again separated by acids. It is easily incinerated, and the ashes contain a considerable portion of phosphate of lime, though none of that salt can be detected in it before incineration.

It is this peculiar substance which adheres to the teeth, and gives origin to the tartar with which they are often encrusted. This tartar according to the analysis of Berzelius is composed of

* Vorbeyen, Textor, Nuck, &c. as quoted by Haller, Physiol. vi. 55. Fourcroy, ix. 365.

† Annals of Philosophy, ii. 379.

Earthy phosphates.................. 79·0
Undecomposed mucus .... 12·5
Peculiar salivary matter............ 1·0
Animal matter soluble in muriatic acid. 7·5
                                     _____
                                      100·0 *

Saliva of
the horse.

'Such are the properties of human saliva. The saliva of the horse was analysed by Hapel Delachenier in 1780. He collected 12 ounces of it in the space of 24 hours by puncturing the salivary duct. Its colour was greenish-yellow; its feel soapy; it had a weak disagreeable smell and a saline taste. Boiling water and alcohol coagulated it in part; as did the acids. When sulphuric acid was used, sulphate of soda was obtained. It putrified in about 14 days; and when allowed to evaporate spontaneously, it left a black residuum like earth. When distilled, it yielded an insipid watery liquid, crystals of carbonate of ammonia, a thick black empyreumatic oil, carbureted hydrogen, and carbonic acid; and a charcoal remained.

It is rather surprising that no experiments have been hitherto made on the saliva of dogs; though the *hydrophobia* has been usually ascribed to the infusion of the saliva of that animal rendered morbid by disease.†

The pancreatic juice has never been examined with much attention; but it does not appear, from the experiments that have been made, to differ much from saliva.

SECT. XV.

OF BILE.

BILE is a liquid of a yellowish-green colour, an unctuous feel, bitter taste, and peculiar smell, which is secreted by the liver; and in most animals considerable quantities of it are usually found collected in the gall bladder.

History.

Great attention has been paid to this liquid by physicians; because the ancients were accustomed to ascribe a very great number of diseases, and even affections of the

* Annals of Philosophy, ii. 381.
† The remarks of Dr. Mead in his Essays on Poisons are too hypothetic and absurd to be transcribed.

mind, to its agency. Several important observations were made on it by Boyle, Boerhaave, Verheyen, Ramsay, and Baglivi; and some facts have since been added to our chemical knowledge of bile by Maclurg and Fourcroy. But the most accurate chemical analyses were those of Cadet, published in the Memoirs of the French Academy for 1767, and of Van Bochante, published in 1778, till Thenard read his very ingenious experiments on it to the National Institute in 1805.* Berzelius indeed had given a still more accurate analysis of bile in the second volume of his *Animal Chemistry*, published at Stockholm in 1808. But as that book was in the Swedish language, his results remained unknown to Chemists, till he published his " General Views of the Composition of Animal Fluids," in the third volume of the Medico-chirurgical Transactions, in 1812.

I shall in the first place state the nature and properties of ox bile, and then gave an account of the bile of other animals as far as it has been examined.

1. Ox bile is a liquid of a yellowish-green and sometimes of a deep-green colour. Its taste is very bitter, but at the same time sweetish. Its smell is feeble, but peculiar and disagreeable. It does not act on vegetable blues. Its consistence varies very much. Sometimes it is a thin mucilage; sometimes very viscid and glutinous; sometimes it is perfectly transparent, and sometimes it contains a yellow coloured matter which precipitates when the bile is diluted with water.

Properties of ox bile.

The specific gravity of ox bile seems to vary, like that of all other animal fluids. According to Hartmann, it is 1·027;† according to Thenard, 1·026 at the temperature of 43°. When strongly agitated, it lathers like soap; and for this reason, as well as from a medical theory concerning its use, it has been often called an *animal soap*.

It mixes readily with water in any proportion, and assumes a yellow colour; but it refuses to unite with oil; when the two fluids are agitated together, the instant that they are left at rest the oil separates and swims on the surface.‡ Bile, however, dissolves a portion of soap readily, and is often employed to free cloth from greasy spots.

Action of heat.

* Mem. d'Arcueil, i. 23 and 46.   † Haller's Phys. vi. 546.
‡ Ramsay, Thesaur. Med. Edin. ii. 459. Maclurg, p. 10.

When distilled to dryness it becomes at first slightly muddy; then it froths violently, and a colourless liquid passes into the receiver, having a smell similar to that of bile, and slightly precipitating superacetate of lead. The residue in the retort, when well dried, amounts to from $\frac{1}{8}$th to $\frac{1}{9}$th of the whole. It has a greenish yellow colour, a very bitter taste, slightly deliquesces in the air, and is almost totally soluble in water and alcohol. When strongly heated it is decomposed, and gives the usual products of animal substances : only the proportion of oil is greater, and that of carbonate of ammonia smaller, than what is furnished by by most animal bodies. A voluminous charcoal remains behind containing soda and several saline bodies; namely, common salt, phosphate of soda, sulphate of soda, phosphate of lime, and some traces of oxide of iron. The soda does not exceed $\frac{1}{200}$th part of the bile.

When an acid is added to bile, even in a minute quantity, it acquires the property of reddening vegetable blues. The addition of a little more acid occasions a precipitate, and sulphuric acid occasions a greater precipitate than any other acid. This precipitate consists of a yellow coloured matter often visible in bile, and which is insoluble in water. If we continue to add sulphuric acid after the yellow matter has been removed, the picromel precipitates in combination with it and constitutes the green coloured matter formerly distinguished by the name of *resin* of bile. Thenard separated the picromel by means of acetate and subacetate of lead, and he considered it as two distinct substances, to which he gave the names of *resin and picromel*. Berzelius has rectified this mistake. Many years ago I mixed a quantity of muriatic acid with ox bile, decanted the liquid portion from the coagulum which precipitated. The liquid was put into a phial and placed near a window through which the sun shone for several hours every day. After some months I found the picromel precipitated to the bottom in the form of small spheres. Its colour was white, with a slight yellowish green tint, and its taste was sweet with an impression of bitterness.

By evaporating a quantity of bile to dryness, calcining it, and proceeding in the usual way, Thenard ascertained the proportion of salts which it contained. The following was the result of his analysis of 800 parts of bile.

Water	700·0	Chap. II.
Picromel and resin	84·3	
Yellow matter	4·5	
Soda.	4·0	
Phosphate of soda	2·0	
Muriate of soda	3·2	
Sulphate of soda	0·8	
Phosphate of lime.............	1·2	
Oxide of iron	Trace	
	800·0	

The albumen, announced as a constituent of ox bile by Cadet * and Ramsay,† was the yellow matter of Thenard.

2. Such are the properties and the constituents of ox bile, as far as they have been examined by Thenard. From the experiments of the same chemist it appears, that the bile of the calf, the dog, the sheep, and the cat, resemble that of the ox exactly, both in their properties and their constituents.‡ *Bile of other animals.*

3. The bile of the sow differs entirely from that of all these animals. It contains neither albumen, nor animal matter, nor picromel, but is merely a soap, as it contains a great quantity of resin and of soda, and is decomposed with facility by all the acids, even by vinegar. It contains traces also of several salts; but Thenard did not ascertain their nature.§ *Of the sow.*

4. The bile of the common hen, of the turkey, and the duck, has a good deal of resemblance to that of quadrupeds. But it differs in the following particulars: 1. It contains a considerable quantity of albumen; 2. The picromel has no sensible sweet taste, but is very acrid and bitter; 3. It contains very little soda; 4. The resin is not precipitated by common superacetate of lead; but superacetate, boiled with $\frac{1}{4}$th of its weight of litharge, occasions it to precipitate.‖ *Of fowls.*

5. The bile of the thornback and salmon is yellowish white. When evaporated it leaves a matter which has a very sweet and slightly acrid taste. It appears to contain no resin. The bile of the carp and the eel is very green, very bitter, contains little or no albumen, but yields soda, *Of fishes.*

* Mem. Par. 1767, p. 340.　　　　† Thesaur. Edin. ii. 460.
‡ Mem. d'Arcueil, i. 48.　§ Ibid. p. 49.　‖ Ibid. p. 50.

resin, and a sweet acrid matter similar to that which may be obtained from salmon bile.*

6. Human bile differs considerably from that of all other animals examined. Its colour is sometimes green, sometimes yellowish brown; sometimes it is nearly colourless. Its taste is not very bitter. It is seldom completely liquid, but usually contains some yellow matter suspended in it. When evaporated to dryness it leaves a brown matter amounting to about $\frac{1}{11}$th of the original weight. When this matter is calcined it yields all the salts which are to be found in ox bile. All the acids decompose human bile, and throw down a copious precipitate consisting of albumen and resin. One part of nitric acid is capable of saturating 100 parts of bile. The superacetate of lead throws down the resin, and leaves nothing but a yellowish liquid consisting of the salts of bile, and some atoms of a peculiar animal matter, the nature of which was not ascertained. The following were the proportions of these substances obtained by Thenard from 1100 parts of human bile :

1000·0 water
       from 2 to 10 yellow insoluble matter.
       yellow matter in solution, a trace.
  42·0 albumen.
  41·0 resin.
   5·6 soda.
   4·5 phosphate of soda, sulphate of soda, muriate of soda, phosphate of lime, oxide of iron.

The following are the constituents which Berzelius found in human bile :

Water	908·4
Picromel	80·0
Albumen	3·0
Soda	4·1
Phosphate of lime	0·1
Common salt	3·4
Phosphate of soda with some lime	1·0

                                1000·0†

* Mem. d'Arcueil, i. 53.   † Djur kemien, ii. 48.

SECT. XVI.

OF THE CERUMEN OF THE EAR.

CERUMEN is a viscid yellow-coloured liquid secreted by the glands of the auditory canal, which gradually becomes concrete by exposure to the air. For all the facts respecting its composition at present known, we are indebted to Fourcroy and Vauquelin, especially the last, who analysed a considerable portion of it.

It has an orange-yellow colour and a bitter taste. When slightly heated upon paper, it melts, and stains the paper like an oil; at the same time it emits a slightly aromatic odour. On burning coals it softens, emits a white smoke, which resembles that given out by burning fat; it afterwards melts, swells, becomes dark-coloured, and emits an ammoniacal and empyreumatic odour. A light coal remains behind. *Properties.*

When agitated in water, cerumen forms a kind of emulsion, which soon putrifies, depositing at the same time white flakes.

Alcohol, when assisted by heat, dissolves $\frac{5}{8}$ of the cerumen; the $\frac{3}{8}$ which remain behind have the properties of albumen, mixed however with a little oily matter. When the alcohol is evaporated, it leaves a deep-orange residuum of a very bitter taste, having a smell and a consistence analogous to turpentine. It melts when heated, evaporates in a white smoke without leaving any residuum, and in short resembles very strongly the *resin of bile*. Ether also dissolves this oily body; but it is much less bitter and much lighter coloured. When the albuminous part of cerumen is burnt, it leaves traces of soda and of phosphate of lime. From these facts Vauquelin considers cerumen as composed of the following substances: *Contains albumen,*

And resin.

1. Albumen.
2. An inspissated oil.
3. A colouring matter.
4. Soda.
5. Phosphate of lime.

Composition.

The presence of the colouring matter is inferred from the portion taken up by ether being less coloured than that taken up by alcohol.*

* Fourcroy, ix. 373.

2

SECT. XVII.

OF TEARS AND MUCUS.

1. THAT peculiar fluid which is employed in lubricating the eye, and which is emitted in considerable quantities when we express grief by weeping, is known by the name of *tears.* For an accurate analysis of this fluid we are indebted to Messrs. Fourcroy and Vauquelin. Before their dissertation, which was published in 1791, appeared, scarcely any thing was known about the nature of tears.

Properties.   The liquid called tears is transparent and colourless like water; it has scarcely any smell, but its taste is always perceptibly salt. Its specific gravity is somewhat greater than that of distilled water. It gives to paper stained with the juice of the petals of mallows or violet a permanently green colour, and therefore contains a fixed alkali.* It unites with water, whether cold or hot, in all proportions. Alkalies unite with it readily, and render it more fluid. The mineral acids produce no apparent change upon it.† Exposed to the air, this liquid gradually evaporates, and becomes thicker. When nearly reduced to a state of dryness, a number of cubic crystals form in the midst of a kind of mucilage. These crystals possess the properties of muriate of soda; but they tinge vegetable blues green, and therefore contain an excess of soda. The mucilaginous matter acquires a yellowish-colour as it dries.‡

This liquid boils like water, excepting that a considerable froth collects on its surface. If it be kept a sufficient time at the boiling temperature, $\frac{96}{100}$ parts of it evaporate in water, and there remain about ·04 parts of a yellowish-matter, which by distillation in a strong heat yields water and a little oil: the residuum consists of different saline matters.§

When alcohol is poured into this liquid, a mucilaginous matter is precipitated in the form of large white flakes. The alcohol leaves behind it, when evaporated, traces of muriate of soda and soda. The residuum which remains behind, when inspissated tears are burnt in the open air,

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* Fourcroy and Vauquelin, Jour. de Phys. xxxix. 256.   † Ibid. 257.
‡ Ibid.   § Ibid.

exhibits some traces of phosphate of lime and phosphate of soda.*

Thus it appears that tears are composed of the following ingredients:

1. Water.
2. Mucus.
3. Muriate of soda.
4. Soda.
5. Phosphate of lime.
6. Phosphate of soda.

Composition.

The saline parts amount only to about 0·01 of the whole, or probably not so much.

The *mucus* contained in the tears has the property of absorbing oxygen gradually from the atmosphere, and of becoming thick and viscid, and of a yellow colour. It is then insoluble in water, and remains long suspended in it without alteration. When a sufficient quantity of chlorine is poured into tears, a yellow flaky precipitate appears, absolutely similar to this inspissated mucilage. The chlorine loses its peculiar odour; hence it is probable that oxygen has united to the mucilage. The property which this mucilage has of absorbing oxygen, and of acquiring new qualities, explains the changes which take place in tears which are exposed for a long time to the action of the atmosphere, as is the case with those persons who labour under a fistula lachrymalis.†

Properties of the mucilage.

2. The mucus of the nose has also been examined by Fourcroy and Vauquelin. They found it composed of precisely the same ingredients with the tears. As this fluid is more exposed to the action of the air than the tears, in most cases its mucilage has undergone less or more of that change which is the consequence of the absorption of oxygen. Hence the reason of the greater viscidity and consistence of the mucus of the nose; hence also the great consistence which it acquires during colds, where the action of the atmosphere is assisted by the increased action of the parts.‡

Mucus of the nose.

According to the analysis of Berzelius, the constituents of the mucus of the nose are as follows:

* Fourcroy and Vauquelin, Jour. de Phys. xxxix. 259.
† Ibid. 257. ‡ Ibid. 259.

Book V.

Water	933·7
Mucus	53·3
Muriate of potash and soda	5·6
Lactate of soda with animal matter	3·0
Soda..	0·9
Albumen and animal matter soluble in water, but insoluble in alcohol, with a trace of phosphate of soda	3·5
	1000·0*

The mucus of the nose when immersed in water imbibes so much as to become transparent, and when dried on blotting paper loses nearly all the moisture it had imbibed. This may be repeated as often as we please; but the mucus gradually assumes a yellow colour. Though boiled in water it does not lose its mucilaginous nature. It dissolves in diluted sulphuric acid. Nitric acid at first coagulates it; but if the digestion be continued, the mucus is at last dissolved into a yellow clear liquid. Acetic acid hardens and does not dissolve it even in a boiling heat. Caustic alkali renders it at first more viscid, but finally dissolves it into a clear liquid. Tannin coagulates it.†

Expectorated matter.

The matter expectorated from the lungs and bronchiæ might be supposed to be mucilaginous; but from the experiments on it by Dr. Pearson, who has examined it with much care and ingenuity,‡ this does not appear to be the case. Dr. Pearson distinguishes seven different kinds of expectorated matter. 1. The jelly-like semitransparent kind of a bluish hue, excreted in a state of health; 2. The thin mucilage-like transparent matter so copiously expectorated in bronchial catarrhs; 3. The thick opaque straw-coloured, or white and very tenacious matter, coughed up in a great variety of bronchial and pulmonary affections, especially in that of tubercles; 4. Puriform matter, secreted without any division of continuity or breach of surface of the bronchial membrane, very commonly occurring in pulmonary consumptions: 5. The matter which consists of opaque viscid masses, together with transparent fluid; or the second sort above stated with nodules of the third and

* Annals of Philosophy, ii. 382.   † Berzelius, ibid.
‡ Pearson on Expectorated Matter. Phil. Trans. 1809.

fourth kind; 6. Pus from the vomicæ of tubercles; 7. Pus from vomicæ by simple inflammation of the lungs and without tubercles.

From the experiments of Dr. Pearson, it appears that the constituents of the first five of these species are nearly the same. The chief variation is in the proportions of the ingredients. They all consist of water holding in solution a quantity of albumen or animal oxide (as Dr. Pearson terms it), coagulable by heat and by the usual chemical agents. This albumen is combined with potash* which it neutrallizes. This albumen sometimes amounts to the twelfth or even the tenth of the expectorated matter; and when smallest it is never less than $\frac{1}{45}$th. The usual proportion varies from $\frac{1}{16}$th to $\frac{1}{20}$th. The potash varies between $\frac{1}{2}$ and $\frac{3}{4}$ths of a part in 1000 of the expectorated matter.

Expectorated matter yields traces of sulphur, and perhaps also of phosphorus, and it contains the following saline substances: 1. Muriate of soda, varying from $1\frac{1}{2}$ to $2\frac{1}{2}$ in the 1000 of expectorated matter; 2. Phosphate of lime about $\frac{1}{2}$ a part in the 1000; 3. Ammonia united probably to phosphoric acid; 4. A phosphate probably of magnesia; 5. Carbonate of lime; 6. A sulphate; 7. Vitrifiable matter probably silica; 8. Oxide of iron. The whole of these last six substances scarcely amounts to one part in the 1000 of expectorated matter.

The proportion of saline matter and of albumen present in expectorated matter varies much in different circumstances. The thicker it is in general the smaller is the quantity of saline matter; whereas when very thin it is often impregnated with salts, especially with muriate of soda to a great degree, and tastes distinctly salt and hot.

* Dr. Pearson thinks that the alkali in animal fluids is not soda, as has hitherto been supposed, but potash. He has found this to be the case in blood, dropsy fluid, pus, liquid from blisters, urine, and mucus of the nose.

SECT. XVIII.

LIQUOR OF THE PERICARDIUM.

THIS is a liquor which lubricates the heart. It has been examined by Dr. Bostock, having being obtained from the pericardium of a boy who had died suddenly.*

It had the colour and appearance of the serum of the blood. Evaporated to dryness, it left a residue amounting to $\frac{1}{13}$th of its weight. When exposed to the heat of boiling water, it became opaque and thready. It was copiously precipitated by corrosive sublimate before boiling; but when boiled, evaporated to dryness, and redissolved, the solution was not affected by this salt. These experiments show us that it contained albumen. When saturated with corrosive sublimate, infusion of galls produced no effect, indicating the absence of gelatin. It was copiously precipitated by subacetate of lead, even after being boiled to dryness and the residue redissolved in water. Nitrate of silver indicated the presence of muriatic acid. Dr. Bostock, from his experiments, considers it as composed of

Water	92·0
Albumen	5·5
Mucus	2·0
Muriate of soda ...	0·5
	100·0

SECT. XIX.

OF THE HUMOURS OF THE EYE.

Structure of the eye.

THE eye is one of the most delicate and complicated organs in the body; at the same time its structure, and the uses of its parts, are better understood than almost any of the other instruments of sensation. It is composed of several concentric coats, which have not been chemically

* Nicholson's Jour. xiv. 147.

examined; but, from the experiments of Hatchett on simi-
lar substances, we may consider it as probable that they pos-
sess the properties of coagulated albumen. The internal
part of the eye is chiefly filled with three transparent sub-
stances, which have been called *humours* by anatomists;
namely, 1. The *aqueous humour*, immediately behind the
cornea; 2. The *crystalline humour* or *lens;* and, 3. The
vitreous humour, behind the lens, and occupying the great-
est part of the eye. We knew scarcely any thing of the
chemical properties of these humours till Mr. Chenevix pub-
lished an analysis of them in the Philosophical Transac-
tions for 1802. Since that time an analysis of them has
likewise been published by Nicholas,* and by Berzelius.†

I. Most of the experiments of Chenevix were made upon
the eyes of sheep, as most easily procured. He afterwards
tried the properties of humours from the eyes of other
animals.

Eye of
sheep.

1. The aqueous humour of the eye of the sheep is a clear
transparent liquid like water, which has very little smell or
taste when fresh. Its specific gravity is 1·0090 at the tem-
perature of 60°.

Aqueous
humour.

It scarcely alters vegetable blues when fresh.‡ When
exposed to the air it evaporates slowly, and becomes slightly
putrid. When boiled a very slight coagulum is formed.
When 100 parts are evaporated to dryness, they leave eight
parts of residuum. Tannin occasions a precipitate in it both
before boiling and after it. Nitrate of silver occasions a pre-
cipitate of muriate of silver; but no precipitate is produced
by other metallic salts. Hence it appears that the aqueous
humour is water slightly impregnated with the following
substances:

1. Albumen.
2. Gelatin.
3. Muriate of soda.

For Mr. Chenevix found that the muriatic acid was in com-
bination with soda. Nicholas has likewise detected a little
phosphate of lime in it.

Its constituents according to the analysis of Berzelius,
are,

* Ann. de Chim. liii. 307.   † Annals of Philosophy, ii. 385.
‡ Nicholas found that it turned paper stained with the petals of the
mallow to green.

Water .... 98·10
Albumen .... Trace
Muriates and lactates .... 1·15
Soda with animal matter soluble only in water .. 0·75
                                                _____
                                                100·00

Vitreous
humour.

2. The vitreous matter possesses the very same properties as the aqueous; even its specific gravity is the same, or only a very little greater. Its constituents according to the analysis of Berzelius, are

Water .... 98·40
Albumen .... 0·16
Muriates and lactates .... 1·42
Soda with animal matter soluble only in water .. 0·02
                                              _____
                                              100·00

Lens.

3. The crystalline lens is solid: densest in the centre, and becoming less solid towards the circumference. It is composed of concentric coats, and is transparent. Its specific gravity is 1·1000. When fresh it has little taste. It putrifies very rapidly.

It is almost completely soluble in water. The solution is partly coagulated by heat, and gives a copious precipitate with tannin both before the coagulation and after it. It gives no traces of muriatic acid. Its composition according to the analysis of Berzelius, is as follows:

Water 58
Peculiar matter .... 35·9
Muriates, lactates, and animal matter, soluble } 2·4
    in alcohol .... }
Animal matter soluble only in water with some } 1·3
    phosphates .... }
Portions of the remaining insoluble cellular } 2·4
    membrane .... }
                                              _____
                                              100·0

The peculiar matter of the lens possesses all the chemical characters of the colouring matter of the blood, except colour. When burnt it leaves a little ash containing a very small portion of iron. When its solution in water is coagulated by boiling, the liquid in which the coagulum was

formed reddens litmus, has the smell of the humours of Chap. II.
the muscles, and like them contains free lactic acid.*

II. The humours of the human eye are composed of the Human
same ingredients as those of the sheep; the only perceptible eye.
difference consists in their specific gravity. The specific
gravity of the human aqueous and vitreous humours is
1·0053; that of the crystalline 1·0790.

III. The humours of the eyes of oxen resemble those of Eye of
the sheep in their composition. The specific gravity of the oxen.
aqueous and vitreous humours is 1·0088; that of the crys-
talline 1·0765.

From these three sets of experiments Mr. Chenevix has
drawn, as a probable conclusion, that the difference between
the density of the aqueous and crystalline humours, and
that of the crystalline, is in the inverse ratio of the diame-
ter of the eye, taken from the cornea to the optic nerve.

The crystalline of the ox weighed 30 grains. When the
whole of it was pared away except the six grains in the
centre, the specific gravity was found to be 1·194.†

IV. Mr. Chenevix, in his paper, makes no mention of Eye of
the eyes of birds; but Sir H. Davy published an abstract of birds.
it in the first volume of the Journal of the Royal Institu-
tion. He there states that Mr. Chenevix found the hu-
mours of the eyes of birds composed of the same constitu-
ents as the eyes of other animals; but that he found at the
same time the specific gravity of the vitreous humour in
these animals greater than the specific gravity of the crys-
talline.‡

V. A curious set of experiments has been made by Leo-
pold Gmelin on the black pigment, which lines the choroid
coat of the eye. From 500 eyes of oxen and calves he
collected 75 grains of this substance. Its colour is blackish
brown. It is tasteless, and adheres to the tongue like clay.
It is insoluble in water, alcohol, ether, oils, lime water, and
distilled vinegar. It dissolves in potash and ammonia when
assisted by heat, and is again precipitated by acids. Sul-
phuric acid dissolves it and acquires a black colour. Mu-
riatic acid forms only an imperfect solution. Nitric acid

* Berzelius, Ann a lof Philosophy, ii. 385.
† See Phil. Trans. 1802, and Phil. Mag. xvi. 268.
‡ Jour. of the Royal Instit. i. 297.

Book V. dissolves it, and changes its colour to reddish-brown. When distilled it yields water, a brown oil, and carbonate of ammonia. It gives out at the same time carbureted hydrogen, carbonic oxide, azotic and oxygen gases. The coal remaining in the retort consists almost entirely of charcoal.[*]

SECT. XX.

OF SINOVIA.

WITHIN the capsular ligament of the different joints of the body there is contained a peculiar liquid, intended evidently to lubricate the parts, and to facilitate their motion. This liquid is known among anatomists by the name of *sinovia*.

Whether it be the same in different animals, or even in all the different joints of the same animal, has not been determined, as no accurate analysis of the sinovia of different animals has been attempted. The only analysis of sinovia which has hitherto appeared is that by Mr. Margueron, which was published in the 14th volume of the *Annales de Chimie*. He made use of sinovia obtained from the joints of the lower extremities of oxen.

Sinovia of the ox. The sinovia of the ox, when it has just flowed from the joint, is a viscid semitransparent fluid, of a greenish-white colour, and a smell not unlike frog-spawn. It very soon acquires the consistence of jelly; and this happens equally whether it be kept in a cold or a hot temperature, whether it be exposed to the air or excluded from it. This consistence does not continue long; the sinovia soon recovers again its fluidity, and at the same time deposits a thready-like matter.[†]

Sinovia mixes readily with water, and imparts to that liquid a great deal of viscidity. The mixture froths when agitated; becomes milky when boiled, and deposits some pellicles on the sides of the dish; but its viscidity is not diminished.[‡]

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[*] Schweigger's Jour. x. 507.
[†] Margueron, Ann. de Chim. xiv. 124.   [‡] Ibid. p. 126.

When alcohol is poured into sinovia, a white substance precipitates, which has all the properties of albumen. One hundred parts of sinovia contain 4·52 of albumen. The liquid still continues as viscid as ever; but if acetic acid be poured into it, the viscidity disappears altogether, the liquid becomes transparent, and deposits a quantity of matter in white threads, which possesses the following properties:
1. It has the colour, smell, taste, and elasticity of vegetable gluten. 2. It is soluble in concentrated acids and pure alkalies. 3. It is soluble in cold water; the solution froths. Acids and alcohol precipitate the fibrous matter in flakes. One hundred parts of sinovia contain 11·86 of this matter. *

When the liquid, after these substances have been separated from it, is concentrated by evaporation, it deposits crystals of acetate of soda. Sinovia, therefore, contains *soda*. Margueron found that 100 parts of sinovia contained about 0·71 of soda.

When strong sulphuric, muriatic, nitric, acetic, or sulphurous acid is poured into sinovia, a number of white flakes precipitate at first, but they are soon redissolved, and the viscidity of the liquid continues. When these acids are diluted with five times their weight of water, they diminish the transparency of sinovia, but not its viscidity; but when they are so much diluted that their acid taste is just perceptible, they precipitate the peculiar thready matter, and the viscidity of the sinovia disappears.†

When sinovia is exposed to a dry atmosphere, it gradually evaporates, and a scaly residuum remains, in which cubic crystals, and the white saline efflorescence are apparent. The cubic crystals are muriate of soda. One hundred parts of sinovia contain about 1·75 of this salt. The saline efflorescence is carbonate of soda. ‡

Sinovia soon putrifies in a moist atmosphere, and during the putrifaction ammonia is exhaled. When it is distilled in a retort, there comes over first, water, which soon putrifies; then water containing ammonia; then empyreumatic oil and carbonate of ammonia. From the residuum muriate and carbonate of soda may be extracted by lixiviation. The coal contains some phosphate of lime. §

* Margueron, Ann. de Chim. xiv. 126, 130. † Ibid. p. 127.
‡ Ibid. p. 125. § Ibid. p. 128.

Book V.   From the analysis of Mr. Margueron, it appears that
          sinovia is composed of the following ingredients:

Composi-
tion.
          Fibrous matter ....   11·86
          Albumen ....   4·52
          Muriate of soda ....   1·75
          Soda ....   ·71
          Phosphate of lime ....   ·70*
          Water ....   80·46
                                     ————
                                     100·00

Gouty con-   How far the sinovia of the human body resembles that
cretions.
          of oxen it is impossible to say.   The following fact renders
          it probable that it either contains different ingredients, or
          is liable to alteration from disease.   Concretions often form
          in the joints of gouty people, and make their way through
          the skin.   These, in common language, are called *chalk-
          stones.*   Dr. Wollaston, Dr. Pearson, and Mr. Tennant
          analysed some of them, and found them composed of *urate
          of soda.*†   This analysis has been repeated by Fourcroy, and
          confirmed.‡   It is doubtless this fact that has induced Four-
          croy to conjecture that uric acid forms a constituent part of
          sinovia.§

                          SECT. XXI.

                          OF SEMEN.

          THE peculiar liquid secreted in the testes of males, and
          destined for the impregnation of females, is known by the
          name of *semen.*   The human semen and the melt of fresh
          water fishes alone have hitherto been subjected to chemical
          analysis.   Nothing is known concerning the seminal fluid
          of other animals.   J. Vauquelin published an analysis of
          the human semen in 1791.

Properties.   Semen, when newly ejected, is evidently a mixture of

          * Mr. Hatchett found only 0·208 of phosphate of lime in the sinovia
     which he examined.   He found, however, traces of some other phos-
     phate ; probably phosphate of soda.   Phil. Trans. 1799, p. 246.
          † Jour. de Phys. xlv. 399.   ‡ Fourcroy, x. 267.
          § Ibid. ix. 224.

two different substances : the one fluid and milky, which is supposed to be secreted by the prostate gland ; the other, which is considered as the secretion of the testes, is a thick mucilaginous substance, in which numerous white shining filaments may be discovered.* It has a slight disagreeable odour, an acrid irritating taste, and its specific gravity is greater than that of water. When rubbed in a mortar it becomes frothy, and of the consistence of pomatum, in consequence of its enveloping a great number of air-bubbles. It converts paper stained with the blossoms of mallows or violets to a green colour, and consequently contains an alkali.†

As the liquid cools, the mucilaginous part becomes transparent, and acquires greater consistency ; but in about twenty minutes after its emission, the whole becomes perfectly liquid. This liquefaction is not owing to the absorption of moisture from the air, for it loses instead of acquiring weight during its exposure to the atmosphere ; nor is it owing to the action of the air, for it takes place equally in close vessels.‡

Semen is insoluble in water before this spontaneous liquefaction, but afterwards it dissolves readily in it. When alcohol or chlorine is poured into this solution, a number of white flakes are precipitated.§ Concentrated alkalies facilitate its combination with water. Acids readily dissolve the semen, and the solution is not decomposed by alkalies ; neither indeed is the alkaline solution decomposed by acids.‖

Lime disengages no ammonia from fresh semen ; but after that fluid has remained for some time in a moist and warm atmosphere, lime separates a great quantity from it. Consequently ammonia is formed during the exposure of semen to the air.**

When chlorine is poured into semen, a number of white flakes precipitate, and the acid loses its peculiar odour. These flakes are insoluble in water, and even in acids. If the quantity of acid be sufficient, the semen acquires a yellow colour. Thus it appears that semen contains a mucilaginous substance analogous to that of the

Contains mucilage,

* Vauquelin, Ann. de Chim. ix. 64.   † Ibid. p. 65.
‡ Ibid. p. 66.   § Ibid. p. 70.   ‖ Ibid. p. 71.
** Ibid. p. 71.

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tears, which coagulates by absorbing oxygen. Mr. Vau-quelin obtained from 100 parts of semen six parts of this mucilage.

Phosphate of lime,

When semen is exposed to the air about the temperature of 60°, it becomes gradually covered with a transparent pellicle, and in three or four days deposits small transparent crystals, often crossing each other in such a manner as to represent the spokes of a wheel. These crystals, when viewed through a microscope, appear to be four-sided prisms, terminated by very long four-sided pyramids. They may be separated by diluting the liquid with water, and decanting it off. They have all the properties of phosphate of lime.* If, after the appearance of these crystals, the semen be still allowed to remain exposed to the atmosphere, the pellicle on its surface gradually thickens, and a number of white round bodies appear on different parts of it. These bodies also are phosphate of lime, prevented from crystallizing regularly by the too rapid abstraction of moisture. Mr. Vauquelin found that 100 parts of semen contain three

And soda.

parts of phosphate of lime.† If at this period of the evaporation the air becomes moist, other crystals appear in the semen, which have the properties of carbonate of soda. The evaporation does not go on to complete exsiccation, unless at the temperature of 77°, and when the air is very dry. When all the moisture is evaporated, the semen has lost 0·9 of its weight; the residuum is semitransparent like horn, and brittle.‡

When semen is kept in very moist air, at the temperature of about 77°, it acquires a yellow colour, like that of the yolk of an egg; its taste becomes acid, it exhales the odour of putrid fish, and its surface is covered with abundance of the *byssus septica.*§

Action of heat.

When dried semen is exposed to heat in a crucible, it melts, acquires a brown colour, and exhales a yellow fume, having the odour of burnt horn. When the heat is raised, the matter swells, becomes black, and gives out a strong odour of ammonia. When the odour of ammonia disappears, if the matter be lixiviated with water, an alkaline solution may be obtained, which, by evaporation, yields

* Vauquelin, Ann. de Chim. ix, 67 and 73.   † Ibid. p. 68.
‡ Ibid. p. 68.   § Ibid. p. 68.

crystals of carbonate of soda. Mr. Vauquelin found that 100 parts of semen contain one part of soda.* If the residuum be incinerated, there will remain only a quantity of white ashes, consisting of phosphate of lime.

Thus it appears that semen is composed of the following ingredients:

Water 90
Mucilage 6
Phosphate of lime...... 3
Soda 1
                     ————
                      100

II. Fourcroy and Vauquelin published a set of experi- ments on the milt of the carp in the year 1807,† from which it appears that the nature and composition of this substance is different from that of every other hitherto examined. The milt of this fish, as is well known, has a whitish colour, a soft consistence, a greasy feel, and a smell similar to that of fish. It is neither acid nor alkaline. When triturated with potash no ammoniacal odour is exhaled, and it forms with the alkali a thick magma. Thirty parts of milt mixed with six parts of potash, and a sufficient quantity of water, and distilled, yielded only traces of ammonia, coming obviously from some muriate of ammonia, which exists naturally in the milt. When milt is dried slowly in a moderate heat it loses $\frac{3}{4}$ths of its weight, becomes yellow and brittle. When heated in a platinum crucible it softens and then melts, exhaling yellow vapours having the smell of animal oil. The charcoal formed contains a notable quantity of uncombined phosphoric acid, together with some phosphate of lime and phosphate of magnesia. As the acid did not exist in the milt it must have been formed during the combustion; and hence it follows that milt contains a notable quantity of phosphorus as a constituent.

One hundred and twenty-three parts of fresh milt, cautiously distilled in an earthen-ware crucible, gradually heated to whiteness, furnished the following products: 1. A great deal of colourless water holding in solution carbonate of ammonia, a good deal of prussiate of ammonia,

* Ann. de Chim. ix. 75. † Ibid. lxiv. 5.

and traces of muriate of ammonia; 2. A transparent oil slightly yellow; 3. A fluid blood-red oil; 4. A thick blackish-brown oil; 5. Crystals of carbonate and prussiate of ammonia; 6. A quantity of phosphorus; 7. A small quantity of carbonic acid and heavy inflammable air. The charcoal remaining in the retort amounts to $7\frac{1}{2}$ parts, and contains no disengaged phosphoric acid.

When milt is triturated in distilled water a white opaque liquid is obtained, which does not become transparent though passed through the filter. When the liquid is boiled an albuminous matter coagulates; and if the residuary liquid be evaporated sufficiently it gelatinizes; a proof that it contains gelatin. Alcohol digested on milt dissolves a substance which possesses the properties of animal soap. When it is separated the milt becomes dry and harsh to the feel; a proof that its unctuosity was owing to the presence of the animal soap.

Constituents.

Thus it appears that milt contains albumen, gelatin, phosphorus, phosphate of lime, phosphate of magnesia, and muriate of ammonia.

SECT. XXII.

OF THE LIQUOR OF THE AMNIOS.

THE fœtus in the uterus is enveloped in a peculiar membranous covering, to which anatomists have given the name of *amnios*. Within this amnios there is a liquid, distinguished by the name of the *liquor of the amnios*, which surrounds the fœtus on every part. This liquid, as might have been expected, is very different in different animals; at least the liquor amnii in women and in cows, which alone have hitherto been analised, have not the smallest resemblance to each other. These two liquids have been analysed by Vauquelin and Buniva, and the result of their analysis has been published in the 33d volume of the *Annales de Chimie*.

Liquor of the human amnios.

1. The liquor of the amnios of women is a fluid of a slightly milky colour, a weak pleasant odour, and a saltish

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taste. The white colour is owing to a curdy matter Chap. II.
suspended in it, for it may be obtained quite transparent
by filtration.*

Its specific gravity is 1·005. It gives a green colour to
the tincture of violets, and yet it reddens very decidedly
the tincture of turnsole. These two properties would
indicate at once the presence of an acid and of an alkali.
It froths considerably when agitated. On the application
of heat it becomes opaque, and has then a great resem-
blance to milk diluted with a large quantity of water. At
the same time it exhales the odour of boiled white of egg.†

Acids render it more transparent. Alkalies precipitate
an animal matter in small flakes. Alcohol likewise pro-
duces a flaky precipitate, which, when collected and dried,
becomes transparent and very like glue. The infusion of
nutgalls produces a very copious brown-coloured precipi-
tate. Nitrate of silver occasions a white precipitate, which
is insoluble in nitric acid, and consequently is muriate of
silver.‡

When slowly evaporated, it becomes slightly milky, a
transparent pellicle forms on its surface, and it leaves a
residuum which does not exceed 0·012 of the whole. By
lixiviating this residuum, and evaporating the ley, crystals
of muriate and carbonate of soda may be obtained. The
remainder, when incinerated, exhales a fetid and amme-
niacal odour, resembling that of burning horn; the ashes
consist of a small quantity of carbonate of soda, and of
phosphate and carbonate of lime.§

Thus we see that the liquor of the human amnios is Composi-
composed of about tion.

Water	98·8
Albumen	
Muriate of soda, soda	} 1·2
Phosphate of lime, lime	
	100·0

While the foetus is in the uterus, a curdy-like matter is Curdy mat-
deposited on the surface of its skin, and in particular parts ter deposit-
of its body. This matter is often found collected in con- ed on the foetus.

* Ann. de Chim. xxxiii. 270.   † Ibid p. 271.
‡ Ibid. p. 271.   § Ibid. p. 272.

Book V. siderable quantities. It is evidently deposited from the liquor of the amnios; and consequently the knowledge of its peculiar nature must throw considerable light upon the properties and use of that liquor. For an analysis of this substance we are also indebted to Vauquelin and Buniva.

Its colour is white and brilliant; it has a soft feel, and very much resembles newly prepared soap. It is insoluble in water, alcohol, and oils. Pure alkalies dissolve part of it, and form with it a kind of soap. On burning coals it de- crepitates like a salt, becomes dry and black, exhales vapours which have the odour of empyreumatic oil, and leaves a residuum which is very difficultly reduced to ashes. When heated in a platinum crucible it decrepitates, lets an oil exude, curls up like horn, and leaves a residuum, consisting chiefly of carbonate of lime.*

These properties show that this matter is different from every one of the component parts of the liquor of the amnios, and that it has a great resemblance to the *fat.* It is probable, as Vauquelin and Buniva have conjectured, that it is formed from the albumen of that liquid, which has undergone some unknown changes. It has been long known that the parts of a fœtus, which has lain for some time after it had been deprived of life in the uterus, are sometimes converted into a kind of fatty matter. It is evident that this substance, after it is deposited upon the skin of the fœtus, must preserve it in a great measure from being acted upon by the liquor of the amnios.

Liquor of the amnios of the cow.

2. The liquor of the amnios of the cow † has a viscidity similar to mucilage of gum arabic, a brownish-red colour, an acid and bitter taste, and a peculiar odour, not unlike that of some vegetable extracts. Its specific gravity is 1·028. It reddens the tincture of turnsole, and, therefore, contains an acid. Muriate of barytes causes a very abun- dant precipitate, which renders it probable that it contains sulphuric acid. Alcohol separates from it a great quantity of a reddish-coloured matter.‡

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* Ann. de Chim. xxxiii. 274.

† A minute account of the liquor amnii, and of the liquor alantoidis, of the cow, has been published by Dzondi; for an abstract of which see Gehlen's Jour. Second Series, ii. 652.

‡ Ann. de Chim. xxxiii. 275.

When this liquid is evaporated, a thick frothy scum gathers on the surface, which is easily separated, and in which some white acid-tasted crystals may be discovered. By continuing the evaporation, the matter becomes thick and viscid, and has very much the look of honey. Alcohol boiled upon this thick matter, and filtered off, deposits upon cooling brilliant needle-form crystals nearly an inch in length. These crystals may be obtained in abundance by evaporating the liquor of the amnios to a fourth part of its bulk, and then allowing it to cool. The crystals soon make their appearance. They may be separated and puri- fied by washing them in a small quantity of cold water. These crystals are *amniotic* acid.*

If after the separation ef this acid the liquor of the amnios be evaporated to the consistence of a syrup, large transparent crystals appear in it, which have all the proper- ties of sulphate of soda. The liquid of the amnios of cows contains a considerable quantity of this salt.

Thus it appears that the liquor of the amnios of cows contains the following ingredients :

Composition.

1. Water.
2. A peculiar animal matter.
3. Acid.
4. Sulphate of soda.

The animal matter possesses the following properties : it has a reddish-brown colour and a peculiar taste ; it is very soluble in water, but insoluble in alcohol, which has the property of separating it from water. When exposed to a strong heat it swells, exhales first the odour of burning gum, then of empyreumatic oil and of ammonia, and at last the peculiar odour of prussic acid becomes very conspi- cuous. It differs from gelatin in the viscidity which it com- municates to water, in not forming a jelly when concen- trated, and in not being precipitated by tannin. It must be therefore ranked among the very undefined and inaccu- rate class of *animal mucilages.* When burnt, it leaves a very large coal, which is readily incinerated, and leaves a little white ashes, composed of phosphate of magnesia, and a very small proportion of phosphate of lime.†

Dr. Prout examined the liquor amnii, taken from the uterus of a cow, slaughtered in an early period of gestation.

* Ann. de Chim. xxxiii. 276.   † Ibid. 278.

Its colour was yellow, its smell like that of new milk, its taste like that of fresh whey. He could not detect in it any amniotic acid, but it contained a sensible quantity of sugar of milk. Its constituents were as follows :

Water 977
Albumen .... 2·6
Substances soluble in alcohol .... 16·6
Substances soluble in water, chiefly sulphate ⎱
    of soda ? and other salts, also sugar of milk ⎰ 3·8
                                      _____
                                      1000·0 *

The portion soluble in alcohol consisted partly of the lactates, but chiefly of a peculiar substance, having considerable external resemblance to the external brown parts of roasted veal.

SECT. XXIII.

OF ANIMAL POISONS.

SEVERAL animals are furnished with liquid juices of a poisonous nature, which, when poured into fresh wounds, occasion the disease or death of the wounded animal. Serpents, bees, scorpions, spiders, are well known examples of such animals. The chemical properties of these poisonous juices deserve peculiar attention; because it is only from such an investigation that we can hope to explain the fatal changes which they induce on the animal economy, or to discover an antidote sufficiently powerful to counteract their baneful influence. Unfortunately the task is difficult, and perhaps surpasses our chemical powers. For the progress already made in the investigation, we are indebted almost entirely to the labours of Fontana.

Poison of the viper.

1. The poison of the viper is a yellow liquid, which lodges in two small vesicles in the animal's mouth. These communicate by a tube with the crooked fangs, which are hollow, and terminate in a small cavity. When the animal

* Annals of Philosophy, v. 416.

bites, the vesicles are squeezed, and the poison forced through the fangs into the wound. This structure was partly observed by Redi, an Italian Philosopher; and his discoveries were completed and confirmed by the experiments and observations of Francini,* Tysson,† Mead,‡ and Fontana.

This poisonous juice occasions the fatal effects of the viper's bite. If the vesicles be extracted, or the liquid prevented from flowing into the wound, the bite is harmless. If it be infused into wounds made by sharp instruments, it proves as fatal as when introduced by the viper itself. Some of the properties of this liquid were pointed out by Mead; but it was Fontana who first subjected it to a chemical examination, sacrificing many hundred vipers to his experiments. The quantity contained in a single vesicle scarcely exceeds a drop.

It has a yellow colour, has no taste; but when applied to the tongue occasions numbness. It has the appearance of oil before the microscope, but it unites readily with water. It produces no change on vegetable blues.

Resembles gum.

When exposed to the open air, the watery part gradually evaporates, and a yellowish-brown substance remains, which has the appearance of gum arabic. In this state it feels viscid like gum between the teeth; it dissolves readily in water, but not in alcohol; and alcohol throws it down in a white powder from water. Neither acids nor alkalies have much effect upon it. It does not unite with volatile oils nor sulphuret of potash. When heated it does melt, but swells, and does not inflame till it has become black. These properties are similar to the properties of gum, and indicate the gummy nature of this poisonous substance. Fontana made a set of experiments on the dry poison of the viper, and a similar set on gum arabic, and obtained the same results.

From the observations of Dr. Russel, there is reason to believe that the poisonous juices of the other serpents are similar in their properties to those of the viper.

This striking resemblance between gums and the poison of the viper, two substances of so opposite a nature in their

* New Abridg. of the Phil. Trans. ii. 8.   † Phil. Trans. vol. xii.
‡ Mead on Poisons, p. 35.

Book V. effects upon the living body, is a humiliating proof of the small progress we have made in the chemical knowledge of these intricate substances. The poison of the viper, and of serpents in general, is most hurtful when mixed with the blood. Taken into the stomach it kills if the quantity be considerable. Fontana has ascertained that its fatal effects are proportional to its quantity, compared with the quantity of the blood. Hence the danger diminishes as the size of the animal increases. Small birds and quadrupeds die immediately when they are bitten by a viper; but to a full-sized man the bite seldom proves fatal.

Ammonia proposed as an antidote. Ammonia has been proposed as an antidote to the bite of the viper. It was introduced in consequence of the theory of Dr. Mead, that the poison was of an acid nature. The numerous trials of that medicine by Fontana robbed it of all its celebrity; but it has been lately revived and recommended by Dr. Ramsay as a certain cure for the bite of the rattlesnake.*

Venom of the bee and wasp, 2. The venom of the bee and the wasp is also a liquid contained in a small vesicle forced through the hollow tube of the sting into the wound inflicted by that instrument.† From the experiments of Fontana we learn that it bears a striking resemblance to the poison of the viper. That of the bee is much longer in drying when exposed to the air than the venom of the wasp.

Of the scorpion, 3. The poison of the scorpion resembles that of the viper also. But its taste is hot and acrid, which is the case also with the venom of the bee and the wasp.

Of spiders. 4. No experiments upon which we can rely have been made upon the poison of the spider tribe. From the rapidity with which these animals destroy their prey, and even one another, we cannot doubt that their poison is sufficiently virulent.‡

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* Phil. Mag. xvii. 125. The reader will find an interesting dissertation on the different remedies applied to the cure of the rattlesnake in the Amer. Trans. vol. iii. p. 100, by Dr. Smith Barton. The observations of Fontana in his treatise on poisons deserve particular attention.

† See a curious account of the structure of the sting by Dr. Hooke in his Micrographia.

‡ Dr. Mead's romantic account of the bite of the tarantula will entertain the reader. See Mead on Poisons, p. 57.

SECT. XXIV.

OF THE AIR CONTAINED IN THE SWIMMING BLADDERS OF FISHES.

MANY fish are furnished with a bladder filled with air, by means of which they are supposed to rise or sink in the water. When they wish to rise they are supposed to dilate their air bladder; when they wish to sink they compress it. Whether this be the use of the air bladder of fishes is somewhat doubtful. Most fish have a peculiar depth at History. which they almost always remain. Thus the flat fish constantly affect the bottom of the sea, while there are others that as constantly affect the surface. From the late observations of Biot it appears, that when a fish is suddenly brought from a great depth towards the surface, the air bladder swells so much that the fish cannot again sink; nay, it often bursts; and the air making its way into the stomach, swells it up and forces it into the mouth or œsophagus. The air with which these bladders is filled was first examined by Dr. Priestley in 1774. From his observations it appears that it varies in its nature. The roach was the fish the air bladder of which he examined. At first he found it filled with azote, but afterwards he got a mixture of oxygen and azote.*

Fourcroy long after examined the air in the air bladder of the carp, and found it almost pure azote; and similar results were obtained by other chemists. But by far the most complete analysis of this kind of air has been made by Biot, while in Yviza and Formentera, two islands a little to the south of Majorca and Minorca. He was employed by the French government to prolong the meridian of France to the Balearean islands, and embraced the opportunity which presented itself to examine the air in the bladders of the different species of fish caught in the neighbourhood of these islands. Next season he returned to the same islands with Mr. Laroche, who repeated and confirmed his preceding experiments.†

Biot found the air in the air-bladders a mixture of azotic Experi-

* Priestley on Air, ii. 462.
† Biot's Memoirs are printed in the Mem. D'Arcueil, i. 252, and ii. 8.

ments of
Biot.

and oxygen gas in very variable proportions.   No traces of hydrogen gas could be detected; nor was there any sensible quantity of carbonic acid.   The proportion of oxygen gas was very various, being sometimes very minute, and sometimes constituting almost the whole of the gas.   The air bladders of those fish which live near the surface contained least oxygen gas, and the bladders of those which were brought up from a great depth contained the most.   The following table exhibits the proportion of oxygen in 100 parts of the air in the different fish examined.

Proportion
of oxygen.

Names of the Fish.	Proportion of Oxygen.
Mugil cephalus (*Linn.*)	Quantity insensible.
Ditto.	Ditto.
Murœnophis helena (*Lacepede*)	Very little.
Sparus annularis (*Linn.*) female..	0·09
Ditto, male	0·08
Sparus sargus (*Linn.*) female....	0·09
Ditto, male	0·20
Holocentrus marinus (*Lacepede*)	0·12
Labrus turdus (*Linn.*).	0·16
Sparus melanurus (*Linn.*)	0·20
Labrus turdus (*Var. Linn.*).	0·24
Sciæna nigra, female	0·27
Ditto, male	0·25
Labrus turdus (*Linn.*) female	0·24
Ditto, male	0·28
Sparus dentex (*Linn.*) female . ..	0·40
Sphyrœna spet. (*Lacepede*)......	0·44
Sparus argenteus	0·50
Sparus erythrinus.............	Much
Holycentrus gigas	0·69
Gadus merluccius (*Linn.*)	0·79
Trygla lyra (*Linn.*)............	0·87

The depth at which the fish in the preceding table are caught increases gradually, as well as the proportion of oxygen, from the beginning to the end of the table.   The last-mentioned fish, the trygla lyra is always caught at a very great depth.   The experiments of Laroche confirm the accuracy of this curious fact.   The mean result, furnished by all the fishes taken at a depth greater than 150 feet, was 0·70 of oxygen; while the mean result, furnished

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by the fish caught at less depths, was 0·29. This superior purity is not owing to any superior purity in the air of the water of the sea at great depths. The air obtained from sea water, brought up from a great depth, yielded 0·265 of oxygen, while that from water taken at the surface was purer.

It is very remarkable that the air in the bladder of fishes, taken near the surface, should be almost pure azote. But this holds also with respect to fresh water fish. Thus Biot found the air in the air bladder of a carp to contain 0·03 of oxygen, while that of a tench contained 0·16; and Geoffroy and Vauquelin found the air in the air bladder of pikes, loaches, and perches, to contain 0·05 of oxygen. Humboldt likewise found very little oxygen in the air bladder of the gymnotus electricus.

SECT. XXV.

OF SWEAT.

A QUANTITY of matter is constantly emitted from the skin; this matter is invisible, and is distinguished by the name of *perspiration*. Several experiments were made by Lavoisier and Seguin to ascertain its amount. Mr. Cruickshanks * made numerous trials to determine its nature, and it has been subjected to a chemical examination by Thenard.† Berzelius also has made some experiments on it.

1. Mr. Cruickshanks put his hand into a glass vessel, and luted its mouth at his wrist by means of a bladder. The interior surface of the vessel became gradually dim, and drops of water trickled down. By keeping his hand in this manner for an hour, he collected 30 grains of a liquid, which possessed all the properties of pure water.‡ On repeating the same experiment at nine in the evening (thermometer 62°), he collected only 12 grains. The mean of these is 21 grains. But as the hand is more exposed than the trunk of the body, it is reasonable to sup-

1. Water.

* Cruickshanks on Insensible Perspiration.
† Ann. de Chim. lix. 263.   ‡ On Insensible Perspiration, p. 68.

2 N 2

Book V. pose that the perspiration from it is greater than that from the hand. Let us therefore take 30 grains per hour as the mean; and let us suppose, with Mr. Cruickshanks, that the hand is $\frac{1}{60}$th of the surface of the body: The perspiration in an hour would amount to 1880 grains, and in 24 hours to 43,200 grains, or seven pounds six ounces troy. This is almost double of the quantity ascertained by Lavoisier and Seguin. Hence we may conclude that more matter is perspired through the hand than the other parts of the body, provided Mr. Cruickshanks's estimate of the ratio between the surface of the hand and body be not erroneous.

He repeated the experiment again after hard exercise, and collected in an hour 48 grains of water.* He found also, that this aqueous vapour pervaded his stocking without difficulty; and that it made its way through a shamoy leather glove, and even through a leather boot, though in a much smaller quantity than when the leg wanted that covering.†

It is not difficult to see why the quantity of watery vapour diminishes with cold. When the surface of the body is exposed to a cold temperature, the capacity of the cutaneous vessels diminishes, and consequently the quantity which flows through them must decrease.

Sweat. When the temperature, on the other hand, is much increased, either by being exposed to a hot atmosphere, or by violent exercise, the perspired vapour not only increases in quantity, but even appears in a liquid form. This is known by the name of *sweat*. In what manner sweat is produced, is not at present known; but we can see a very important service which it performs to the animal. No sooner is it thrown upon the surface of the skin than it begins to evaporate. But the change into vapour requires heat; accordingly a quantity of heat is absorbed, and the temperature of the animal is lowered. This is the reason that animals can endure to remain for some time in a much higher temperature without injury than could have been supposed.

The experiments of Tillet, and the still more decisive

On Insensible Perspiration, p. 70.　　　　† Ibid. p. 82.

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experiments of Fordyce and his associates, are well known. These gentlemen remained a considerable time in a temperature exceeding the boiling point of water.

2. Besides water, it cannot be doubted that *carbon* is also Carbon. emitted from the skin; but in what state, the experiments hitherto made do not enable us to decide. Mr. Cruickshanks found that the air of the glass vessel in which his hand and foot had been confined for an hour contained carbonic acid gas; for a candle burned dimly in it, and it rendered lime-water turbid.* And Mr. Jurine found that air which had remained for some time in contact with the skin consisted almost entirely of carbonic acid gas.† The same conclusion may be drawn from the experiments of Ingenhousz and Milly.‡ Trousset has observed that air was separated copiously from a patient of his while bathing. §

Now it is evident that the carbonic acid gas which appeared during Mr. Cruickshanks's experiment did not previously exist in the glass vessel; consequently it must have either been transmitted ready formed through the skin, or formed during the experiment by the absorption of oxygen gas, and the consequent emission of carbonic acid gas. The experiments of Mr. Jurine do not allow us to suppose the first of these to be true; for he found that the quantity of air allowed to remain in contact with the skin did not increase. Consequently the appearance of the carbonic acid gas must be owing either to the emission of carbon, which forms carbonic acid gas by combining with the oxygen gas of the air, or to the absorption of oxygen gas, and the subsequent emission of carbonic acid gas; precisely in the same manner, and for the same reason, that these substances are emitted by the lungs. The last is the more probable opinion; but the experiments hitherto made do not enable us to decide.

3. Besides water and carbon, or carbonic acid gas, the 3. An oily skin emits also a particular odorous substance. That every matter. animal has a peculiar smell, is well known: the dog can discover his master, and even trace him to a distance, by the scent. A dog, chained some hours after his master had

* On Insensible Perspiration, p. 70 and 81.
† Encyc. Meth. Med. i. 515.   ‡ Ibid. p. 511.
§ Ann. de Chim. xlv. 73.

Book V. set out on a journey of some hundred miles, followed his footsteps by the smell, and found him on the third day in the midst of a crowd.* But it is needless to multiply instances of this fact; they are too well known to every one. Now this smell must be owing to some peculiar matter which is constantly emitted; and this matter must differ somewhat either in quantity or some other property, as we see that the dog easily distinguishes the individual by means of it. Mr. Cruickshanks has made it probable that this matter is an oily substance; or at least that there is an oily substance emitted by the skin. He wore repeatedly, night and day, for a month, the same vest of fleecy hosiery during the hottest part of the summer. At the end of this time he always found an oily substance accumulated in considerable masses on the nap of the inner surface of the vest, in the form of black tears. When rubbed on paper, it makes it transparent, and hardens on it like grease. It burns with a white flame, and leaves behind it a charry residuum.†

4. An acid, and   4. Berthollet has observed the perspiration acid;‡ and he has concluded that the acid which is present is the phosphoric: but that has not been proved. Thenard obtained *acetic* acid; but Berzelius has rendered it probable that the true acid of sweat is the *lactic,* and that in Thenard's experiments the acetic was formed at the expense of the lactic. He evaporated a few drops of sweat to dryness in a watch glass. The yellowish residue had all the appearance under the microscope of the usual mixture of the muriates of potash and soda, with lactic acid, lactate of soda and its accompanying animal matter. It reddened litmus and dissolved in alcohol.§

5. Animal matter.   5. The small quantity of animal matter which Thenard found in the perspired matter possessed characters which induced him to consider it as similar to gelatin in its nature.

Fourcroy and Vauquelin have ascertained that the scurf which collects on the skins of horses consists chiefly of phosphate of lime, and urea is even sometimes mixed with it.

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* Cruickshanks on Insensible Perspiration, p. 93.   † Ibid. p. 92.
    ‡ He observed that a blue paper, applied to a part labouring under a gouty paroxysm, became always red. Jour. de Phys. xxviii. 275.
    § Annals of Philosophy, ii. 415.

Such are the constituents of *perspired matter*. Though the sweat has not been directly analysed, there is every reason to believe that it is composed of similar constituents.

SECT. XXVI.

OF URINE.

No animal substance has attracted more attention than urine, both on account of its supposed connection with various diseases, and on account of the very singular products which have been obtained from it. Mr. Boyle, and the other chemists who were his contemporaries, were induced to attend particularly to this liquid, by the discovery of a method of obtaining phosphorus from it. Boerhaave, Haller, Haupt, Margraff, Pott, Rouelle, Proust, and Klaproth, successively improved the method of obtaining the phosphoric salts from urine, or added something to our knowledge of the component parts of these salts. Scheele added greatly to our knowledge of urine by detecting several new substances in it which had not been suspected. Cruickshanks has given us a very valuable paper on urine in the second edition of *Rollo's Diabetes*. Fourcroy and Vauquelin have published an elaborate analysis of it; and Mr. Proust has published another, no less ingenious, in which he points out the existence of several substances which had been overlooked by other chemical philosophers. But the most elaborate and exact analysis of urine has been made by Professor Berzelius.*

Fresh urine differs considerably in its appearance according to the state of the person and the time at which it is voided. In general, healthy urine is a transparent liquid of a light-amber colour, an aromatic odour resembling that of violets, and a disagreeable bitter taste. Its specific gravity varies, according to Mr. Cruickshanks, from 1·005 to 1·033.† When it cools, the aromatic smell leaves it, and is succeeded by another, well known by the name of *urinous*

Margin note: History.

Margin note: Properties.

* Djur kemien, ii. 278.

† Dr. Henry informs us that he never found it higher than 1·020. Annals of Philosophy, i. 28.

smell. This smell is succeeded in two or three days by another, which has a considerable resemblance to that of sour milk. This smell gradually disappears in its turn, and is succeeded by a fetid alkaline odour.

Contains an acid,

1. Urine reddens paper stained with turnsole and with the juice of radishes, and therefore contains an acid. This acid has been generally considered as the phosphoric; Thenard affirms that it is in reality the acetic.* But Berzelius has shown that it is the lactic.†

Phosphate of lime,

2. If a solution of ammonia be poured into fresh urine, a white powder precipitates, which has the properties of phosphate of lime. The presence of this substance in urine was first discovered by Scheele.‡ The phosphate of lime is obviously kept in solution by the acetic acid. Scheele affirms that it is most abundant in the urine of the sick. Berthollet has observed, that the urine of gouty people is more acid than that of people in perfect health. The average quantity of phosphate of lime in healthy urine is, as Cruickshanks has ascertained, about $\frac{1}{900}$ of the weight of the urine.§

Phosphate of magnesia,

3. If the phosphate of lime precipitated from urine be examined, a little magnesia will be found mixed with it. Fourcroy and Vauquelin have ascertained that this is owing to a little phosphate of magnesia which urine contains, and which is decomposed by the alkali or lime employed to precipitate the phosphate of lime.‖

4. Berzelius informs us that there is a little fluate of lime mixed with the phosphate of lime of urine. He mixed the phosphates of urine with their own weight of sulphuric acid and exposed a piece of glass to the fumes prepared for etching. It was sensibly corroded, and thus showed the evolution of fluoric acid.**

Sulphate of potash and soda.

5. Urine contains likewise a notable proportion of sulphuric acid united both to potash and to soda. This was ascertained by Berzelius. If urine be acidulated with nitric acid to prevent the precipitation of the phosphates, and then mixed with muriate of barytes, a copious precipitate of

* Ann. de Chim. lix. 269.   † Annals of Philosophy, ii. 418.
‡ Scheele, i. 208.   § Phil. Mag. ii. 241.
‖ Ann. de Chim. xxxi. 66. The same discovery had been previously made by Dr. Wollaston. See his examination of calculi, Phil. Trans. 1797.   ** Annals of Philosophy, ii. 416.

sulphate of barytes falls. If the urine after the removal of this precipitate be supersaturated with ammonia, the phosphates fall down, and along with them there is an additional quantity of sulphate of barytes.*

6. Proust informs us that carbonic acid exists in urine, *Carbonic* and that its separation occasions the froth which appears *acid,* during the evaporation of urine.† Fourcroy and Vauquelin, on the other hand, consider this acid as formed during the evaporation by the decomposition of the urea. The observations of Proust confirm those that had been made by Priestley and Percival. Vogel has confirmed the assertion of Proust. He put a quantity of fresh urine under the exhausted receiver of an air pump. Many air bubbles were extricated. This air was made to pass through lime water, which became milky and carbonate of lime was deposited. Thus showing that the air evolved was carbonic acid gas.‡

6. When fresh urine cools, it often lets fall a brick co- *Uric acid,* loured precipitate, which Scheele first ascertained to be crystals of uric acid. All urine contains this acid, even when no sensible precipitate appears when it cools. For, if a sufficient quantity of clear and fresh urine be evaporated to $\frac{1}{178}$ of its weight, a subtle powder precipitates to the bottom, and attaches itself in part very firmly to the vessel. This part may be dissolved in pure alkali, and precipitated again by acetic acid. It exhibits all the properties of uric acid.§ The fact is, that the precipitate which usually falls when urine cools consists chiefly of phosphate of lime and uric acid. It may be dissolved in diluted nitric acid. If the solution be heated and evaporated to dryness, it assumes a fine rose colour if uric acid be present.‖ The proportion of uric acid varies considerably in urine. It crystallizes in small red prisms, partly on the surface, if urine be mixed with some nitric acid, and left exposed to the air. Indeed, from the experiments of Dr. Egan, we learn that all acids when mixed with urine throw down uric acid in crystals.**

8. During intermittent fevers, and especially during dis- *Rosacic acid,*

* Berzelius, Annals of Philosophy, ii. 417.
† Ann. de Chim. xxxvi. 260.   ‡ Ibid. xciii. 71.
§ Scheele, i. 207.   ‖ Cruickshanks,
** Phil. Mag. xxiii. 298.

Book V. cases of the liver, a copious sediment of a brick-red colour is deposited from urine. This sediment contains the rosacic acid of Proust.

Benzoic acid,

9. If fresh urine be evaporated to the consistence of a syrup, and muriatic acid be then poured into it, a precipitate appears which possesses the properties of benzoic acid. Scheele first discovered the presence of benzoic acid in urine. He evaporated it to dryness, separated the saline part, and applied heat to the residuum. The benzoic acid was sublimed, and found crystallized in the receiver. The above method was first proposed by Fourcroy and Vauquelin.* By it very considerable quantities of benzoic acid may be obtained from the urine of horses and cows, where it is much more abundant than in human urine. In human urine it varies from $\frac{1}{1000}$ to $\frac{1}{10000}$ of the whole.† Proust affirms that the acid obtained by Scheele's process is not the benzoic, but another possessed of similar properties ; but differing in this circumstance, that nitric acid decomposes it, whereas it only whitens benzoic acid.‡

10. When an infusion of tannin is dropped into urine, a white precipitate appears, having the properties of the combination of tannin and albumen. Urine, therefore,

Albumen and gelatin,

contains albumen or gelatin. These substances had been suspected to be in urine, but their presence was first demonstrated by Seguin, who discovered the above method of detecting them. Their quantity in healthy urine is very small, often indeed not sensible. Cruickshanks found that the precipitate afforded by tannin in healthy urine amounted to $\frac{1}{240}$th part of the weight of urine.§ In many diseases the quantity of these matters is very much increased. The urine of dropsical people often contains so much albumen, that it coagulates not only on the addition of acids, but even on the application of heat.‖ In all cases of impaired digestion, the albuminous part of urine is much increased. This forms one of the most conspicuous and important distinctions between the urine of those who enjoy good and bad health.**

Urea,

11. If urine be evaporated by a slow fire to the con-

* Ann. de Chim. xxxi. 62.   † Ibid. p. 63.
‡ Ibid. xxxvi. 275.   § Phil. Mag. ii. 243.
‖ Cruickshanks, Phil. Mag. ii. 248.
** Fourcroy and Vauquelin, Ann. de Chim. xxxi. 61.

sistence of a thick syrup, it assumes a deep brown colour, and exhales a fetid ammoniacal odour. When allowed to cool, it concretes into a mass of crystals, composed of all the component parts of urine. If four times its weight of alcohol be poured upon this mass, at intervals, and a slight heat be applied, the greatest part of it is dissolved. The alcohol, which has acquired a brown colour, is to be decanted off, and distilled in a retort in a sand heat, till the mixture has boiled for some time, and acquired the consistence of a syrup. By this time the whole of the alcohol has passed off, and the matter, on cooling, crystallizes in quadrangular plates which intersect each other. This substance is *urea*, which composes $\frac{3}{100}$ of the urine, provided the watery part be excluded. To this substance the taste and smell of urine are owing. It is a substance which characterizes urine, and constitutes it what it is, and to which the greater part of the very singular phenomena of urine are to be ascribed.

It may be detected by evaporating urine to the consistence of a syrup, and pouring into it concentrated nitric acid. Immediately a great number of white shining crystals appear in the form of plates, very much resembling crystallized boracic acid. These crystals are urea combined with nitric acid.

The quantity of urea varies exceedingly in different urines. In the urine voided soon after a meal, very little of it is to be found, and scarcely any at all in that which hysterical patients void during a paroxysm.

12. If urine be slowly evaporated to the consistence of a syrup, a number of crystals make their appearance on its surface: these possess the properties of muriate of soda. Urine therefore contains muriate of soda. It is well known that muriate of soda crystallizes in cubes; but when obtained from urine it has the form of octahedrons. This singular modification of its form is owing to the action of urea.* It has been long known that urine saturated with muriate of soda deposits that salt in regular octahedrons. *Muriate of soda,*

13. The saline residuum which remains after the separation of urea from crystallized urine by means of alcohol has been long known by the names of *fusible salt of urine* *Phosphates of ammonia and of soda,*

* Fourcroy and Vauquelin,

Book V. and *microcosmic salt*. Various methods of obtaining it have been given by chemists, from Boerhaave, who first published a process, to Rouelle and Chaulnes, who gave the method just mentioned. If this saline mass be dissolved in a sufficient quantity of hot water, and allowed to crystallize spontaneously in a close vessel, two sets of crystals are gradually deposited. The lowermost set has the figure of flat rhomboidal prisms; the uppermost, on the contrary, has the form of rectangular tables. These two may be easily separated by exposing them for some time to a dry atmosphere. The rectangular tables effloresce and fall to powder, but the rhomboidal prisms remain unaltered.

When these salts are examined, they are found to have the properties of phosphates. The rhomboidal prisms consist of phosphate of ammonia united to a little phosphate of soda; the rectangular tables, on the contrary, are phosphate of soda united to a small quantity of phosphate of ammonia. Urine, then, contains phosphate of soda and phosphate of ammonia.

Muriate of ammonia, 14. When urine is cautiously evaporated, a few cubic crystals are often deposited among the other salts; these crystals have the properties of muriate of ammonia. Now the usual form of the crystals of muriate of ammonia is the octahedron. The change of its form in urine is produced also by urea. This salt is obtained in greater abundance when the crystals of urea obtained from the alcohol solution are distilled.*

Sulphur. 15. When urine is boiled in a silver basin, it blackens the basin; and if the quantity of urine be large, small crusts of sulphuret of silver may be detached. Hence we see that urine contains sulphur. This sulphur exhales along with the carbonic acid when the urine putrifies; for the fumes which separate from urine in that state blacken paper stained with acetate of lead.†

16. The *cloud* which appears when urine cools, and which may always be detected in greater or smaller quantity in urine, is the *mucus* of the bladder. It may be separated by the filter. This mucus facilitates the deposition of crystals of uric acid. Hence when it happens to be detained in

* Fourcroy and Vauquelin.
† Proust, Ann. de Chim. xxxvi. 258.

the bladder it may serve as a nucleus for the formation of calculus.

The constituents of healthy urine according to the analyses of Berzelius are as follows:

Water.	933·00	Constitu- ents.
Urea.......................................	30·10	
Sulphate of potash...........................	3·71	
Sulphate of soda.............................	3·16	
Phosphate of soda	2·94	
Muriate of soda	4·45	
Phosphate of ammonia	1·65	
Muriate of ammonia	1·50	
Free lactic acid ⎫		
Lactate of ammonia ⎪		
Animal matter soluble in alcohol ⎬	17·14	
Urea not separable from the preceding ⎭		
Earthy phosphates with a trace of fluate of lime.	1·00	
Uric acid...................................	1·00	
Mucus of the bladder........................	0·32	
Silica	0·03	

1000·00*

No substance putrifies sooner, or exhales a more detes- table odour, during its spontaneous decomposition, than urine; but there is a very great difference in this respect in different urines. In some, putrifaction takes place almost instantaneously as soon as it is voided; in others, scarcely any change appears for a number of days. Fourcroy and Vauquelin have ascertained that this difference depends on the quantity of gelatin and albumen which urine contains. When there is very little of these substances present, urine remains long unchanged; on the contrary, the greater the quantity of gelatin or albumen, the sooner does putrifaction commence. The putrifaction of urine, therefore, is in some degree the test of the health of the person who has voided it: for a superabundance of albumen in urine always indicates some defect in the power of digestion.†

The rapid putrifaction of urine, then, is owing to the action of albumen on urea. We have seen already the faci-

* Annals of Philosophy, ii. 423.   † Fourcroy, Ann. de Chim. xxxi. 61.

lity with which that singular substance is decomposed, and that the new products into which it is changed are, ammonia, carbonic acid, and acetic acid. Accordingly, the putrifaction of urine is announced by an ammoniacal smell. Mucilaginous flakes are deposited, consisting of part of the gelatinous matter. The lactic acid is saturated with ammonia, and the phosphate of lime, in consequence, is precipitated. Ammonia combines with the phosphate of magnesia, forms with it a triple salt, which crystallizes upon the sides of the vessel in the form of white crystals, composed of six-sided prisms, terminated by six-sided pyramids. The uric and benzoic acids are saturated with ammonia; the acetic acid, and the carbonic acid, which are the products of the decomposition of the urea, are also saturated with ammonia; and notwithstanding the quantity which exhales, the production of this substance is so abundant, that there is a quantity of unsaturated alkali in the liquid. Putrified urine, therefore, contains chiefly the following substances, most of which are the products of putrifaction :

Ammonia.
Carbonate of ammonia.
Phosphate of ammonia.
Phosphate of magnesia and ammonia.
Urate of ammonia.
Acetate of ammonia.
Benzoate of ammonia.
Muriate of soda.
Muriate of ammonia.

Besides the precipitated albumen and phosphate of lime.*

Distillation of urine.   The distillation of urine produces almost the same changes; for the heat of boiling water is sufficient to decompose urea, and to convert it into ammonia, carbonic and acetic acids. Accordingly, when urine is distilled, there come over water, containing ammonia dissolved in it, and carbonate of ammonia in crystals; the acids contained in urine are saturated with ammonia, and the gelatin and phosphate of lime pricipitate.†

Changes in it by disease.   Such are the properties of human urine in a state of health: but this excretion is singularly modified by disease;

* Ann. de Chim. xxxi. 70.   † Ibid. xxxi. 55.

and the changes to which it is liable have attracted the at-
tention of physicians in all ages, because they serve in some
measure to indicate the state of the patient, and the pro-
gress of the disease under which he labours. The following
are the most remarkable of these changes that have been
observed.*

1. In *inflammatory* diseases the urine is of a red colour,
and peculiarly acrid; it deposits no sediment on standing,
but with corrosive sublimate it yields a copious precipitate.

2. During *jaundice* the urine has an orange-yellow colour,
and communicates the same tint to linen. Muriatic acid
renders this urine green, and thus detects the presence of a
little bile.

From the experiments of Fourcroy and Vauquelin, we
learn that urine sometimes in these cases contains a sub-
stance analogous to the *yellow* matter which they formed
by the action of nitric acid on muscular fibres.†

3. About the end of *inflammatory* diseases the urine be-
comes abundant, and deposits a copious pink-coloured sedi-
ment, composed of rosacic acid, a little phosphate of lime,
and uric acid.

4. During *hysterical* paroxisms the urine usually flows
abundantly. It is limpid and colourless, containing much
salt, but scarcely any urea or gelatin.

5. Mr. Berthollet observed, that the urine of *gouty* per-
sons contains usually much less phosphoric acid than healthy
urine. But during a gouty paroxism it contains much
more phosphoric acid than usual; though not more than
constantly exists in healthy urine.‡

6. In general *dropsy*, the urine is loaded with albumen,
and becomes milky, or even coagulates when heated, or at
least when acids are mixed with it. In dropsy from dis-
eased liver, no albumen is present; the urine is scanty,
high coloured, and deposits the pink-coloured sediment.

In certain cases, females have been observed to pass urine
which had the appearance of milk, and which upon ex-
amination, proved to differ from common urine in con-
taining a notable proportion of the curdy part of milk.§

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* See Cruickshanks, Phil. Mag. ii. 240; and Fourcroy, x. 166.
† Phil. Mag. xxiii. 331. ‡ Jour. de Phys. xxviii. 275.
§ See the analysis of a specimen of this urine by Caballe, Ann. de
Chim. lv. 64.

7. In *dyspepsia* the urine always yields a copious precipitate with tan, and putrifies rapidly.

8. The urine of *rickety* patients is said to be loaded with phosphate of lime, or, according to others, with oxalate of lime.

9. Mr. Rose has ascertained that in chronic hepatitis the urine is destitute of urea.* This curious fact has been confirmed by the experiments of Dr. Henry.†

10. In *diabetes* the urine is sweet-tasted, and often loaded with saccharine matter. In one case, the urine emitted daily by a diabetic patient, according to the experiments of Cruickshanks, contained 29 ounces of sugar.‡

The urine of other animals differs considerably from that of man. For the analysis of the urine of quadrupeds hitherto made we are chiefly indebted to Rouelle junior. The following facts have been ascertained by that chemist, and by the experiments of Fourcroy, Vauquelin, Brande, and Chevreul.

I. The urine of the horse has a peculiar odour: after exercise it is emitted thick and milky; at other times it is transparent, but becomes muddy soon after its emission. When exposed to the air, its surface becomes covered with a crust of carbonate of lime. It gives a green colour to syrup of violets, and has the consistence of mucilage. The following are its constituents, as estimated by Fourcroy and Vauquelin from their experiments:

Carbonate of lime .... 0·011
Carbonate of soda .... 0·009
Benzoate of soda .... 0·024
Muriate of potash .... 0·009
Urea .... 0·007
Water and mucilage ...... 0·940

1·000 §

The urine of the horse has been analysed by Mr. Brande. The salts which it contains are, according to him, the following:

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* Annals of Philosophy, v. 42.   † Ibid. vi. 392.
‡ The reader may consult a set of comparative experiments on healthy and diabetic urine by Nicolas, Ann. de Chim. xliv. 32; the analysis of diabetic urine by Sorg (Gehlen's Jour. vi. 9,) and by Dupuytren and Thenard (Ann. de Chim. lix. 41.)   § Mem. de l'Instit. ii. 431.

Carbonate of lime.   Muriate of soda.

Carbonate of soda.   Benzoate of soda.

Sulphate of soda.   Phosphate of lime.

These saline substances amount to about $\frac{1}{8}$th of the urine.* The urine of the horse has been recently subjected to a new examination by Chevreul expressly to ascertain whether it contained phosphate of lime announced in it by Brande. His experiments confirmed those of Fourcroy and Vauquelin. The urine yielded no traces of phosphate of lime; but it contained magnesia and sulphate of potash, neither of which substances had been observed by Mr. Brande.†

From the late experiments of Mr. Giese, we learn that the quantity of benzoate of soda varies considerably in the urine of horses. In some specimens he found it in abundance, and easily precipitated by muriatic acid. In others there was little or none. He could detect no benzoic acid in the food of horses. Hence he considers it as formed within the animal, and he thinks that it appears only in cases of disease. ‡

II. The urine of the ass was likewise examined by Mr. Brande. It is transparent, but mucilaginous. It gives a green colour to syrup of violets, but no carbonate of lime is deposited from it on standing. It contains, according to Brande, urea, more phosphate of lime than the urine of the horse, carbonate of soda, sulphate of soda, muriate of soda, and probably muriate of potash. It contains no ammonia.§ *The ass.*

III. The urine of the cow has a strong resemblance to that of the horse; it has nearly the same odour and the same mucilaginous consistence. It tinges syrup of violets green, and deposits a gelatinous matter. On standing, small crystals are formed on its surface. It contains, according to Rouelle, *The cow.*

1. Carbonate of potash.   4. Benzoic acid.

2. Sulphate of potash.   5. Urea.

3. Muriate of potash.

* Ann. de Chim. lxvii. 276.   † Ibid. 303.

‡ Phil. Mag. xvii. 151.   § Ann. de Chim. lxvii. 277.

The urine of the cow has been more recently examined by Mr. Brande. He found it composed of the following constituents:

Water....................	65
Phosphate of lime...........	3
Muriate of potash ⎱ .... Muriate of ammonia ⎰	15
Sulphate of potash..........	6
Carbonate of potash ⎱ ...... Carb. of ammonia ⎰	4
Urea......................	4
Loss......................	3
	———
	100

He obtained from it likewise a quantity of benzoic acid, but conceives that this acid was formed during the process.*

IV. The urine of the camel was also examined by Rouelle. Its odour resembles that of the urine of the cow; its colour is that of beer; it is not mucilaginous, and does not deposit carbonate of lime. It gives a green colour to syrup of violets, and effervesces with acids like the urine of the horse and cow. Rouelle obtained from it,

1. Carbonate of potash.   3. Muriate of potash.
2. Sulphate of potash.   4. Urea.

This urine has been more recently examined by Mr. Brande.† He obtained from it the following substances:

Water........................	75
Phosphate of lime ⎤ Muriate of ammonia ⎥ Sulphate of potash ⎬ .... Urate of potash ⎥ Carbonate of potash ⎦	6
Muriate of potash...............	8
Urea.........................	6
Loss........................	5
	———
	100

Chevreul subjected the urine of the camel to a rigid ex-

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* Ann. de Chim. lxvii. 268.   † Ibid. 266.

amination, on purpose to ascertain whether it really con-
tained the phosphate of lime announced as a constituent of
it by Mr. Brande. He could detect none of it whatever,
but separated from the urine of the camel the following
substances :

Albumen.	A little sulphate of soda.
Carbonate of lime.	Much sulphate of potash.
Carbonate of magnesia.	A little carbonate of potash.
Silica.	Benzoic acid.
An atom of sulphate of lime.	Urea.
A trace of iron	A red oil, to which the urine
Carbonate of ammonia.	owes its smell and colour.
A little muriate of potash.	

The last substance, the oil, seems to have been taken by
Brande for uric acid.*

V. The urine of the rabbit has been analysed by Vau-
quelin. When exposed to the air, it becomes milky, and
deposits carbonate of lime. It gives a green colour to
syrup of violets, and effervesces with acids. That chemist
detected in it the following substances :

1. Carbonate of lime.	6. Muriate of potash.
2. Carbonate of magnesia.	7. Urea.
3. Carbonate of potash.	8. Gelatin.
4. Sulphate of potash.	9. Sulphur.
5. Sulphate of lime.	

VI. Vanquelin has also made some experiments on the
urine of the guinea pig; from which it appears that it re-
sembles the urine of the other quadrupeds. It deposits
carbonate of lime, gives a green colour to syrup of violets,
and contains carbonate and muriate of potash, but no phos-
phate nor uric acid.†

VII. The urine of the lion and tiger is alkaline at the
moment of its emission. It contains a quantity of am-
monia. It is destitute of uric acid and of phosphate of
lime. Its constituents as determined by Vauquelin are the
following :‡

* Ann. de Chim. lxvii. 294.   † Fourcroy, x. 181.
‡ Ann. de Chim. lxxxii. 198.

1. Urea.	5. Muriate of ammonia.
2. Animal mucus.	6. Trace of phosphate of lime.
3. Phosphate of soda.	7. Much sulphate of potash.
4. Phosphate of ammonia.	8. A trace of muriate of soda.

The castor.   VIII. The urine of the castor has a striking resemblance to that of herbivorous animals in general. Vauquelin obtained from it the following substances : *

1. Urea.	5. Acetate of magnesia?
2. Animal mucus.	6. Sulphate of potash.
3. Benzoate of potash.	7. Muriates of potash and soda.
4. Carbonates of lime and magnesia.	8. Vegetable colouring matter.
	9. Trace of iron.

Fowls.   IX. From the experiments of Fourcroy and Vauquelin, we learn that the urine of domestic fowls contains uric acid.†

The existence of that acid in the urine of fowls was called in question by Gehlen; but it has been fully confirmed by the experiments of Chevreul.‡

Urinary excretions of insects.   X. Some experiments on the urinary excretions of certain insects have been made by M. Scholz. He obtained from it the following constituents :

Uric acid.	94
Ammonia.	2
Phosphate of lime.	3·33
	———
	99·33 §

SECT. XXVII.

OF FECES.

THE excrementitious matter of animals, evacuated *per anum*, consists of all that part of the food which cannot be employed for the purposes of nutrition, considerably altered, at least in part, and mixed or united with various bodies employed during digestion to separate the useless parts of the food from the nutritious. An accurate exami-

* Ann. de Chim. lxxxii. 201.   † Jour. de Phys. lix. 66.
‡ Ann. de Chim. lxvii. 305.   § Gilbert's Annalen, xliii. 83.

nation of these matters has long been wished for by physiologists, as likely to throw much new light on the process of digestion. For if we knew accurately the substances which were taken into the body as food, and all the new substances which were formed by digestion; that is to say, the component parts of chyle and of excrement, and the variation which different kinds of food produce in the excrement, it would be a very considerable step towards ascertaining precisely the changes produced on food by digestion.

Some of the older chemists had turned their attention to the excrements of animals;[*] but no discovery of importance rewarded them for their disagreeable labour. Vauquelin has ascertained some curious facts respecting the excrementitious matter of fowls. In the summer of 1806, a laborious set of experiments on human feces was published by Berzelius, undertaken, as he informs us, chiefly with a view to elucidate the function of digestion.[†] About two years before, Thaer and Einhof had published a similar set of experiments on the excrements of cattle; made chiefly to discover, if possible, how they act so powerfully as manure.[‡] I shall in this Section give a view of the results obtained by these different chemists.

I. The appearance of human feces requires no particular detail. Their colour is supposed to depend upon the bile mixed with the food in the alimentary canal. When too light, it is supposed to denote a deficiency of bile; when too dark, there is supposed to be a redundancy of that secretion. The smell is fetid and peculiar, which after some time gradually changes into a sourish odour. The taste is sweetish bitter. The colour of vegetable blue infusions is not altered by fresh feces, indicating the absence of any uncombined acid or alkali.[§]

1. The consistency of human feces varies considerably in different circumstances; but at a medium, they may be stated to lose three-fourths of their weight when dried upon a water bath.[||]

2. They do not mix readily with water; but by sufficient

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* Van Helmont's Custos Errans. Sect. vi. Opera Helmont, p. 147. Neumann's Works, p. 585. † Gehlen's Jour. vi. 509.

‡ Gehlen's Jour. iii. 276. § Ibid. vi. 512. || Ibid. vi. 535.

agitation and maceration, they may be diffused through it. The liquid, in this state, being strained through a linen cloth, leaves a matter of a greyish-brown colour, retaining a peculiar odour, which adheres long and obstinately to all those substances that come in contact with this residue. When dried, this substance exhibits the remains of vegetable matters used in food, and perhaps also of some animal matters. Its quantity amounts to about seven per cent. of the feces.*

3. The strained liquid deposited, on standing, a yellowish-green slimy matter, which was separated by the filter. It amounted when dry to 14 per cent. of the feces employed. From the numerous experiments of Berzelius upon this matter, it appears to be composed chiefly of three substances: 1. A fatty matter, separated by means of alcohol, which possesses many properties in common with picromel, and which Berzelius considers as that substance a little altered. 2. A peculiar yellow-coloured substance, dissolved by water after the fatty matter is removed. This substance Berzelius compares to gelatin; but it appears to be rather more closely allied to mucus, or, at least, to contain mucus as a constituent. It dissolves in water, but not in alcohol; tannin makes its solution muddy, but occasions no precipitate; acetate of lead occasions a copious white precipitate, but does not deprive the solution of its yellow colour. It soon runs to putrifaction, exhaling the odour of putrid urine. 3. A greenish-grey residue, insoluble both in water and alcohol, and leaving, when incinerated, some silica and phosphate of potash.†

4. The liquid which passed through the filter was at first light-yellow; but by exposure to the air it became brown, which gradually deepened in colour, till the solution grew at last muddy. When concentrated by evaporation, small transparent crystals made their appearance: which proved, on examination, to be crystals of ammonio-phosphate of magnesia. The solution, on examination, was found to contain the following substances: 1. Albumen, which was obtained by mixing the concentrated solution with alcohol. The precipitate consisted of a mixture of albumen and phosphoric salts. The albumen obtained from 100 parts

* Gehlen's Jour. vi. 513.   † Ibid. 526—534.

of feces amounted only to 0·9 parts.   2. Bile.   By this
Berzelius understood a mixture of picromel and soda.
The presence of this substance was inferred from the nature
of the precipitate obtained by acids, and the salt of soda
obtained by evaporating the residue.   The quantity con-
tained in 100 parts of feces was 0·9.   3. A peculiar substance,
of a reddish-brown colour, soluble both in water and al-
cohol.   Acids give it an intense brown colour.   A small
quantity of tannin throws it down of a red colour and in a
pulverulent form ; a large quantity throws it down in grey-
ish-brown flakes.   It is precipitated by muriate of tin,
nitrate of silver, and acetate of lead.   When heated it melts
and emits the smell of ammonia.   It leaves behind it when
burnt, traces of soda and of phosphoric salts.   Berzelius
supposes that this substance is formed from the picromel,
by some change which it undergoes after the feces are ex-
posed to the air.   The quantity of it obtained from 100
part of feces was 2·7 parts.   4. Various salts: these in all,
from 100 parts of feces (including the ammonio-phosphate
of magnesia), amounted to 1·2 parts.   Their relative pro-
portions were as follows :

Carbonate of soda 35
Muriate of soda 4
Sulphate of soda 2
Amm.-phosphate of magnesia .. 2
Phosphate of lime 4

Such are the constituents of human feces, according to
the experiments of Berzelius.   The following table exhibits
the result of his analysis.*

Water .... 73·3
Vegetable and animal remains .... 7·0
Bile .... 0·9
Albumen .... 0·9
Peculiar and extractive matter .... 2·7
Salts .... 1·2
Slimy matter ; consisting of picromel, pe-⎫
   culiar animal matter, and insoluble re- ⎬ 14·0
   sidue ....⎭

_____

100·0

* Gehlen's Jour. vi. 536.

II. The excrementitious matter examined by Thaer and Einhof was that of cattle fed at the stall, chiefly on turnips. It had a yellowish-green colour, a smell somewhat similar to that of musk, and but little taste. Its specific gravity was 1·045. It did not alter vegetable blues, and of course contained no uncombined acid or alkali.

1. Sulphuric acid, when mixed with this matter, developes the odour of acetic acid; but Thaer and Einhof have shown that this acid does not exist in the feces, but is formed by the action of the sulphuric acid. The pure alkalies, nitric and muriatic acids, produce little change on the feces of cattle, at least when not assisted by heat.

2. When 100 parts are dried on a steam bath, they leave $28\frac{1}{8}$ of solid matter.

3. When eight ounces, or 3840 grains, were diffused through water, they let fall a quantity of sand, weighing 45 grains.

4. The watery solution, being strained through a linen cloth, left 600 grains of a yellowish fibrous matter, which possessed the properties of the fibrous matter of plants.*

5. The liquid, on standing, deposited a slimy substance, which was separated by filtration. It weighed when dry 480 grains. To this matter the feces owe their peculiar colour and smell. It was insoluble in water and alcohol. When heated it smelled like ox bile. It burnt like vegetable matter. Alkalies scarcely affected it. Sulphuric acid developed the odour of acetic acid. Chlorine rendered it yellow. Thaer and Einhof considered this substance as the remains of the vegetable matter employed as food by the cattle; but it is extremely probable that it might contain also a portion of picromel, as Berzelius detected that substance in similar matter from the human feces.

6. The filtered solution passed through colourless, but on exposure to the air became in a few minutes wine-yellow and then brown. When evaporated to dryness it left a brownish matter, of a bitterish taste, and weighing 90 grains. It was soluble in water, insoluble in alcohol, and precipitated from water by that liquid. It was not precipitated by infusion of galls. The solution was found to

* Gehlen, iii. 286.

contain some phosphoric salts. The 90 grains of residue,
when heated, burnt like animal matter. They soon ran
into putrifaction, exhaling ammonia. *

7. When evaporated to dryness and burnt, this excrementitious matter left behind it an ash, which was found (not reckoning the sand) to consist of the following salts and earths in the proportion stated : †

Lime	12
Phosphate of lime	12·5
Magnesia	2
Iron	5
Alumina with some manganese	14
Silica	52
Muriate and sulphate of potash	1·2

8. Thaer and Einhof made numerous experiments on the putrifaction of cow dung, both in close vessels and in the open air, from which it would appear that the process resembles closely the putrifaction of vegetable matter; the oxygen of the air being abundantly changed into carbonic acid. ‡

III. To Vauquelin we are indebted for an analysis of the Excrements of fowls. fixed parts of the excrements of fowls, and a comparison of them with the fixed parts of the food ; from which some very curious consequences may be deduced.

He found that a hen devoured in ten days 11111·843 grains troy of oats. These contained

Phosphate of lime	126·509 grains
Silica	219·548
	356·057

During these ten days she laid four eggs; the shells of which contained 98·779 grains phosphate of lime, and 453·417 grains carbonate of lime. The excrements emitted during these ten days contained 175·529 grains phosphate of lime, 53·494 grains of carbonate of lime, and 185·266 grains of silica. Consequently the fixed parts thrown out of the system during these ten days amounted to

* Gehlen, iii. 287.　　† Ibid. 321.　　‡ Ibid. 295, 313.

Phosphate of lime .... 274·305 grains.
Carbonate of lime .... 511·911
Silica .... 185·266

Given out ...... 971·482
Taken in ...... 356·057

Surplus .... 615·425

Consequently the quantity of fixed matter given out of the system in ten days exceeded the quantity taken in by 615·425 grains.

The silica taken in amounted to .... 219·548 grains.
That given out was only .... 185·266

Remain   34·282

Fowls seem to form lime and phosphorus.

Consequently there disappeared 34·282 grains of silica.

The phosphate of lime taken in was .. 136·509 grains.
That given out was .... 274·305

137·796

Consequently there must have been formed, by digestion in this fowl, no less than 137·796 grains of phosphate of lime, besides 511·911 grains of carbonate. Consequently lime (and perhaps also phosphorus) is not a simple substance, but a compound, and formed of ingredients which exist in oat-seed, water, or air, the only substances to which the fowl had access. Silica may enter into its composition, as part of the silica had disappeared; but if so, it must be combined with a great quantity of some other substance.*

These consequences are too important to be admitted without a very rigorous examination. The experiment must be repeated frequently, and we must be absolutely certain that the hen has no access to any calcareous earth, and that she has not diminished in weight; because in that case some of the calcareous earth, of which part of her body is composed, may have been employed. This rigour is the more necessary, as it seems pretty evident, from experiments made long ago, that *some* birds at least cannot produce eggs unless they have access to calcareous earth.

* Ann. de Chim. xxix. 61.

Dr. Fordyce found, that if the canary bird was not supplied with lime at the time of her laying, she frequently died, from her eggs not coming forward properly.* He divided a number of these birds at the time of their laying eggs into two parties : to the one he gave a piece of old mortar, which the little animals swallowed greedily ; they laid their eggs as usual, and all of them lived ; whereas many of the other party, which were supplied with no lime, died. †

Vauquelin also ascertained, according to Fourcroy, that pigeons' dung contains an acid of a peculiar nature, which increases when the matter is diluted with water; but gradually gives place to ammonia, which is at last exhaled in abundance. ‡

IV. The white matter voided by dogs who feed chiefly on bones, was formerly used in medicine under the name of *album græcum.* It has not been examined by modern chemists; but is supposed to consist in a great measure of the earthy part of the bones used as food.§

SECT. XXVIII.

OF MORBID CONCRETIONS.

HARD substances occasionally make their appearance in different parts of the animal body, both in the solids and in the the cavities destined to contain the fluids. In the first case, they are usually denominated *concretions* or *ossifications;* in the second, *calculi.* The knowledge of these bodies is of importance both to the physiologist and physician. The formation is an irregularity in the animal economy, and is likely therefore to throw light upon its functions; for we succeed best in detecting the secrets of Nature when she deviates from that regularity which she usually follows. They often produce the most excruciating diseases; and the sufferings of the patient can only be effectually relieved by removing their cause. The different animal concretions at present known may be divided into five classes :

* On Digestion, p. 25.   † Ibid. p. 26.
‡ Fourcroy, x. 70.   § Neumann's Chemistry, p. 585.

1. Ossifications.   4. Urinary calculi.
2. Intestinal concretions.   5. Gouty calculi.
3. Biliary calculi.

We shall take a view of each of these classes in order.

I. OSSIFICATIONS.

All the concretions which make their appearance in the solids of the animal body may be comprehended under this title with propriety; because they have all a close resemblance to bone, being composed of similar constituents. The following are the most remarkable of these concretions.

1. Pineal
concretions.

1. *Pineal concretions.*—It is well known to anatomists that small concretions like sand are often found lodged in that part of the brain called the *pineal gland.* It was suspected from analogy that they consisted chiefly of phosphate of lime; but Dr. Wollaston was the first who examined them chemically, and proved the truth of this opinion. He dissolved some of the sand in nitric acid, and evaporated the solution; small crystalline needles made their appearance, indicating the presence of phosphate of lime.*

2. Salivary
concretions.

2. *Salivary concretions.*—Small concretions occasionally make their appearance in the salivary glands, especially the parotid and sublingual. From the experiments of Wollaston and of Fourcroy, we learn that the basis of these concretions is phosphate of lime, united to a membranous substance, which retains the shape of the concretion after the solution of the phosphate. This at least was the case in a small salivary calculus which I examined.† In a salivary concretion weighing $1\frac{1}{2}$ grain, examined by Dr. Bostock, the whole consisted of phosphate of lime, excepting a few films of matter which was considered as coagulated albumen.‡

3. Pancreatic concretions.

3. *Pancreatic concretions.*—The hard substances sometimes found in the pancreas are said to be of the same nature

* See Dr. Wollaston's important paper on Urinary and Gouty Concretions, Phil. Trans. 1797, p. 386. I shall have occasion to refer to it very frequently in the subsequent part of this Section.

† Wollaston, Phil. Trans. 1797, p. 386. Fourcroy, ix. 367.

‡ Nicholson's Jour. xiii. 374.

with those of the salivary glands. The assertion, I presume,
is merely from analogy.

4. *Pulmonary concretions.*—Many people subject to cough,
or threatened with consumption, occasionally cough up
small rounded white concretions. It is very common to
find the lungs of such persons filled with similar bodies.
I examined some of these bodies coughed up by a consump-
tive patient, and found them composed of phosphate of
lime united to a thick membranous substance, which re-
tained the form of the concretion. The same result had
been obtained long before by Fourcroy.* It is probable
that pulmonary concretions very frequently contain both
phosphate and carbonate of lime. This, Dr. Henry in-
forms me, was the case with several of these bodies exa-
mined by him. In some cases they appear to contain no
phosphate. Thus a pulmonary calculus examined by Mr.
Crumpton † was composed of

Carbonate of lime 82
Animal matter and water 18
_____
100

5. *Hepatic concretions.*—The liver also is sometimes full
of similar bodies. The shape of the hepatic concretions, as
far as my observations go, is more irregular, and I have
seen them of greater size than the pulmonary concretions.
By my analysis, they are composed of phosphate of lime
and a tough animal membranous matter.

6. *Concretions in the prostate.*—From the experiments of
Dr. Wollaston, we learn that the concretions which some-
times form in the prostate gland have likewise phosphate of
lime for their basis.

7. The extremities of the muscles and the larger blood
vessels sometimes harden, and assume the appearance of
bone. It is believed that this change is a real ossification,
or that these bodies are converted into real bone. I do not
know whether any such ossifications have been analysed.

II. INTESTINAL CONCRETIONS.

Concretions of very considerable size are sometimes found
lodged in the stomach and intestines; seldom indeed in the

* Ann. de Chim xvi. 91. † Phil. Mag. xiii. 287.

human body, but more frequently in some of the inferior animals. Some of these bodies have acquired great celebrity under the name of *bezoars;* but their medical virtue, at least in this country, has long ago sunk to its just level. It is to Fourcroy and Vauquelin that we are indebted for almost all the knowledge of these concretions which we possess. They have distinguished no fewer than seven species of them, all composed of different ingredients. These species, distinguished by the constituents of each, are as follows.*

1. Superphosphate of lime.
2. Phosphate of magnesia.
3. Ammonio-phosphate of magnesia.

4. Biliary.
5. Resinous.
6. Fungous.
7. Hairy.

1. *Superphosphate of lime.*—The intestinal concretions belonging to this species are composed of concentric layers, easily separable from each other and very brittle. They redden vegetable blues, and are partially soluble in water. The layers are unequally thick, and differ in their colour.† They were found in the intestines of different mammalia.

2. *Phosphate of magnesia.*—These concretions are uncommon. They are semitransparent, and have usually a yellowish colour. Their specific gravity is 2·160. They are formed of layers less numerous and not so easily separated as those of the preceding species.‡

3. *Phosphate of ammonia-and-magnesia.*—This species is the most common of the intestinal concretions. Its colour is grey or brown, and it is composed of crystals diverging like rays from a centre. It has some resemblance to calcareous spar. It contains abundance of animal matter. This species occurs frequently in the intestines of herbivorous animals, as the horse, the elephant, &c.

4. *Biliary.*—This is a species of concretion found frequently in the intestines of oxen, and likewise in their gallbladder, and employed by painters as an orange-yellow pigment. Its colour is reddish-brown. It is not composed of layers, but is merely a coagulated mass, and appears to be but little different from the matter of bile.

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* Ann. de Mus. d'Hist. Nat. iv. 331.   † Ibid. i. 102, and iv. 331.
‡ Ibid. iv. 332.

When heated it melts. It dissolves readily in alkalies. Alcohol dissolves it partially, and acquires a very bitter taste.*

5. *Resinous.*—To this species belong many of the oriental bezoars, formerly so celebrated, obtained from the intestines of animals with which we are unacquainted. They are fusible and combustible, composed of concentric layers, smooth, soft, and finely polished. Fourcroy and Vauquelin have distinguished two varieties: the first of a pale-green colour, a slightly bitter taste, almost completely volatile; giving by heat a solid tenacious matter, soluble in alcohol, and separating in crystals as the solution cools. This matter consists partly of bile, partly of resin. The second variety has a brown or violet colour; its taste is not bitter; it does not dissolve in alcohol, but is soluble in alkalies. The solution becomes purple-red when allowed to dry in the open air. When distilled it yields a yellow sublimate, having the smell and taste of soot, and insoluble in water and alcohol.†

6. *Fungous.* This species consists of concretions composed of pieces of the *boletus igniarius*, disposed in layers, and cemented by an animal matter. These pieces had been doubtless swallowed by the animals in whose intestines they were found.‡

7. *Hairy.*—Balls of hair felted together, sometimes pure, sometimes covered with animal matter, and sometimes mixed with vegetable remains, occur very frequently in the intestines of animals.§

8. *Ligniform.*—This eighth species must be added in consequence of the experiments of Berthollet. Among the presents sent to Bonaparte by the king of Persia were three bezoars, which were consigned to Berthollet for analysis. They all belonged to this species. They had an oval shape, and a very smooth surface. Their colour externally was greenish-black, internally brown. They were formed of irregular concentric layers. In the centre of one was found a collection of straws and other vegetable fragments; in that of the others, small pieces of wood about the size of a pin. Their specific gravity was 1·463. They were

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* Ann. de Mus. d'Hist. Nat. iv. 333. † Ibid. 334. ‡ Ibid. 335.
§ Ibid. 336.

Book V. insoluble in water, alcohol, and diluted muriatic acid. Po-
tash ley dissolved them readily, and they were thrown down
unaltered by muriatic acid. When distilled they yielded
the products of wood, and left a quantity of charcoal in the
retort, which, when incinerated, gave traces of sulphate of
soda, muriate of soda, lime, and silica. Thus it appears
that they possessed all the properties of pure woody fibre.
They must have been formed in the stomach of the animals.
and not in the alimentary canal.*

III. BILIARY CALCULI.

History.   Hard bodies sometimes form in the gall-bladder, or in
the duct through which the bile passes into the intestinal
canal, and stop up the passage altogether. These concre-
tions have got the name of *biliary calculi* or *gall-stones*.
They naturally drew the attention of physicians, because it
was soon ascertained that they occasioned the disease called
jaundice. Accordingly they were examined and described
by different chemists; and the facts ascertained before 1764
were collected by Haller in the sixth volume of his Physio-
logy. Since that period, a treatise has been published on
them by Vicq d'Azyr ; and several new facts have been dis-
covered by Poulletier de la Sale, Fourcroy, Gren, and
Saunders. Thenard has lately subjected them to examina-
tion.†

Divisible   Such of the biliary calculi as have been hitherto examined
into four   with attention may be arranged under four classes.
classes.   1. The first kind comprehends those which have a white
colour, and a crystallized, shining, lamellated structure.
They consist of adipocire.
2. The second species are polygonal, of a light greyish-
brown colour. Externally they have a covering composed
of thin concentric layers, within a matter either crystallized
or having the appearance of coagulated honey. They are
composed chiefly of adipocire ; but contain a small portion
of brown matter, considered as matter of bile a little altered.
3. The third kind are of a brown colour, and are supposed
to be composed of altered matter of bile.
4. The fourth comprehends those gall-stones which do
not flame, but gradually waste away at a red heat.

* Mem. d'Arcueil, ii. 448.   † Ibid. i. 59.

Let us take a view of each of these classes of biliary calculi.

1. The first species of biliary calculi was pointed out for the first time by Haller in a dissertation published in 1749. Walther afterwards added several new facts; and at last it was accurately described by Vicq d'Azyr. It is almost always of an oval shape, sometimes as large as a pigeon's egg, but commonly about the size of a sparrow's; and for the most part only one calculus (when of this species) is found in the gall-bladder at a time. It has a white colour; and when broken, presents crystalline plates or striæ, brilliant and white like mica, and having a soft greasy feel. Sometimes its colour is yellow or greenish; and it has constantly a nucleus of inspissated bile.* Its specific gravity is inferior to that of water: Gren found the specific gravity of one 0·803.†

When exposed to the temperature of about 278°, ‡ this crystallized calculus softens and melts, and crystallizes again when the temperature is lowered.§ It is altogether insoluble in water; but hot alcohol dissolves it with facility. Alcohol, of the temperature of 167° dissolves $\frac{1}{20}$ of its weight of this substance; but alcohol, at the temperature of 60° scarcely dissolves any of it.|| As the alcohol cools, the matter is deposited in brilliant plates resembling talc or boracic acid.** It is soluble in oil of turpentine.†† When melted it has the appearance of oil, and exhales the odour of melted wax: when suddenly heated it evaporates altogether in a thick smoke. It is soluble in pure alkalies, and the solution has all the properties of a soap. Nitric acid also dissolves it; but it is precipitated altered by water.‡‡ Indeed the greatest part separates as the liquid cools, and swims on the surface like drops of oil, and seems by the action of the acid to be brought nearly to the state of a resin.§§ Fourcroy, who first examined this peculiar matter of biliary calculi, has given it the name of *adipocire*, from its resemblance both to fat and to wax. Chevreul could

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* Fourcroy, Ann. de Chim. iii. 245.   † Ann. de Chim. v. 186.
  ‡ Chevreul, Ann. de Chim. xcv. 7.   § Ann. de Chim. ii. 123.
  || Ann. de Chim. ii. 180.   ** Ibid. iii. 256.
  †† Gren, ibid. v. 187.
  ‡‡ Fourcroy, ibid. iii. 247.
  §§ Bostock, Nicholson's Jour. iv. 138.

not succeed in converting it into soap, by boiling it with potash ley.

2d Species nearly simi-lar.   2. The second kind of biliary calculi is of a polygonal shape, and a number of them almost always exist in the gall-bladder together. To this, probably, they owe their peculiar form. Most commonly they have three blunt angles, and have some resemblance to two low tetrahedrons, applied base to base, with their edges and angles rounded off. They vary considerably in their specific gravity. A specimen seemingly belonging to this species, examined by Dr. Bostock, was of the specific gravity 0·900.* The mean specific gravity of six which I analysed was 1·061, and they all sunk in water. Their outer surface is smooth, and has a soft feel. When broken they exhibit a thin outer crust, composed of concentric layers, alternately crystallized in small rays inclining towards the centre. The nucleus, in all the specimens which I have examined, had the appearance of granulated honey.

These calculi, in their composition, differ but little from the last species, since they consist almost entirely of adipocire. In six gall-stones which I analysed, this matter amounted to at least $\frac{19}{20}$ths of the whole. The residue was a reddish-brown substance, insoluble in alcohol. Nitric acid dissolved it readily, and formed a pink-coloured liquid, from which ammonia threw down no precipitate. Pure potash ley dissolved most of it readily when assisted by heat. From the solution, muriatic acid threw down a dark-green matter, which had a bitter taste, dissolved in alcohol, melted when heated, and exhibited most of the properties of picromel. The residue, insoluble in potash, was in grey flakes, and resembled albumen in such of its properties as could be traced. But as it never exceeded $\frac{1}{8}$th of a grain, it was not possible to ascertain its nature with precision.

3d, of altered yellow matter.   3. I have never had an opportunity of seeing any gall-stones from the human species belonging to the third kind, or composed entirely of altered yellow matter. But in the gall-stones examined by Thenard several were of this kind.

4. Concerning the fourth species of gall-stone very little is known with accuracy. Dr. Saunders tells us that he has

* Bostock, Nicholson's Jour. iv. 136.

met with some gall-stones insoluble both in alcohol and oil of turpentine; some of which do not flame, but become red, and consume to an ash like a charcoal.* Haller quotes several examples of similar calculi.† Probably they do not differ from the third kind.

5. The gall-stones of oxen are always of a yellow colour, and consist of the yellow matter of bile mixed with minute traces of bile which may be separated by water. They are tasteless, when thus washed, and insoluble in water and alcohol. They are used by painters, though their colour is not permanent, but soon changes to a brown.‡

IV. URINARY CALCULI.

It is well known that concretions not unfrequently form in the bladder, or the other urinary organs, and occasion one of the most dismal diseases to which the human species is liable.

These concretions were distinguished by the name of *calculi*, from a supposition that they are of a stony nature. They have long attracted the attention of physicians. Chemistry had no sooner made its way into medicine than it began to exercise its ingenuity upon the urinary calculi; and various theories were given of their nature and origin. According to Paracelsus, who gave them the ridiculous name of *duelech*, urinary calculi were composed of a mucilaginous tartar which floated in the blood vessels. The schoolmen, on the other hand, considered them as a peculiar mucilage concocted and petrified by the heat of the body. These opinions were ably refuted by Van Helmont in his Treatise De Lithiasi, which contains the first attempt towards an analysis of urine and urinary calculi; and, considering the period at which it was written, is certainly possessed of uncommon merit. He demonstrates that the materials of calculi exist in urine: he considers them as composed of a volatile earthy matter and the saline spirit of urine which coagulates instantaneously when they combine together; but which are prevented from combining in healthy people by the presence of what he calls *scoria*,

History.

* On the Liver, p. 112.   † Physiol. vi. 567.
‡ Thenard, Mem. d'Arcueil, i. 59.

which saturates the salt of urine.* Boyle extracted from calculi, by distillation, oil and a great quantity of volatile salts. Boerhaave supposed them compounds of oil and volatile salts. Slare attempted a chemical analysis of them.† Hales extracted from them a prodigious quantity of air. He gave them the name of *animal tartar*, pointed out several circumstances in which they resemble common tartar, and made many experiments to find a solvent of them.‡ Drs. Whytt and Alston pointed out alkalies as solvents of calculi. It was an attempt to discover a more perfect solvent that induced Dr. Black to make those experiments which terminated in the discovery of the nature of the alkaline carbonates.

Such was the state of the chemical analysis of calculus, when in 1776, Scheele published a dissertation on the subject in the Stockholm Transactions; which was succeeded by some remarks of Bergman. These illustrious chemists completely removed the uncertainty which had hitherto hung over the subject, and ascertained the nature of the calculi which they examined.

Since that time considerable additional light has been thrown upon the nature of these concretions by the labours of Austin, Walther, Brugnatelli, Pearson, &c. But the most important additions to our knowledge of calculi were made by Dr. Wollaston. That skilful chemist distinguished them into species, and ascertained the composition of each, pointing out several new constituents which had not been suspected before.§ The dissertation on calculi by Fourcroy and Vauquelin is no less important. Most of their results indeed had been anticipated by Wollaston: but they analysed about 500 calculi with precision; a number sufficient to enable them to make a more exact arrangement of them than could be obtained, till the frequency of the occurrence of every ingredient was known. They detected also some substances in calculi which had not been observed in them before. A valuable dissertation on the subject has been published by Mr. Brande. He examined 150 calculi in the Hunterian museum, and has rectified some mistakes of his predecessors, and added several new facts.‖

* De Lithiasi, p. 21.
† Phil. Trans. xvi. 140.
‡ Veget. Stat. ii. 189.
§ Phil. Trans. 1797.
‖ Phil. Trans. 1808.

Urinary calculi are usually spheroidal or egg-shaped;
sometimes they are polygonous, or resemble a cluster of
mulberries; and in that case they are distinguished by the
epithet *mulberry.* Their size is various; sometimes they
are very small, and sometimes as large as a goose-egg, or
even larger. The colour of some of them is a deep brown
resembling that of wood. In some cases they are white,
and not unlike chalk; in others, of a dark-grey, and hard.
These different colours are often intermixed, and occur of
various degrees of intensity. Their surface in some cases
is polished like marble; in others, rough and unequal;
sometimes they are covered with semitransparent crystals.
Their specific gravity varies from 1·213 to 1·976. *

The substances hitherto discovered in urinary calculi are
the following:

    1. Uric acid.
    2. Phosphate of lime.†
    3. Phosphate of magnesia and ammonia.
    4. Oxalate of lime.
    5. Muriate of ammonia.
    6. Magnesia.
    7. Phosphate of iron.
    8. Silica.
    9. Urea.
    10. Cistic oxide.
    11. Mucus.

1. Uric acid was first discovered in calculi by Scheele.
The greater number of those concretions hitherto analysed
consisted of it. All those analysed by Scheele were com-
posed of it entirely. Of 300 calculi analysed by Dr.
Pearson, scarcely one was found which did not contain a
considerable quantity of it, and the greater number mani-
festly were formed chiefly of it. Fourcroy and Vauquelin
found it also in the greater number of the 500 calculi which
they analysed. Of 150 examined by Brande only 16 were
composed entirely of this acid; but almost the whole of
them contained this acid.

The presence of this acid may be easily ascertained by

* Fourcroy, x. 213.
† Brugnatelli found also phosphate of lime, with excess of acid in
calculi. See Ann. de Chim. xxxii. 183.

the following properties: The calculi formed of it are brown, polished, and resemble wood. A solution of potash or soda dissolves it readily, and it is precipitated by the weakest acids. The precipitate is soluble in nitric acid; the solution is of a pink colour, and tinges the skin red.

2. Phosphate of lime.

2. Phosphate of lime was observed in calculi by Bergman; afterwards it was found in abundance by Pearson, and more lately by Fourcroy and Vauquelin. Dr. Wollaston was the first who observed calculi composed of it entirely. The calculi which he examined were brown, and so smooth externally as to appear polished. They were composed of laminæ easily separable into concentric crusts. In the calculi observed by Fourcroy and Vauquelin, the phosphate of lime was white, without lustre, friable, stained the hands, paper, and cloth. It had very much the appearance of chalk, broke under the forceps, was insipid and insoluble in water. It is soluble in nitric, muriatic, and acetic acids, and is again precipitated by ammonia, fixed alkalies, and oxalic acid. It is intimately mixed with a gelatinous matter, which remains under the form of a membrane when the earthy part is dissolved by very diluted acids.*

3. Phosphate of magnesia and ammonia.

3. The calculi containing phosphate of magnesia and ammonia were first distinguished by Mr. Tennant; but for their first analysis we are indebted to Dr. Wollaston. He first pointed out the presence of the triple phosphate, ascertained its characters, and showed how it might be imitated by art.† Fourcroy and Vauquelin, who detected it soon after, though their experiments were not published before the year 1800, suppose that it owes its existence to a commencement of putrifaction of the urine in the bladder. It occurs in white, semitransparent, lamellar layers; sometimes it is crystallized on the surface of the calculi in prisms, or what are called *dog-tooth* crystals. Its powder is of a brilliant white; it has a weak sweetish taste; it is somewhat soluble in water, and very soluble in acids, though greatly diluted. Fixed alkalies decompose it, leaving magnesia undissolved.

It never forms entire calculi. Sometimes it is mixed with phosphate of lime, and sometimes layers of it cover

* Fourcroy, Ann. de Chim. xxxii. 218.   † Phil. Trans. 1797.

uric acid or oxalate of lime. It is mixed with the same gelatinous matter as phosphate of lime.*

4. Oxalate of lime was first detected in calculi by Dr. Wollaston.† The calculi containing it had been distinguished by the name of *mulberry;* but scarcely any of their characters was known till they attracted his attention. In all the calculi which he examined, the oxalate was mixed with phosphate of lime, and usually also with uric acid; but Fourcroy and Vauquelin found several in which it was united only to animal matter. It commonly forms a very hard calculus, of a dark-green colour, difficult to saw asunder, admitting a polish like ivory, exhaling, when sawed, an odour like that of semen. Insoluble and indecomposable by alkalies; soluble in very diluted nitric acid, but slowly and with difficulty. It may be decomposed by the carbonates of potash and soda. When burnt, it leaves behind a quantity of pure lime, amounting to one-third of its weight, which may be easily recognised by its properties.‡

5. Muriate of ammonia was first detected in calculi by Brande. Fourcroy and Vauquelin had announced the existence of urate of ammonia in calculi. They founded their opinion chiefly on the easy solubility of the supposed urate in alkaline leys, and the smell of ammonia given out during the solution. Brande found that if such calculi were treated with water, a portion was dissolved, and the residue consisted of pure uric acid. The matter dissolved was partly urea and partly muriate of ammonia. To the first of these bodies he ascribed the easy solubility of the calculus, and to the second the smell of ammonia which it gave out during its solution. From his experiments it does not appear that any such salt as urate of ammonia is present in calculi.§

6 and 7. The presence of magnesia and phosphate of iron in calculi, has been announced by Alemani, an Italian apothecary. He analysed an urinary calculus, and obtained from it

* Fourcroy, Ann. de Chim. xxxii. 219.   † Phil. Trans. 1797.
‡ Fourcroy, Ann. de Chim. xxxii. 220.   § Phil. Mag. xxxii. 171.

Magnesia................ 51·00
Silica.................. 20·00
Phosphate of iron .... 21·84
Carbonate of magnesia .... 4·00
Loss.................... 3·16
                         ――――――
                         100·00

As no details are given, we have no means of ascertaining how far these results are to be considered as correct.*

8. Silica.   8. Silica has only been found in two instances by Fourcroy and Vauquelin, though they have analysed about 600 calculi. It must therefore be considered as a very uncommon ingredient of these concretions. In the two instances in which it occurred, it was mixed with phosphate of lime.† The two calculi containing it were mulberry ones, but of a lighter colour than usual, extremely hard, and difficult to saw or reduce to powder. The presence of silica may be easily detected by its fusibility into glass with fixed alkalies, and its other well known properties. Professor Wurzer has detected silica, to the amount of one per cent. in a calculus which he analysed. It was composed of

Phosphate of lime .... 17·33
Uric acid .... 75·34
Animal matter........ 6·33
Silica. .... 1·00
                      ――――――
                      100·00 ‡

Silica was found also in an excessive proportion in the calculus analysed by Alemani, the result of which has been stated above.

9. Urea.   9. Urea was suspected to exist in calculi by Fourcroy and Vauquelin, but was first detected by Mr. Brande. He obtained it by digesting the calculi supposed to contain it in water or alcohol, and evaporating the solution. The proportion of it seems sometimes to be great. In one instance Mr. Brande found 36 per cent. of animal matter, the greatest part of which no doubt was urea. §

10. Cistic oxide.   10. The substance called cistic oxide was discovered,

* Ann. de Chim. lxv. 222.   † Fourcroy, ibid. xxxii. 221.
‡ Gehlen's Jour. Second Series, ii. 265.   § Phil. Mag. xxxii. 171.

and its nature ascertained, by Dr. Wollaston. A small calculus, passed from the bladder of a man, was entirely composed of it. It was white, dense, brittle, and had pretty much the appearance of magnesian lime-stone. The characters of this new and peculiar animal substance, as ascertained by Dr. Wollaston, are the following: 1. It dissolves and combines equally with acids and alkalies, and crystallizes with both. 2. It is precipitated from nitric acid by alcohol. 3. It does not become red when treated with nitric acid. 4. It produces no change on vegetable blues. 5. It is insoluble in water, alcohol, and ether. 6. When distilled it yields carbonate of ammonia and oil, and leaves only a very small fixed residue, which is phosphate of lime. This substance has only been found hitherto in three or four calculi.

11. All calculi contain an animal matter, which serves as a cement to glue the other ingredients together. This matter is often very small in quantity, though sometimes it is very considerable. Fourcroy and Vauquelin at first considered it as albumen, but they have lately announced that they have ascertained it to be mucus; an opinion much more likely to be correct, as mucus is secreted by the internal surface of the bladder, and of course is always present in more or less quantity.

Such are the component parts of urinary calculi; but as these substances often occur mixed together in various ways, it is a point of some consequence to be able to ascertain the component parts of the different calculi from their appearance, and to know what substances usually associate together; as this knowledge may lead hereafter to the true theory of their formation, and thus perhaps enable us to prevent that most dreadful of all diseases. Fourcroy and Vauquelin, after an examination of more than 600 calculi, have divided them into three genera and twelve species. The following is a view of their arrangement:

GENUS I. *Calculi composed of one ingredient.*

Sp. 1. Uric acid.
Sp. 2. Urate of ammonia.
Sp. 3. Oxalate of lime.

GENUS II. *Calculi composed of two ingredients.*

Sp. 1. Uric acid and the phosphates in layers.
Sp. 2. Ditto, mixed together.
Sp. 3. Urate of ammonia and the phosphates in layers.
Sp. 4. Ditto, mixed together.
Sp. 5. The phosphates mixed or in layers.
Sp. 6. Oxalate of lime and uric acid in layers.
Sp. 7. Oxalate of lime and the phosphates in layers.

GENUS III. *Calculi containing more than two ingredients.*

Sp. 1. Uric acid, the phosphates, and oxalate of lime.
Sp. 2. Uric acid, urate of ammonia, the phosphates, silica.

Let us take a view of each of these species.

Description of the species. Sp. 1. *Uric acid.* Colour that of wood, various shades of yellow or red. Texture laminar and radiated, compact and fine. Specific gravity from 1·5 to 1·786; sometimes so low as 1·276. Surface usually smooth and polished. Completely soluble in fixed alkaline leys, without emitting any odour of ammonia. This species is the most common. One fourth of the 600 calculi examined by Fourcroy and Vauquelin belonged to it.

Sp. 2. *Urate of ammonia.* Colour brownish white. Texture laminar; laminæ easily separated from each other. Specific gravity from 1·225 to 1·720. Surface often crystallized. Soluble in hot water, especially when reduced to powder. Soluble in fixed alkalies, while ammonia is evolved. This species is uncommon. Brande has made it probable that it does not exist, and that the calculi, referred to it by Fourcroy and Vauquelin, are composed of uric acid, urea, and muriate of ammonia.

Sp. 3. *Oxalate of lime.* Colour soot brown. Texture dense and hard, resembling ivory. Surface unequal, and full either of pointed or rounded protuberances. Hence the epithet *mulberry*, by which the calculi of this species are distinguished. Specific gravity from 1·428 to 1·976. When sawn, exhales the odour of semen. When **calcined**, leaves a residuum of carbonate of lime. Insoluble in alkalies; soluble with difficulty in acids. This species occurs frequently.

Sp. 4. *Uric acid and the phosphates in layers.* Surface white like chalk, and friable or sparry and semitransparent, according as the outermost coat is phosphate of lime or of magnesia. Often large. When cut, they present a nucleus of uric acid. Sometimes this nucleus is covered with alternate layers of the two phosphates. Specific gravity very variable. This species is not uncommon. About $\frac{1}{50}$th of the calculi examined by Fourcroy and Vauquelin belonged to it.

Sp. 5. *Uric acid and the phosphates mixed together.* This species varies in its appearance. Sometimes the component parts alternate in visible layers; at others they are too thin to be perceived by the eye, and can only be ascertained by analysis. Specific gravity from 1·213 to 1·739. This species is not uncommon. About $\frac{1}{40}$th of the calculi analysed by Fourcroy and Vauquelin belonged to it.

Sp. 6. *Urate of ammonia and the phosphates in layers.* This species resembles the fourth in its appearance; but its nucleus, instead of uric acid, is composed of urate of ammonia. It is not very common, and the calculi belonging to it are smaller than those of the fourth species.

Sp. 7. *Urate of ammonia and the phosphates mixed.* This species resembles the fifth, but may be distinguished by a colour less yellow, and by the ammonia emitted when the calculi are treated with potash. The calculi belonging to it are small and rather uncommon.

Sp. 8. *The two phosphates mixed or in layers.* Colour white like chalk. Texture laminar; friable, easily separated, and staining the surface of other bodies like chalk. Often mixed with thin layers of phosphate of magnesia and ammonia, sparry and semitransparent. Specific gravity from 1·138 to 1·471. Soluble in acids, insoluble in alkalies. About $\frac{1}{15}$th of the calculi examined by Fourcroy and Vauquelin belonged to this species.

Sp. 9. *Oxalate of lime and uric acid in layers.* The calculi belonging to this species have a nucleus of oxalate of lime covered with a layer, more or less thick, of uric acid; or they consist of a small calculus of the third species covered with a layer belonging to the first species. They are easily distinguished when sawn in two. About $\frac{1}{30}$th of the 600 calculi analysed by Fourcroy and Vauquelin belonged to this species.

Sp. 10. *Oxalate of lime and the phosphates in layers.* The calculi belonging to this species have a nucleus of oxalate of lime covered with a coat of the phosphates. Externally, therefore, they are the same with the fourth and eighth species; while the internal nucleus belongs to the third species. They are easily distinguished therefore when sawn in two. The calculi of this species are the most numerous of all, next to those of the first species. About ⅕th of those examined by Fourcroy and Vauquelin belonged to it.

Sp. 11. *Uric acid or urate of ammonia, the phosphates, oxalate of lime.* The calculi of this species have a nucleus of oxalate of lime, over this a coat of uric acid or urate of ammonia, or of a mixture of both; while the outermost coat is composed of the phosphates.

Sp. 12. *Uric acid, urate of ammonia, the phosphates, silica.* The calculi of this species bear a considerable resemblance to those of the last. The nucleus is composed of silica and phosphate of lime, then there is a coat of uric acid and urate of ammonia, and over all a coat of the phosphates. Only four calculi of this kind have been observed.

Such is the arrangement of Fourcroy and Vauquelin, certainly the most complete which has hitherto appeared. Dr. Wollaston had previously given another, which in many respects deserves the preference in a practical view. It consists of a small number of genera, admirably well distinguished by their characters and constituents. It certainly deserves the peculiar attention of surgeons. He divides calculi into four kinds. They are as follows:

1. *Uric calculi.* These are the calculi composed of uric acid, or which consist chiefly of that substance. They are either completely soluble in pure alkaline leys or nearly so.

2. *Fusible calculi.* Composed chiefly of phosphate of lime and phosphate of magnesia and ammonia. Before the blowpipe they melt into enamel. They are completely soluble, or nearly so, in muriatic acid.

3. *Mulberry calculi.* Composed of oxalate of lime or of oxalate and phosphate of lime. In the state of powder they are slowly dissolved by muriatic acid. The residuum is uric acid.

4. *Bone earth calculi.* These, as the name implies, are

composed chiefly of phosphate of lime. They are soluble in muriatic acid.

From the observations and experiments of Mr. Brande, it appears that the calculi formed in the kidneys almost always consist of uric acid and animal matter. Sometimes, but very rarely, they consist of oxalate of lime; and when calculi remain in the kidney a considerable time after they have been formed, their external coat consists sometimes of the triple phosphate of magnesia and phosphate of lime.*

Of 150 calculi found in the bladder, and analysed by Mr. Brande, the following was the composition :

16 Composed of uric acid.

45 .... uric acid, with a small relative propor-
            tion of the phosphates.

66 .... the phosphates with a small proportion
            of uric acid.

12 .... the phosphates entirely.

5 .... uric acid with the phosphates and
            nuclei of oxalate of lime.

6 .... chiefly oxalate of lime.

_____

150†

From the preceding account of the different urinary cal-
culi, it appears that most of their component parts exist in urine. But little satisfactory is known concerning the manner in which these concretions are formed, or of the cause of their formation. Whenever any solid body makes its way into the bladder, it has been observed that it is soon encrusted with a coat of phosphate of lime; and this first nucleus soon occasions a calculus. Concretions of uric acid seldom or never form in the bladder, unless a primitive nucleus has originated in the kidneys. The gravel which is so frequently emitted by persons threatened with the stone consists always of this acid. As oxalic acid does not exist in urine, some morbid change must take place in the urine when calculi composed of oxalate of lime are deposited. Brugnatelli's discovery of the instantaneous conversion of uric acid into oxalic acid by chlorine, which has been confirmed by the experiments of Fourcroy

* Phil. Mag. xxxii. 167.   † Ibid. 171.

Book V. and Vauquelin, throws considerable light upon the forma-
tion of oxalic acid in urine, by showing us that uric acid is
probably the basis of it; but in what manner the change is
actually produced, it is not so easy to say.

Attempts to discover a solvent of calculi.   As our ignorance of the cause of urinary concretions
puts it out of our power to prevent their formation, the
ingenuity of physicians has been employed in attempting to
discover substances capable of dissolving them after they
have formed, and thus to relieve the human race from one
of the most dreadful diseases to which it is subject. These
attempts must have been vain, or their success must have
entirely depended upon chance, till the properties of the
concretions themselves had been discovered, and the sub-
stances capable of dissolving them ascertained by experi-
ment. I shall therefore pass over the numerous lithonthrip-
tics * which have been recommended in all ages, and sa-
tisfy myself with giving an account of the experiments
made by Fourcroy and Vauquelin to dissolve stones by in-
jections through the urethra, made after their analysis of
the urinary calculi.

The component parts of urinary calculi, as far as sol-
vents are concerned, may be reduced under three heads;

Solvents.   1. Uric acid and urate of ammonia.
                   2. The phosphates.
                   3. Oxalate of lime.

1. A solution of pure potash and soda, so weak that it
may be kept in the mouth, and even swallowed without
pain, soon dissolves calculi composed of uric acid, or urate
of ammonia, provided they be kept plunged in it.

2. The phosphates are very quickly dissolved by nitric
or muriatic acid, so weak that it may be swallowed without
inconvenience, and possessed of no greater acridness than
urine itself.

3. Oxalate of lime is much more difficult of solution than
the preceding substances. Calculi composed of it are
slowly dissolved by nitric acid, or by carbonate of potash
or soda, weak enough not to irritate the bladder: but the
action of these substances is slow, and scarcely complete.

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* There is no room to believe that any of these medicines hitherto
proposed, whether alkalies or acids, have any effect as solvents of cal-
culi.

These solvents injected into the bladder repeatedly, and
retained in it as long as the patient can bear their action
without inconvenience, ought to act upon the stone and
gradually dissolve it. The difficulty, however, is to deter-
mine the composition of the calculus to be acted upon, in
order to know which of the solvents to employ. But as no
method of deciding this point with certainty is at present
known, we must try some one of the solvents for once or
twice, and examine it after it has been thrown out of the
bladder. Let us begin, for instance, with injecting a weak
solution of potash; and after it has remained in the blad-
der half an hour, or longer if the patient can bear it, let
the liquid, as soon as passed, be filtered and mixed with a
little muriatic acid; if any uric acid has been dissolved, a
white solution will make its appearance. This precipitate
is a proof that the calculus is composed of uric acid. If it
does not appear, after persevering in the alkaline solution
for some days, then there is reason to expect the presence
of the phosphates; of course a weak muriatic acid solution
should be injected. After this solution is emitted, let it be
mixed with ammonia, and the phosphate of lime will pre-
cipitate, if the calculus be composed of it. If neither of
these solutions take up any thing, and if the symptoms are
not alleviated, we must have recourse to the action of nitric
acid, on the supposition that the calculus is composed of
oxalate of lime. These different solutions must be per-
sisted in, and varied occasionally as they lose their efficacy,
in order to dissolve the different coats of the calculus. Such
are the methods pointed out by Fourcroy and Vauquelin.
It is scarcely necessary to observe, that the bladder should
be evacuated of urine previous to the injections, and that
the injections should be previously heated to the temperature
of the body.

The calculi found in the bladder of the inferior animals
have been examined by different chemists, especially by
Fourcroy and Vauquelin, and by Dr. Pearson and Mr.
Brande. As far as experiment has hitherto gone, they
consist chiefly of the three following species :

1. *Carbonate of lime.* These calculi have a white colour,
are opaque, and are easily recognized by the action of acids.
They occur most frequently in the bladder of the gramini-
vorous animals, and seem to have been first detected by

Fourcroy and Vauquelin. The lime is cemented by an animal matter. Calculi belonging to this species have been found in the bladder of the horse,* the sow,† the rabbit,* the ox.‡

2. *Earthy phosphate.* These calculi belong chiefly to the carnivorous animals, and seem first to have been examined by Dr. Pearson. They consist sometimes of phosphate of lime and animal matter, sometimes of a mixture of phosphate of lime and phosphate of ammonia and magnesia and animal matter. They have been found in the bladder of the dog,§ the hog,‖ the rat,** and the cat:** and a calculus from a horse, examined by Dr. Pearson, was obviously composed of the two phosphates. I found the calculus from a hog composed entirely of phosphate of lime.††

3. *Oxalate of lime.* Calculi composed of this substance have been recently detected by Fourcroy and Vauquelin from the bladder of the dog and the rat.‡‡

The following table exhibits a view of the constituents of the calculi of different animals analysed by Mr. Brande:

	Horse.§§			Sheep.	Dog.		Hog.	Rabbit.
Phosphate of lime...	76	45	60	72	64	80		39
Carbonate of lime...	22	10	40	20		20	90	42
Phosph. of mag. and ammonia } ..		28			30			
Animal matter		15		8	6			19
Loss	2	2					10	
	100	100	100	100	100	100	100	100

Several calculi from the bladder of the ox, likewise examined by Mr. Brande, were composed of carbonate of lime and animal matter.‖‖

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* Pearson.   † Brugnatelli and Fourcroy.   ‡ Fourcroy.
§ Pearson.   ‖ Bartholdi.   ** Fourcroy and Vauquelin.
†† Annals of Philosophy, ii. 59.
‡‡ Ann. de Mus. d'Hist. Nat. iv. 338.
§§ The first calculus in the table was from the kidney, all the rest were from the bladder.
‖‖ Phil. Mag. xxxii. 175.

Thus it appears that the calculi of carnivorous animals resemble the human in their composition, excepting that uric acid has never been detected in them.

v. GOUTY CONCRETIONS.

It is well known that concretions occasionally make their appearance in joints long subject to gout. These concretions, from their colour and softness, have received the name of *chalk-stones.* They are usually small, though Chalk they have been observed of the size of an egg.* It had stones. long been the opinion of physicians that these concretions were similar to the urinary calculi. Of course, after the discovery of uric acid by Scheele, it was usual to consider the gouty chalk stones as collections of that acid. They Consist of were subjected to a chemical analysis by Dr. Wollaston in urate of 1797, who found them composed of uric acid and soda. soda.

Gouty concretions are soft and friable. Cold water has little effect upon them; but boiling water dissolves a small portion. If an acid be added to this solution, small crystals of uric acid are deposited on the sides of the vessel.

These concretions are completely soluble in potash when the action of the alkaline solution is assisted by heat.

When treated with diluted sulphuric or with muriatic acid, the soda is separated; but the uric acid remains, and may be separated by filtration. The liquid, when evaporated, yields crystals of sulphate or muriate of soda, according to the acid employed. The residuum possesses all the characters of uric acid. When distilled it yields ammonia, prussic acid, and the acid sublimate of Scheele. When dissolved in a little nitric acid, it tinges the skin of a rose colour, and when evaporated leaves a rose-coloured deliquescent residuum. It is soluble in potash, and may be precipitated by any acid, and by ammonia; first in the state of a jelly, and then breaking down into a white powder.

When uric acid, soda, and a little warm water, are triturated together, a mass is formed, which, after the surplus of soda is washed off, possesses the chemical properties of gouty concretions.†

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* Severinus.   † See Dr. Wollaston's analysis, Phil. Trans. 1797.

SECT. XXIX.

MORBID SECRETIONS.

Various.

In different diseases to which the animal body is subject, various fluids make their appearance which did not exist previously, at least under the form which they assume. Thus in dropsy, the cellular substance, and frequently also the cavities of the head, breast, or abdomen, are filled with a whitish liquid. When any part of the skin is irritated into a blister, the interval between the cutis and cuticle is filled with a transparent fluid: and when any part of the muscles or skin is wounded, the ulcer is soon covered with a thick matter called *pus*. A thin sanies exudes from cancers and carious bones. A chemical knowledge of these secretions cannot but be attended with advantage both to the physiologist and physician. Unfortunately little precise information respecting these fluids can be at present given. It will be worth while, however, to state the observations that have been made.

I. PUS.

The liquid called *pus* is secreted from the surface of an inflamed part, and usually moderates and terminates the inflammation. It assumes different appearances according to the state of the sore. When it indicates a healing sore, it is called *healthy* or *good-conditioned* pus. This liquid possesses the following properties:

Properties of healthy pus.

It is of a yellowish-white colour, and of the consistence of cream. Its taste is insipid, and it has no smell when cold. Before the microscope it exhibits the appearance of white globules swimming in a transparent fluid.* Its specific gravity varies from 1·031 to 1·033.†

It produces no change on vegetable blues.‡ When exposed to a moderate heat it gradually dries, and assumes the appearance of horn. When exposed to destructive distillation, Bergman obtained first about one-fourth of the pus in the state of insipid water. On increasing the fire, a

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* Home on Ulcers.   † Pearson, Nicholson's Jour. xxx. 17.
‡ Cruickshanks.

liquid came over, containing abundance of ammonia, and accompanied by gaseous bodies, which were not examined. Some concrete carbonate of ammonia sublimed, accompanied by empyreumatic oil. A light brilliant coal remained of difficult incineration. The ashes gave traces of iron.*

When pus is left exposed to the air, it gradually becomes acid, according to Hildebrant; and Haller affirms that it sometimes gives a red colour to litmus even when recent. When thrown into water it sinks to the bottom. When agitated the mixture becomes milky; but the pus separates again when allowed to remain undisturbed. However, by repeated agitation, and especially by the application of heat, a milky liquid is obtained, which passes in that state through the filter.

Alcohol thickens pus, but does not dissolve it; neither does pus unite with oils.

Sulphuric acid dissolves it, and forms a purple coloured solution. When diluted with water, the dark colour disappears, and the pus separates; either sinking to the bottom, or rising to the surface, according to the quantity of water added, and the time that the solution has been allowed to stand. Diluted sulphuric acid does not act upon it.

Concentrated nitric acid effervesces with it, and forms a yellow solution, which when recent is decomposed by water, the pus subsiding in the state of grey flakes.

Muriatic acid also dissolves it when heated, and the pus is separated by water.

With the fixed alkaline leys it forms a whitish ropy fluid, which is decomposed by water; the pus precipitating. Pure ammonia reduces it to a transparent jelly, and gradually dissolves a considerable portion of it.†

When nitrate of silver is dropped into the solution of pus in water, a white precipitate separates. Nitrate of mercury and corrosive sublimate occasion a much more copious flaky precipitate.‡

Such are the properties of healthy pus hitherto observed by chemists. They indicate a considerable analogy with albumen. Various observations have been made to enable

* Gren's Handbuch, ii. 426.　　　† Cruickshanks.　　　‡ Ibid.

physicians to distinguish pus from the mucus of the internal cavities, especially of the lungs. In cases of copious expectoration, it is sometimes of consequence to know whether the matter thrown out of the lungs is pus or mucus. Mr. Charles Darwin made a set of experiments on the subject, and pointed out three criteria which distinguished pus. 1. Sulphuric acid dissolves it. When the solution is diluted the pus precipitates; but mucus treated in the same manner swims. But this distinction depends upon the quantity of water added, and is therefore ambiguous. 2. Pus is diffusible through diluted sulphuric acid, through water, and through brine; but mucus is not. 3. Alkaline leys dissolve pus; water precipitates pus thus dissolved, but not mucus. How far these two last distinctions can be trusted, is rather doubtful. Grasmeyer has proposed the following method, which he considers as complete. Triturate the substance to be tried with an equal quantity of warm water; then add to it an equal portion of a saturated solution of carbonate of potash, and set the mixture aside. If it contains pus, a transparent jelly subsides in a few hours; but this does not happen if only mucus be present.[*]

2. When the ulcer is ill-conditioned, the pus secreted in it possesses different properties. It has usually a fetid smell, is much thinner, and to a certain degree acrid. We are in possession of two sets of experiments on this unhealthy pus: one by Mr. Cruickshanks on the pus discharged from what is called the *hospital sore*; another by Dr. Crawford on the matter of *cancers*.

Pus of the hospital sore.

The pus from the hospital sore possesses most of the properties of healthy pus; but is distinguished by its odour, and by some shades of difference when exposed to the action of the metallic precipitates. Lime-water changes its fetid odour, but does not destroy it; sulphuric acid increases it, as do alcohol and the solution of oxide of arsenic in potash. Bark has no effect upon it; but it is destroyed by the nitrate of mercury and corrosive sublimate, by nitric acid, and by chlorine. Nitrate of silver does not destroy it. Mr. Cruickshanks supposes that the fetid smell is occasioned by the alteration of some part of true pus.

* Gren's Handbuch, ii. 433. Dr. Pearson's experiments on pus deserve the attention of the reader. See Nicholson's Jour. xxx. 17.

He considers the pus of the hospital sore as a matter *sui* *generis*, which is capable of generating more, and even of producing an alteration in the system. Hence, to heal the sore, the matter must be destroyed, and prevented from appearing again. This was done by washing the sores with nitrate of mercury, diluted nitric acid, and chlorine at every dressing. This method constantly succeeded with Dr. Rollo, except when the sore was too large to admit it to be put in practice completely.

3. The matter of cancer, examined by Dr. Crawford, gave a green colour to syrup of violets. Potash produced no change; but sulphuric acid extricated a gas which possessed many, of the properties of sulphureted hydrogen. This gas he supposes to exist in the matter united to ammonia. The presence of this compound explains the effects of the matter of cancer, and virulent matter in general, upon metallic salts. Dr. Crawford found that the odour of this matter was completely destroyed by chlorine; and therefore recommends it as a proper substance for washing cancerous ulcers.

4. Besides the species mentioned above, there are many others which we know from their effects to be peculiar, though we cannot find any chemical distinctions between them sufficiently well marked. But that they are specifically different cannot be doubted, if we consider that every one of them produces a disease peculiar to itself. The matter of small-pox, of venereal ulcers, of cow-pox, &c. may be mentioned as instances.

II. LIQUOR OF DROPSY.

The liquor which fills the cavities of the body in dropsy has a yellowish-green colour, and is sometimes turbid, sometimes nearly transparent. A few experiments on a colourless liquor extracted from a dropsical patient have been published by Wurzer: from which it appears to have contained albumen, mucus, sulphureted hydrogen, phosphate of lime, muriate of soda, and soda.* To Dr. Bostock we are indebted for an examination of the colourless liquid obtained by puncturing a tumor in the spine, formed in the disease called *spina bifida.* It was slightly

* Gehlen's Jour. v. 663.

Book V. opaque, and did not alter vegetable blues ; heat increased its opacity, but did not coagulate it. Its constituents were found to be as follows :

Water	97·8
Muriate of soda	1·0
Albumen	0·5
Mucus	0·5
Gelatin	0·2

proportions conjectural.

Lime, a trace

100·0 *

III. LIQUOR OF BLISTERS.

The liquid which makes its appearance when the epidermis is raised into blisters is perfectly transparent and liquid. When the blisters are artificial, it is usually yellow, and has the odour of the blistering plaster. From the experiments of Margueron, we learn that it is composed of the same constituents as the serum of the blood. From 200 parts of this liquid he obtained,

Constitu-
ents.

Albumen	36
Muriate of soda	4
Carbonate of soda	2
Phosphate of lime	2
Water	156

200 †

Thus I have given an account of all those secretions which have been attentively examined by chemists. The remainder have been hitherto neglected ; partly owing to the difficulty of procuring them, and partly on account of the multiplicity of other objects which occupied the attention of chemical philosophers. It remains for us now to examine by what processes these different secretions are formed, how the constant waste of living bodies is repaired, and how the organs themselves are nourished and preserved. This shall form the subject of the following Chapter.

* Nicholson's Jour. xiv. 145.   † Ann. de Chim. xiv. 225.

CHAP. III.

OF THE FUNCTIONS OF ANIMALS.

THE intention of the two last Chapters was to exhibit a view of the different substances which enter into the composition of animals, as far as the present limited state of our knowledge puts it in our power. But were our inquiries concerning animals confined to the mere ingredients of which their bodies are composed, even supposing the analysis as complete as possible, our knowledge of the nature and properties of animals would be imperfect indeed.

How are these substances arranged? How are they produced? What purposes do they serve? What are the distinguishing properties of animals, and the laws by which they are regulated?

Animals resemble vegetables in the complexness of their structure. Like them, they are machines nicely adapted for particular purposes, constituting one whole, and continually performing an infinite number of the most delicate processes. But neither an account of the structure of animals, nor of the properties which distinguish them from other beings, will be expected here: these topics belong entirely to the anatomist and physiologist. I mean in the present Chapter to take a view of those processes only that are concerned in the *production* of animal substances, which alone properly belong the Chemistry. The other functions are regulated by laws of a very different nature, which have no resemblance or analogy to the laws of Chemistry or Mechanics.

Animals resemble vegetables.

SECT. I.

OF DIGESTION.

EVERY body knows that animals require food, and that they die sooner or later if food be withheld from them. There is indeed a very great difference in the quantity of food which animals require, and in the time which they can pass without it. In general, those animals which are

Food necessary.

Book V. most active require most, and those which are most indo-
lent require least food.   The cause of this is pretty obvious;
the bodies of animals do not remain stationary, they are
constantly wasting; and the waste is proportional to the
activity of the animal.   Hence the body must receive, from
time to time, new supplies, in place of what has been car-
ried off.   The use of food answers this purpose.

Its nature.   2. We are much better acquainted with the food of ani-
mals than of vegetables.   It consists of almost all the ani-
mal and vegetable substances which have been treated of in
this and the preceding Book : for there are but very few of
them which some animal or other does not use as food.
Man uses as food chiefly the muscles of animals, the seed of
certain grasses, and a variety of vegetable fruits.   Almost
all the inferior animals have particular substances on which
they feed exclusively.   Some of them feed on animals,
others on vegetables.   Man has a greater range ; he can
feed on a very great number of substances.   To enumerate
these substances would be useless; as we are not able to
point out with accuracy what it is which renders one sub-
stance more nourishing than another.

Many substances do not serve as nourishment at all ; and
not a few, instead of nourishing, destroy life.   These last
are called *poisons*.   Some poisons act chemically, by decom-
posing the animal body.   The action of others is not so
well understood.

Converted   3. The food is introduced into the body by the mouth,
into chyme and almost all animals reduce it to a kind of pulpy consist-
in the sto-
mach.   ence.   In man, and many other animals, this is done in
the mouth by means of teeth and the saliva with which it is
there mixed; but many other animals grind their food in a
different manner.   After the food has been thus ground, it
is introduced into the stomach, where it is subjected to new
changes.   The stomach is a strong soft bag, of different
forms in different animals: in man it has some resemblance
to the bag of a *bag-pipe*.   In this organ the food is con-
verted into a soft pap, which has no resemblance to the
food when first introduced.   This pap has been called
chyme.

4. Since chyme possesses new properties, it is evident
that the food has undergone some changes in the stomach,
and that the ingredients of which it was composed have

entered into new combinations. Now, in what manner
have these changes been produced?

At first they were ascribed to the mechanical action of the stomach. The food, it was said, was still farther triturated in that organ: and being long agitated backwards and forwards in it, was at last reduced to a pulp. But this opinion, upon examination, was found not to be true. The experiments of Stevens, Reaumur, and Spallanzani, demonstrated that the formation of chyme is not owing to trituration; for on inclosing different kinds of food in metallic tubes and balls full of holes, in such a manner as to screen them from the mechanical action of the stomach, they found that these substances, after having remained a sufficient time in the stomach, were converted into chyme, just as if they had not been inclosed in such tubes. Indeed the opinion was untenable, even independent of these decisive experiments, the moment it was perceived that chyme differed entirely from the food which had been taken: that is to say, that if the same food were triturated mechanically out of the body, and reduced to pap of precisely the same consistence with chyme, it would not possess the same properties with chyme; for whenever this fact was known, it could not but be evident that the food had undergone changes in its composition.

The change of food into chyme therefore was ascribed by many to *fermentation*. This opinion is indeed very ancient, and it has had many zealous supporters among the moderns. When the word *fermentation* was applied to the change produced on the food in the stomach, the nature of the process called *fermentation* was altogether unknown. The appearances, indeed, which take place during that process had been described, and the progress and the result of it were known: but no attempt had been made to explain the cause of fermentation, or to trace the changes which take place during its continuance. All that could be meant, then, by saying that the conversion of food into chyme in the stomach is owing to fermentation, was merely, that the unknown cause which acted during the conversion of vegetable substances into wine or acid, or during their putrifaction, acted also during the conversion of food into chyme, and that the result in both cases was precisely the same. Accordingly, the advocates for this

Book V. opinion attempted to prove, that air was constantly gene-
rated in the stomach, and that an acid was constantly pro-
duced: for it was the vinous and acetous fermentations
which were assigned by the greater number of physiologists
as the cause of the formation of chyme. Some indeed
attempted to prove that it was produced by the putrifactive
fermentation; but their number was inconsiderable, com-
pared with those who adopted the other opinion.

Our ideas respecting fermentation are now somewhat
more precise. It signifies a slow decomposition, which
takes place when certain animal or vegetable substances are
mixed together at a given temperature; and the consequent
production of particular compounds. If, therefore, the
conversion of the food into chyme be owing to fermentation,
it is evident that it is totally independent of the stomach
any farther than as it supplies temperature; and that the
food would be converted into chyme exactly in the same
manner if it were reduced to the same consistence, and
But with-   placed in the same temperature out of the body. But this is
out reason.   by no means the case; substances are reduced to the state of
chyme in a short time in the stomach, which would remain
unaltered for weeks in the same temperature out of the
body. This is the case with bones; which the experiments
of Stevens and Spallanzani have shown to be soon digested
in the stomach of the dog. Further, if the conversion of
food into chyme were owing to fermentation, it ought to go
on equally well in the stomach and œsophagus. Now, it
was observed long ago by Ray and Boyle, that when vora-
cious fish had swallowed animals too large to be contained
in the stomach, that part only which was in the stomach
was converted into chyme, while what was in the œsopha-
gus remained entire; and this has been fully confirmed by
subsequent observations.

Still farther, if the conversion were owing to fermenta-
tion, it ought always to take place equally well, provided
the temperature be the same, whether the stomach be in a
healthy state or not. But it is well known that this is not
the case. The formation of chyme depends very much on
the state of the stomach. When that organ is diseased,
digestion is constantly ill performed. In these cases,
indeed, fermentation sometimes appears, and produces flatu-
lence, acid eructations, &c. which are the well-known

symptoms of indigestion. These facts, which have been long known, are incompatible with the supposition, that the formation of chyme is owing to fermentation. Accordingly that opinion has been for some time abandoned, by all those at least who have taken the trouble to examine the subject.

The formation of chyme, then, is owing to the stomach; Owing to and it has been concluded, from the experiments of Stevens, the action Reaumur, Spallanzani, Scopoli, Brugnatelli, Carimini, tric juice. &c. that its formation is brought about by the action of a particular liquid secreted by the stomach, and for that reason called *gastric juice*.

That it is owing to the action of a liquid is evident; because, if pieces of food be inclosed in close tubes, they pass through the stomach without any farther alteration than would have taken place at the same temperature out of the body; but if the tubes be perforated with small holes, the food is converted into chyme.

This liquid does not act indiscriminately upon all sub- Nature of stances: for if grains of corn be put into a perforated tube, the gastric and a granivorous bird be made to swallow it, the corn will juice. remain the usual time in the stomach without alteration; whereas if the husk of the grain be previously taken off, the whole of it will be converted into chyme. It is well known, too, that many substances pass unaltered through the intestines of animals, and consequently are not acted upon by the gastric juice. This is the case frequently with grains of oats, when they have been swallowed by horses entire with their husks on. This is the case also with the seeds of apples, &c. when swallowed entire by man; yet these very substances, if they have been previously ground sufficiently by the teeth, are digested. It appears, therefore, that it is chiefly the husk or outside of these substances which resists the action of the gastric juice. We see, also, that trituration greatly facilitates the conversion of food into chyme.

The gastric juice is not the same in all animals; for many animals cannot digest the food on which others live. The *conium maculatum* (hemlock), for instance, is a poison to man instead of food, yet the goat often feeds upon it. Many animals, as sheep, live wholly upon vegetables; and

if they are made to feed on animals, their stomachs will not digest them : others, again, as the eagle, feed wholly on animal substances, and cannot digest vegetables.

The gastric juice does not continue always of the same nature, even in the same animal ; it changes gradually according to circumstances. Graminivorous animals may be brought to live on animal food ; and after they have been accustomed to this for some time, their stomachs become incapable of digesting vegetables. On the other hand, those animals which naturally digest nothing but animal food may be brought to digest vegetables.

5. What is the nature of the gastric juice which possesses these singular properties? It is evidently different in different animals ; but it is a very difficult task, if not an Methods of impossible one, to obtain it in a state of purity. Various procuring attempts have indeed been made by very ingenious phi-it. losophers to procure it ; but their analysis of it is sufficient to show us that they have never obtained it in a state of purity.

The methods which have been used to procure gastric juice are, *first*, to kill the animal whose gastric juice is to be examined after it has fasted for some time. By this method Spallanzani collected 37 spoonfuls from the two first stomachs of a sheep. It was of a green colour, undoubtedly owing to the grass which the animal had eaten. He found also half a spoonful in the stomach of some young crows which he killed before they had left their nest.

Small tubes of metal pierced with holes, and containing a dry sponge, have been swallowed by animals ; and when vomited up, the liquid imbibed by the sponge is squeezed out. By this method, Spallanzani collected 481 grains of gastric juice from the stomachs of five crows.

A *third* method consists in exciting vomiting in the morning, when the stomach is without food. Spallanzani tried this method twice upon himself, and collected one of the times 1 oz. 32 gr. of liquid ; but the pain was so great that he did not think proper to try the experiment a third time. Mr. Gosse, however, who could excite vomiting whenever he thought proper, by swallowing air, has employed that method to collect gastric juice.

Spallanzani has observed that eagles throw up every

morning a quantity of liquid, which he considers as gastric juice; and he has availed himself of this to collect it in considerable quantities.

It is almost unnecessary to remark how imperfect these different methods are, and how far every conclusion drawn from the examination of such juices must deviate from the truth. It is impossible that the gastric juice obtained by any one of these processes can be pure; because in the stomach it must be constantly mixed with large quantities of saliva, mucus, bile, food, &c. It may be questioned, indeed, whether any gastric juice at all can be obtained by these methods; for, as the intention of the gastric juice is to convert the food into chyme, in all probability it is only secreted, or at least thrown into the stomach, when food is present.

We need not be surprised, then, at the contradictory accounts concerning its nature, given us by those philosophers who have attempted to examine it; as these relate not so much to the gastric juice, as to the different substances found in the stomach. The idea that the gastric juice can be obtained by vomiting, or that it is thrown up spontaneously by some animals, is, to say the least of it, very far from being probable.

According to Brugnatelli, the gastric juice of carnivorous animals, as hawks, kites, &c. has an acid and resinous odour, is very bitter, and not at all watery; and is composed of an uncombined acid, a resin, an animal substance, and a small quantity of muriate of soda.* The gastric juice of herbivorous animals, on the contrary, as goats, sheep, &c. is very watery, a little muddy, has a bitter saltish taste, and contains ammonia, an animal extract, and a pretty large quantity of muriate of soda.† Mr. Carminati found the same ingredients; but he supposes that the ammonia had been formed by the putrifaction of a part of their food, and that in reality the gastric juice of these animals is of an acid nature.‡

The accounts which have been given of the gastric juice of man are so various, that it is not worth while to tran-

* Scopoli, Macquer's Dict.   † Ibid.
‡ Sennebier's Observations on Gastric Juice.

scribe them. Sometimes it has been found of an acid nature, at other times not. The experiments of Spallanzani are sufficient to show that this acidity is not owing to the gastric juice, but to the food. He never found any acidity in the gastric juice of birds of prey, nor of serpents, frogs, and fishes. Crows gave an acidulous gastric juice only when fed on grain; and he found that the same observation holds with respect to dogs, herbivorous animals, and domestic fowls. Carnivorous birds threw up pieces of shells and coral without alteration; but these substances were sensibly diminished in the stomachs of hens, even when inclosed in perforated tubes. Spallanzani himself swallowed calcareous substances inclosed in tubes; and when he fed on vegetables and fruits, they were sometimes altered and a little diminished in weight, just as if they had been put into weak vinegar; but when he used only animal food, they came out untouched. According to this philosopher, whose experiments have been by far the most numerous, the gastric juice is naturally neither acid nor alkaline. When poured on the carbonate of potash, it causes no effervescence.

Such are the results of the experiments on the juices taken from the stomach of animals. No conclusion can be drawn from them respecting the nature of the gastric juice. But from the experiments which have been made on the digestion of the stomach, especially by Spallanzani, the following facts are established:

Its effect on the food. The gastric juice attacks the surface of bodies, unites to the particles of them, which it carries off, and cannot be separated from them by filtration. It operates with more energy and rapidity the more the food is divided, and its action is increased by a warm temperature. The food is not merely reduced to very minute parts; its taste and smell are quite changed; its sensible properties are destroyed, and it acquires new and very different ones. This juice does not act as a ferment; so far from it, that it is a powerful antiseptic, and even restores flesh already putrified. There is not the smallest appearance of such a process; indeed, when the juice is renewed frequently, as in the stomach, substances dissolve in it with a rapidity which excludes all idea of fermentation. Only a few air bubbles make their escape,

which adhere to the elementary matter, and buoy it up to the top, and which are probably extricated by the heat of the solution.

With respect to the substances contained in the stomach, only two facts have been perfectly ascertained: the first is, that the juice contained in the stomach of oxen, calves, sheep, invariably contains uncombined phosphoric acid, as Macquart and Vauquelin have demonstrated: the second, that the juice contained in the stomach, and even the inner coat of the stomach itself, has the property of coagulating milk and the serum of blood. Dr. Young found that seven grains of the inner coat of a calf's stomach, infused in water, gave a liquid which coagulated more than 100 ounces of milk; that is to say, more than 6857 times its own weight: and yet, in all probability, its weight was not much diminished.

What the substance is which possesses this coagulating property has not yet been ascertained; but it is evidently not very soluble in water: for the inside of a calf's stomach, after being steeped in water for six hours, and then well washed with water, still furnishes a liquor on infusion which coagulates milk :* And Dr. Young found that a piece of the inner coat of the stomach, after being previously washed with water, and then with a diluted solution of carbonate of potash, still afforded a liquid which coagulated milk and serum.

It is evident, from these facts, that this coagulating sub- stance, whatever it is, acts very powerfully; and that it is scarcely possible to separate it completely from the sto- mach. But we know at present too little of the nature of coagulation to be able to draw any inference from these facts. An almost imperceptible quantity of some substances seems to be sufficient to coagulate milk: For Mr. Vaillant mentions, in his Travels in Africa, that a porcelain dish which he procured, and which had lain for some years at the bottom of the sea, possessed, in consequence, the pro- perty of coagulating milk when put into it; yet it commu- nicated no taste to the milk, and did not differ in appear- ance from other cups.

It is probable that the saliva is of service in the conver-

* Dr. Young.

Book V. sion of food into chyme as well as the gastric juice. It
evidently serves to dilute the food; and probably it may be
serviceable also by communicating oxygen.

Chyme
converted
into chyle
and excre-
ment.

6. The chyme, thus formed, passes from the stomach into
the intestines, where it is subjected to new changes, and at
last converted into two very different substances, chyle and
excrementitious matter.

Nature of
chyle.

The *chyle* is a white-coloured liquid, very much resem-
bling blood in its properties; with this difference that the
globules which float in it instead of being red as is the case
with the colouring globules of the blood, are white. But
the nature and constituents of chyle have been described in
the preceding chapter. Dr. Charles Smith, of New Jersey,
relates an instance of a dropsy of the abdomen, in which
the liquid accumulated appears to have been chyle. The
patient, a boy twelve years of age, was tapped twice, and
each time between seven and eight quarts of liquid ab-
stracted. Its colour was chalky-white, and resembled milk
pretty nearly, both in its taste, smell, and appearance. On
standing a night, it threw up a good cream, though not so
much in proportion as cow's milk usually does.*

Its forma-
tion a che-
mical pro-
cess.

7. Concerning the process by which chyle is formed from
chyme, scarcely any thing is known. It does not appear
that the chyme is precisely the same in all animals; for those
which are herbivorous have a greater length of intestine
than those which are carnivorous. It is certain that the
formation of the chyle is brought about by a chemical
change, although we cannot say precisely what that change
is, or what the agents are by which it is produced. But
that the change is chemical, is evident, because the chyle is
entirely different, both in its properties and appearance,
from the chyme. The chyme, by the action of the intes-
tines, is separated into two parts, chyle and excrement : the
first of which is absorbed by a number of small vessels called
lacteals; the second is pushed along the intestinal canal,
and at last thrown out of the body altogether.

After the chyme has been converted into chyle and excre-
ment, although these two substances remain mixed toge-
ther, it does not appear that they are able to decompose
each other; for persons have been known seldom or never

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* Phil. Mag. ix. 16.

to emit any excrementitious matter *per anum* for years. In
these, not only the chyle, but the excrementitious matter
also, was absorbed by the lacteals; and the excrement was
afterwards thrown out of the body by other outlets, particu-
larly by the skin : in consequence of which, those persons
have constantly that particular odour about them which dis-
tinguishes excrement. Now, in these persons it is evident
that the chyle and excrement, though mixed together, and
even absorbed together, did not act on each other; because
these persons have been known to enjoy good health for
years, which could not have been the case had the chyle
been destroyed.

It has been supposed by some that the decomposition of Use of the
the chyme, and the formation of chyle, is produced by the bile.
agency of the bile, which is poured out abundantly, and
mixed with the chyme, soon after its entrance into the in-
testines. If this theory were true, no chyle could be formed
whenever any accident prevented the bile from passing into
the intestinal canal : but this is obviously not the case ; for
frequent instances have occurred of persons labouring under
jaundice, from the bile ducts being stopped, either by gall-
stones or some other cause, so completely, that no bile could
pass into the intestines ; yet these persons have lived for a
considerable time in that state. Consequently digestion,
and therefore the formation of chyle, must be possible, in-
dependent of bile.

The principal use of the bile seems to be to separate the
excrement from the chyle, after both have been formed, and
to produce the evacuation of the excrement out of the body.
It is probable that these substances would remain mixed to-
gether, and that they would perhaps even be partly absorbed
together, were it not for the bile, which seems to combine
with the excrement, and by this combination to facilitate
its separation from the chyle, and thus to prevent its absorp-
tion. Fourcroy supposes that the bile, as soon as it is mixed
with the contents of the intestinal canal, suffers a decompo-
sition ; that its alkali and saline ingredients combine with
the chyle, and render it more liquid, while its albumen and
picromel combine with the excrementitious matter, and
gradually render them less fluid.* From the experiments

* Fourcroy, x. 48.

Book V. of Berzelius on feces, detailed in the preceding chapter, it cannot be doubted that the constituents of the bile are to be found in the excrementitious matter: so that the ingenious theory of Fourcroy is so far probable. The bile also stimulates the intestinal canal, and causes it to evacuate its contents sooner than it otherwise would do; for when there is a deficiency of bile the body is constantly costive.

Chyle mixes with lymph,

8. The chyle, after it has been absorbed by the lacteals, is carried by them into a pretty large vessel, known by the name of the *thoracic duct.* Into the same vessel likewise is discharged a transparent fluid, conveyed by a set of vessels which arise from all the cavities of the body. These vessels are called *lymphatics,* and the fluid which they convey is called *lymph.* In the thoracic duct, then, the chyle and the lympth are mixed together.

Very little is known concerning the nature of the *lymph,* as it is scarcely possible to collect it in any quantity. It is colourless, has some viscidity, and is said to be specifically heavier than water. Mr. Brande found that it did not coagulate when heated, but he separated albumen by means of the galvanic battery. He found in it also some common salt; but no iron.* From the observations of Berzelius it is probable that it contains the lactates. It is said to be coagulable by heat; if so, it contains albumen. Its quantity is certainly considerable, for the lymphatics are very numerous.

And is conveyed to the lungs.

9. The chyle and lymph being thus mixed together, are conveyed directly into the blood vessels. The effect produced by their union in the thoracic duct is not known, but neither the colour nor external properties of the chyle are altered. In man, and many other animals, the thoracic duct enters at the junction of the left subclavian and carotid veins, and the chyle is conveyed directly to the heart, mixed with the blood, which already exists in the blood vessels. From the heart, the blood and chyle thus mixed together are propelled into the lungs, where they undergo farther changes.

Gases in the intestines.

10. The stomach and intestines usually contain some gaseous matters. Indeed it is probable that common air is swallowed along with the food. But from the experiments of Magendie and Chevreul there is reason to believe, that

* Phil. Trans. 1812, p. 97.

the oxygen gas which usually exists in the stomach in a considerable proportion when compared with the other gases, gradually diminishes, and at last disappears as we proceed along the course of the alimentary canal; while at the same time, the proportion of carbonic acid gas and of hydrogen gas increases. They examined the gaseous contents of the stomach and intestines of four criminals executed in Paris, very soon after death. The results were as follows :

1. Gases in the stomach.

> Oxygen ...... 11·00
> Carbonic acid .. 14·00
> Hydrogen ..... 3·55
> Azote .... 71·45
> ———
> 100·00

2. Gases in the small intestines.

> Oxygen .... 0·00 .... 0·00 .... 0·0
> Carbonic acid .. 24·39 .... 40·00 .... 25·0
> Hydrogen .... 55·53 .... 51·15 .... 8·4
> Azote .... 20·08 .... 8·85 .... 66·6
> ——— ——— ———
> 100·00 100·00 100·0

3. Gases in the large intestines.

> Oxygen .... 0·00 .... 0·0
> Carbonic acid .... 43·50 .... 7·00
> Hydrogen and carbureted }
> hydrogen .... } 5·47 .... 11·6
> Azote .... 51·03 .... 18·4
> ——— ———
> 100·00 100·0

4. Gases in the cœcum.

> Oxygen .... 0·0
> Carbonic acid ...... 12·5
> Hydrogen .... 7·5
> Carbureted hydrogen . 12·5
> Azote .... 67·5
> ———
> 100·00

5. Gases in the rectum.

Oxygen .... 0·00
Carbonic acid .... 42·86
Carbureted hydrogen .. 11·18
Azote .... 45·96
——————
100·00 *

Such are the phenomena of digestion, as far as they have been traced. The food is first conveyed to the stomach, where, by means of the gastric juice, it is converted into chyme. The chyme passes into the intestinal canal, where it is subjected to a new process, being gradually decomposed and converted into chyle and excrementitious matter, which, by means of the bile, are separated from each other. The excrementitious matter is evacuated, but the chyle is absorbed by the lacteals, and conveyed to the blood vessels and lungs. Let us now endeavour to trace the changes produced on it by these organs.

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SECT. II.

OF RESPIRATION.

THE absolute necessity of respiration, or of something analogous, is known to every one; and few are ignorant that in man, and hot blooded animals, the organ by which respiration is performed is the lungs. Now respiration consists in drawing a certain quantity of air into the lungs, and throwing it out again alternately. Whenever this function is suspended, even for a very short time, the animal dies.

The fluid respired by animals is common atmospherical air; and it has been ascertained by experiment, that no other gaseous body with which we are acquainted can be substituted for it. All the known gases have been tried; but they all prove fatal to the animal which is made to breathe them. Gaseous bodies, as far as respiration is con-

* Ann. de Chim. et Phys. ii. 292.

cerned, may be divided into two classes: 1. Unrespirable Chap. III.
gases; 2. Respirable gases.

I. The gases belonging to the first class are of such a Unrespir-able gases.
nature that they cannot be drawn into the lungs of animals
at all; the epiglottis closing spasmodically whenever they
are applied to it. To this class belong carbonic acid, and
probably all the other acid gases, as has been ascertained
by the experiments of Pilatre de Rozier.* Ammoniacal
gas belongs to the same class; for the lungs of animals
suffocated by it were found by Pilatre not to give a green
colour to vegetable blues.†

II. The gases belonging to the second class may be Respirable gases, of four kinds.
drawn into the lungs, and thrown out again without any
opposition from the respiratory organs; of course the ani-
mal is capable of respiring them. They may be divided
into four subordinate classes: 1. The first set of gases oc- 1. Suffo-cate.
casion death immediately, but produce no visible change
in the blood. They occasion the animal's death merely by
depriving him of air, in the same way as he would be suf-
focated by being kept under water. The only gases which
belong to this class are *hydrogen* and *azotic*. 2. The second 2. Kill by ocasioning changes in the blood.
set of gases occasion death immediately, but at the same
time they produce certain changes in the blood, and there-
fore kill not merely by depriving the animal of air, but by
certain specific properties. The gases belonging to this
class are *carbureted hydrogen, sulphureted hydrogen,*‡ *car-* 3. Support life imper-fectly.
bonic oxide, and perhaps also *nitrous gas.* 3. The third set

* Jour. de Phys. xxviii. 418. Pilatre de Rozier went into a brewer's
tub while full of carbonic acid gas evolved by fermentation. A gentle
heat manifested itself in all parts of his body, and occasioned a sensible
perspiration. A slight itching sensation constrained him frequently to
shut his eyes. When he attempted to breathe, a violent feeling of suffo-
cation prevented him. He sought for the steps to get out; but not finding
them readily, the necessity of breathing increased, he became giddy, and
felt a tingling sensation in his ears. As soon as his mouth reached the
air he breathed freely, but for some time he could not distinguish objects;
his face was purple, his limbs weak, and he understood with difficulty
what was said to him. But these symptoms soon left him. He repeated
the experiment often; and always found, that as long as he continued
without breathing, he could speak and move about without inconve-
nience; but whenever he attempted to breathe, the feeling of suffocation
came on. Ibid. p. 422.

† Jour. de Phys. xxviii. 424.

‡ See Chausier's experiments, ibid. lvi. 35.

Book V.

4. May be
breathed
without in-
jury.

Oxygen ne-
cessary in
respiration.

of gases may be breathed for some time without destroy-
ing the animal, but death ensues at last, provided their ac-
tion be long enough continued. To this class belong the
nitrous oxide and oxygen gas.* 4. The fourth set may be
breathed any length of time without injuring the animal.
Air is the only gaseous body belonging to this class.†

It has been long known that an animal can only breathe
a certain quantity of air for a limited time; after which it
becomes the most deadly poison, and produces suffocation
as effectually as the most noxious gas, or a total absence of
air. It was suspected long ago that this change is owing
to the absorption of a part of the air; and Mayow made a
number of very ingenious experiments in order to prove
the fact. In 1757 Dr. Black, by breathing through lime-
water, ascertained that the air, when thrown out of the
lungs, contained carbonic acid.‡ This discovery was still
farther confirmed by Lavoisier in his first dissertation on
respiration, published in the Memoirs of the French Aca-
demy for 1777. Priestley and Scheele demonstrated that
the quantity oxygen in atmospherical air is diminished by
respiration. It was afterwards proved by Lavoisier, and
many other philosophers, who confirmed and extended his
facts, that no animal can live in air totally destitute of
oxygen. Even fish, which do not sensibly respire, die very
soon if the water in which they live be deprived of oxygen
gas. Frogs, which can suspend their respiration at plea-
sure, die in about forty minutes, if the water in which they
have been confined be covered over with oil.§ Insects and
worms, as Vauquelin has proved, exhibit precisely the
same phenomena. They require air as well as other ani-
mals, and die like them if they be deprived of it. They
diminish the quantity of oxygen in the air in which they
live, and give out, by respiration, the very same products
as other animals. Worms, which are more retentive of
life than most other animals, or at least not so much affected
by poisonous gases, absorb every particle of the oxygen

* Perhaps also nitrous gas might have the same effect, if it could be
breathed by an animal whose lungs contained no oxygen.
† For by far the completest account of all the experiments hitherto
made on the respiration of animals, the reader is referred to Dr. Bostock's
excellent Essay on Respiration. Nor are the clearness, impartiality, and
solid judgment of this author inferior to the extent of his information.
‡ Black's Lectures, ii. 87.   § Carradori, Ann. de Chim. xxix. 171.

contained in the air in which they are confined before they die. Mr. Vauquelin's experiments were made on the *gryllus viridissimus*, the *limax flavus*, and *helix pomatia*.*

The quantity of air respired differs very much in different animals. Man and hot-blooded animals are under the necessity of breathing constantly; whereas amphibious animals have a certain power over respiration, and can suspend the function altogether for a limited time. Dr. Barclay has ascertained that these animals acquire a much greater command over their respiratory organs by habit. Fish do not breathe at all, and consume so little air, that the small portion of it held in solution by the water in which they swim is sufficient for them. It appears that the number of respirations made in a given time differ considerably in different men. Dr. Hales reckons them at 20 in a minute. A man on whom Dr. Menzies made experiments, breathed only 14 times in a minute. Sir. H. Davy informs us that he makes between 26 and 27 in a minute. I myself make about 19 at an average. The average of all is 20. Now 20 in a minute make 28,800 in 24 hours.

The quantity of air drawn in and emitted at every respiration must differ considerably with the size of the man and the capacity of his lungs. Dr. Mensies found that a man draws in at a medium 40 cubic inches of air at every inspiration. Dr. Goodwin has concluded, from his experiments, that, after a complete expiration, the mean quantity of air which remains in the lungs amounts to 109 cubic inches; and Menzies has endeavoured to prove that, after an ordinary expiration, there remains 179. Davy has concluded that his lungs, after a forced expiration, still retain 41 cubic inches of air; after a natural expiration they contain . . . . 118 cubic inches.

After a natural inspiration 135
After a forced inspiration 254

By a full forced inspiration, after a forced exspiration, he threw out . . . . 190 cubic inches.
After a natural inspiration . . . . 78·5
After a natural expiration . . . . 67·5

Messrs. Allen and Pepys have calculated that, in an

* Ann. de Chim. xii. 278.

ordinary inspiration, 16·5 cubic inches of air are drawn into the lungs. In their experiments the average quantity of air thrown out of the lungs in an exspiration amounted to 61 cubic inches, but the breathing was much fuller and slower than usual. In one case a forced expiration amounted to 166 cubic inches; in another to 204 cubic inches. From the experiments of the same gentlemen it appears, that the lungs of a stout man about five feet ten inches high after death contain nearly 100 cubic inches of air.*

Dr. Menzies' estimate of an ordinary inspiration seems to approach nearest the average; but Dr. Bostock has shown that his estimate of the capacity of the lungs is too low. Perhaps we shall not err very much if we suppose, with him, that the ordinary quantity of air contained in the lungs is 280 cubic inches; and that 40 inches, or $\frac{1}{7}$th of the whole, is drawn in and thrown out at every ordinary respiration. This, supposing 20 respirations in a minute, will make the quantity of air drawn in and thrown out of the lungs every minute amount to 800 inches; to 48,000 inches in the hour; and to 1,152,000 inches in 24 hours, which amounts to rather more than $52\frac{1}{2}$ lbs avoirdupois. If this estimate is too high, it is probably at least as near the truth as that of Allen and Pepys, which appears as much too low.

Let us now endeavour to trace the changes produced by respiration. These are of two kinds, namely, 1. The changes produced upon the air respired; 2. Changes produced upon the blood exposed to this air. Each of these naturally claims our attention.

Changes produced on the air respired.

I. For our knowledge of the changes produced upon the air by respiration, we are chiefly indebted to Priestley, Cigna, Menzies, Lavoisier, and Seguin, Davy, Allen, and Pepys. These changes are the following: 1. Part of the oxygen of the air respired disappears; 2. Carbonic acid gas is found in its place; 3. It is loaded with water, in the state of vapour.

Change of bulk.

1. A considerable number of experiments have been made to determine the change of bulk which air undergoes by being respired. According to Davy, air, by a single inspiration and expiration, is diminished from $\frac{1}{70}$th to $\frac{1}{100}$th

* Phil. Trans. 1809.

part of its bulk.* In the numerous and accurate experiments made by Allen and Pepys on a very large scale, the average diminution was little more than half a per cent., and even this seems to have been owing rather to unavoidable inaccuracy than to real absorption. In the experiments of Berthollet, conducted also with very great care, the diminution varied from 0·69 to 3·70 per cent.† If, with Dr. Bostock, we take $\frac{1}{80}$th as the average diminution, and 40 inches as the quantity of air drawn into the lungs as each inspiration, then it will follow that half a cubic inch of the air disappears each time we respire. This in a day would amount 14,400 cubic inches, which is rather more than eight cubic feet.

When air is breathed till the animal can support it no longer, the diminution which it undergoes is variously stated. Davy found it to amount to $\frac{1}{18}$th of the whole air;‡ Lavoisier and Goodwyn to $\frac{1}{60}$th;§ Allen and Pepys to $\frac{1}{14}$th;|| and Crawford,** on the other hand, found no diminution at all. These numbers vary so much from each other, and from the estimate from a single respiration, that it is impossible to avoid concluding the diminution to be different at different times. I was induced by a letter from Mr. Dalton, in the summer of 1806, to make some experiments on the subject. In some cases I could perceive no diminution at all; in others it was perceptible. It was greatest when the animal was taken out repeatedly during the experiment, or when air was employed which was purer than that of the atmosphere. I am disposed to consider this diminution as accidental, and owing to some absorption of air altogether independent of respiration, and exceedingly various in different circumstances.

2. When the air drawn into the lungs is thrown out again, it is found deprived of a portion of its oxygen. Various experiments have been made to ascertain how much of this principle is lost by respiration in a given time; but they by no means correspond with one another. Indeed, it is extremely probable, if not absolutely certain, that the degree of effect which the same animal produces upon the

Oxygen consumed.

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* Davy's Researches, p. 431.   † Mem. d'Arcueil, ii. 461.
‡ Davy's Researches, p. 435.   § Bostock on Respiration, p. 87.
|| Phil. Mag. xxxii. 254.   ** Crawford on Heat, p. 146.

air respired differs materially at different times, and in consequence of different circumstances. Nothing therefore beyond an approximation can be expected from our experiments on this function.

Dr. Menzies was the first who attempted to ascertain the quantity of oxygen consumed by a man in a day. According to him, 36 inches are consumed in a minute, and of course 51,840 inches in 24 hours.* This estimate exceeds that obtained by Lavoisier and Davy from their experiments. Lavoisier and Seguin estimate the quantity of oxygen consumed by a man in 24 hours at 46,037 cubic inches, and this nearly coincides with the result which Lavoisier obtained from his last experiments, on which he was occupied when he was dragged to the place of execution. With this also the experiments of Davy coincide very well. He calculates that 31·6 inches of oxygen are consumed in a minute, which, in 24 hours, make 45,504 inches.† This coincidence would dispose us to embrace this result as affording a near approximation to the truth. We may conclude, then, that in a day a man consumes rather more than 25 cubic feet of oxygen. Now, since the oxygen amounts only to about one-fifth of the atmosphere, it follows, that in a day, a man destroys, or renders unfit for supporting combustion and respiration, no less than 125 cubic feet of air. The result obtained by Messrs. Allen and Pepys is somewhat less, or about 27·5 cubic inches per minute. And they think that in ordinary respiration the proportion consumed is much smaller.

Carbonic acid formed.
3. The air which is thrown out of the lungs contains in it a quantity of carbonic acid which did not exist in it previous to its being used for respiration. Dr. Menzies conceived that the bulk of this gas is precisely equivalent to that of the oxygen consumed. This also was the result of the experiments of Dr. Crawford. Lavoisier, in his experiments on the Guinea pig, found it somewhat less. In his first experiment he found the oxygen consumed, to the carbonic acid formed, as 20 to 16·5; in his second, as 20 to 17·3.‡ In his experiments on Seguin, in 1789, the

* Bostock on Respiration, p. 81.   † Davy's Researches, p. 433.
‡ See the details, Mem. Par. 1780, p. 401; Ann. de Chim. v. 261; and in Bostock on Respiration, p. 79.

oxygen consumed was to the bulk of carbonic acid formed nearly as 20 to 16·6; but in those that were made afterwards, the proportion of carbonic acid is diminished by nearly one-half. In Davy's experiments, the bulk of carbonic acid formed corresponded very nearly with that of the oxygen consumed; * so that in this respect they coincided with those of Crawford and Menzies. I was informed by Mr. Dalton, in the summer of 1806, that he had satisfied himself, by a variety of experiments, that the bulk of carbonic acid gas formed was exactly equal to that of the oxygen gas consumed. On repeating the experiment with that particular view, I found that in some cases this took place very nearly; but upon the whole, the bulk of oxygen which disappeared was somewhat greater than that of the carbonic acid formed; but the difference varied considerably, and kept pace with the diminution of the bulk of air by respiration. Hence I consider it as owing to the abstraction of a part of the air by some other way than respiration. If this abstraction be allowed for, I have no doubt, from my own experiments, that the bulk of the carbonic acid formed by respiration is precisely equal to that of the oxygen which has disappeared. The absolute quantity it is difficult to state, as it depends upon a variety of circumstances. I am disposed to consider it, at an average, as approaching to 40,000 cubic inches in 24 hours, though probably somewhat under that quantity. Now, this quantity of carbonic acid contains little less than three quarters of a pound avoirdupois of carbon. Messrs. Allen and Pepys found the carbonic acid formed exactly equal in bulk to the oxygen which had disappeared. It amounted in their experiments to about 27½ cubic inches per minute, or 39,534 cubic inches in 24 hours, a quantity which contains about 11 ounces troy of solid carbon. Air thrown out of the lungs contained in their experiments about 8 per cent. of carbonic acid gas. In Berthollet's experiments, the carbonic acid gas formed varied from 5·53 to 13·82 per cent. But the animal was confined for several hours in the same air. †

4. Dr. Priestley concluded from his experiments, that Azote. not only the oxygen, but the azote also, of the air respired

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* Davy's Researches, p. 431.　　† Mem. d'Arcueil, ii. 461.

was diminished.* This opinion was still farther confirmed by Davy, who found the consumption of azote to amount to about $\frac{1}{7}$th of that of the oxygen.† Dr. Henderson has made experiments with the same result, though the proportion of azote absorbed was rather less. ‡ Upon repeating these experiments, I found likewise a loss of azote; but it was extremely inconstant, sometimes being scarcely perceptible, and at other times considerable. It kept pace with the diminution of the bulk of the air respired, and with the difference between the bulk of the oxygen consumed and the carbonic acid formed. Hence I am disposed to ascribe all these differences to the same cause. I conceive that a portion of the air respired disappears without undergoing any change, and that this portion occasions the diminution of the azote, and the difference between the bulk of the carbonic acid formed and the oxygen consumed. What comes of this portion of air it is difficult to say; but I think it conceivable that the disappearing of such a portion may be confined to the unnatural circumstances occasioned by the experiment; that the difficulty of throwing out the air from the lungs in these circumstances may be such as to induce absorbents to act, and remove a portion which, in the ordinary situation of the lungs, would have been thrown out by expiration. Messrs. Allen and Pepys, in all their experiments, found no change in the azote, and no absorption of it whatever. Hence it is probable that the diminution formerly observed may have been owing to errors in the experiments. Berthollet found the proportion of azote to increase a little instead of diminishing, which he ascribes to the increased bulk of the air from moisture and heat.

Carbonic acid formed at different periods of the day.
5. Dr. Prout has shown by a number of well-conducted experiments on himself, that the proportion of carbonic acid formed at each inspiration is different at different periods of the day. It is at its maximum nearly about noon, and is at its minimum about midnight. It appears farther from his trials that the quantity of carbonic acid gas in expired air begins to increase nearly at twilight. The following table exhibits the proportion per cent. of

* Priestley, ii. 380.   † Davy's Researches, p. 433.
‡ Nicholson's Jour. viii. 44.

carbonic acid in the air expired from his lungs during every hour of the day. The experiments from which it was deduced were made in August.*

Hour A. M.	Carbonic acid per cent.	Hour P. M.	Carbonic acid per cent.
6	3·43	6	3·40
7	3·48	7	3·35
8	3·56	8	3·32
9	3·66	9	3·30
10	3·78	10	3·30
11	3·92	11	3·30
12	4·10	12	3·30
1	3·98	1	3·30
2	3·80	2	3·30
3	3·65	3	3·30
4	3·54	4	3·33
5	3·46	5	3·38

Mean 3·45

Dr. Prout found that alcohol and all fermented liquors diminished the proportion of carbonic acid formed by respiration, and this was confirmed by the experiments of Dr. A. Fyfe. They found likewise that when the constitution is affected by mercury, the proportion of carbonic acid gas in the air expired is diminished. Dr. Fyfe found that the quantity was likewise diminished by a course of nitric acid, and by a vegetable diet.†

6. It is not so easy to determine the proportion of water Water emitted from the lungs mixed with the air expired, as it is emitted. that of the carbonic acid. According to the experiments of Dr. Hales, it amounts in a day to 20·4 oz.; ‡ but his method was not susceptible of great accuracy. Mr. Lavoisier, on the other hand, estimates it rather higher; but the proportion seems rather to have been the result of calculation than of any direct measurement. The result of a few trials which I made during the summer of 1806, gave me very nearly 19 ounces per day as the quantity emitted from my own lungs; but I do not lay much stress

* Annals of Philosophy, ii. 328, and iv. 331.   † Ibid. iv. 334.
‡ Veget. Stat. ii. 327.

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Book V. upon the results, as they were not sufficiently varied to give a fair average; but I think it worth while to mention the method I followed, on account of its simplicity. I filled a a glass with water, and then by breathing on it, and gradually raising its temperature till the vapour of the breath just ceased to be condensed, I ascertained the force of the vapour contained in the air respired from Mr. Dalton's table. Then, ascertaining the force of vapour in the atmosphere at the time, and subtracting it from the force of the vapour in the breath, I obtained the force of the vapour actually emitted from the lungs. Supposing 40 inches of air to be drawn in at each inspiration, it was easy to calculate, from Dalton's table, the weight of the vapour which it contained when emitted.

7. In ordinary cases of respiration, the oxygen, which disappears, is just balanced by the carbonic acid formed, so that the bulk of the air continues unaltered : but it appears from the experiments of Messrs. Allen and Pepys, that when the same quantity of air is breathed backwards and forwards as long as possible, a greater quantity of oxygen disappears than can be accounted for by the carbonic acid formed. This oxygen is absorbed by the system. It diminishes the bulk of the air respired, and amounts to about $\frac{1}{14}$th of the whole air respired at an average.

Respiration of oxygen gas. 8. When oxygen gas, nearly pure, is breathed, rather a greater quantity of carbonic acid is given out; for the air expired contains, at an average, above ten per cent. of that gas. It appears also from the experiments of Messrs. Allen and Pepys, that a portion of the oxygen gas disappears, and then an equal bulk of azotic gas is found in its place. This substitution of azote is greatest at the commencement of the experiment, and diminishes as the respiration continues. It is difficult at present to account for this substitution. The quantity observed, amounting at an average to nearly 80 cubic inches, is too great to be ascribed to an error in the experiment. It can only be fully accounted for when we become acquainted with the composition of azote, which is still unknown.

Of a mixture of oxygen and hydrogen. 9. When an animal is made to breath a mixture of 79 hydrogen gas and 21 oxygen gas, the respiration goes on without any inconvenience; carbonic acid gas is formed as

usual, and at the same time a portion of the oxygen dis-
appears, and azote is found in its place. This mixture has
a sedative effect, and makes the animal sleepy. It appears
probable, from the observations of Messrs. Allen and Pepys,
that during sleep the quantity of carbonic acid formed is
less than when the animal is awake.

10. A great number of experiments have lately been
made on the respiration of fishes by Provençal and Hum-
boldt.* It is well known that these animals require oxygen
gas as well as other animals, and that if the water in which
they are be deprived of the whole of its air, they die very
speedily. Provençal and Humboldt employed for their ex-
periments the water of the Seine. They separated the air
from a quantity of it by boiling, and subjected it to a che-
mical analysis. Into another quantity of the same water
tenches were put and confined for several hours till they
began to suffer; they were then withdrawn, and the air se-
parated from the water in which they had lived, and sub-
jected to chemical analysis. In every case a portion,
both of oxygen and azote had disappeared, and a quantity
of carbonic acid had been formed. The following table ex-
hibits the results of a variety of their experiments.

* Mem. d'Arcueil, ii. 259.

Nature of the gases.	Gases before experiment.	Ditto after ditto.	Difference.	The fishes have		Azote absorbed, the oxygen being 100.	Carb. acid produced, the oxygen absorbed being 100.	Number of fishes and time.
				Absorbed.	Produced.			
Total..	175·0	135·1	39·9	—	—	—	—	Three tenches during 5 hours, 15 minutes.
Oxygen......	52·1	5·6	—	46·5	—	—	—	
Azote	115·9	95·8	—	20·1.	—	43	57	
Carbonic acid	7·0	33·7	—	—	26·7	—	—	
Total	524·0	404·0	119·6	—	—	—	—	Seven tenches during 6 hours.
Oxygen	155·9	44·0	—	111·9	—	—	—	
Azote	347·1	249·5	—	97·6	—	87	80	
Carbonic acid	21·0	110·9	—	—	89·9	—	—	
Total	524·0	453·0	71·0	—	—	—	—	Seven tenches during 8 hours.
Oxygen	155·9	10·5	—	145·4	—	—	—	
Azote	347·1	289·5	—	57·6	—	40	91	
Carbonic acid	21·0	153·0	—	—	132·0	—	—	
Total........	483·0	345·5	137·5	—	—	—	—	One tench during 17 hours.
Oxygen......	143·7	4·2	—	139·5	—	—	—	
Azote	320·0	294·1	—	25·9	—	19	—	
Carbonic acid	19·3	47·2	—	—	27·9	—	20	
Total.........	483·0	408·0	75·0	—	—	—	—	Three tenches during 7½ hours.
Oxygen	143·7	62·6	—	81·1	—	—	—	
Azote	320·0	285·4	—	34·6	—	43	—	
Carbonic acid	19·3	60·0	—	—	40·7	—	50	
Total	483·0	398·6	84·4	—	—	—	—	Three tenches during 5 hours.
Oxygen......	143·7	40·0	—	103·7	—	—	—	
Azote	320·0	246·6	—	73·4	—	71	—	
Carbonic acid	19·3	112·0	—	—	92·7	—	89	
Total........	483·0	372·5	110·5	—	—	—	—	Two tenches during 7 hours.*
Oxygen......	143·7	37·8	—	105·9	—	—	—	
Azote	320·0	252·9	—	67·1	—	63	—	
Carbonic acid	19·3	81·8	—	—	62·5	—	59	

The quantity of gas obtained from the Seine water, was at an average 0·0275 of its bulk, or not quite $\frac{1}{36}$ part; the average quantity of oxygen which this gas contained was 0·310.

From these experiments it appears, that the respiration of fishes differs very much from that of other animals. The oxygen is not merely converted into carbonic acid, as happens during the respiration of men and the larger ani-

* The numbers in this table indicate cubic centimetres. A cubic centimetre is equal to 0·0610 of a cubic inch.

mals; but a portion of it is absorbed and introduced into the system. A portion also of azote is absorbed. The quantity of air consumed by fishes is extremely small, when compared with that consumed by terrestrial animals. This will appear from the following table, in which the bulk of the air consumed, and of the carbonic acid formed in an hour, is stated in cubic inches.

Time.	Oxygen in the air after the experiments.	Number of fish.	Hours the experiment lasted.	Absorption in 1 hour in cubic inches.		Carbonic acid produced, in cubic inches.
				Oxygen.	Azote.	
28 Feb.	0·056	3	5¼	0·0245	0·0106	0·0140
3 March	0·151	7	6	0·0221	0·0192	0·0177
7 March	0·034	7	8½	—	—	0·0185
11 March	0·017	1	17	0·0679	0·0126	0·0136
28 Feb.	0·178	3	7½	0·0298	0·0123	0·0150
24 Feb.	0·141	3	5	0·0575	0·0405	0·0512
20 Feb.	0·130	2	7	0·0635	0·0397	0·0370

From this table, compared with the facts stated in the preceding part of this section, it follows, that in a given time a man consumes 50,000 times as much oxygen gas as a tench. Yet the presence of this principle is equally necessary for the existence of both.

II. Let us now endeavour to ascertain the changes pro- Changes duced on the blood by respiration. The whole of the produced blood is propelled from the heart to the lungs, circulates blood. through the vessels of that organ; and during that circulation it is exposed to the influence of the air which the animal is constantly drawing into the lungs. Now, certain changes are produced upon it by this action, which have been partly traced by the experiments of Priestley, Cigna, Fourcroy, Hassenfratz, Beddoes, Watt, and above all by those of Davy. These changes, as far as we are acquainted with them, are the following: 1. It acquires a florid red

colour, and the chyle disappears; 2. It loses a portion of carbon; 3. It emits water.

1. It has been long known that the blood which flows in the veins is of a dark reddish purple colour, whereas the arterial blood is of a florid scarlet colour. Lower observed that the colour of the venous blood was converted into that of arterial during its passage through the lungs. No chyle can be distinguished by its white colour in the blood after it has passed through the lungs. The changes, then, which take place upon the appearance of the blood are two: 1. It acquires a florid red colour: 2. The chyle totally disappears. Lower himself knew that the change was produced by the air, and Mayo attempted to prove that it was by absorbing a part of the air. But it was not till Dr. Priestley discovered that venous blood acquires a scarlet colour when put in contact with oxygen gas, and arterial blood a dark red colour when put in contact with hydrogen gas; or, which is the same thing, that oxygen gas instantly gives venous blood the colour of arterial; and hydrogen, on the contrary, gives arterial blood the colour of venous blood—it was not till then that philosophers began to attempt any thing like an explanation of the phenomena of respiration.

Action of different gases on blood. The blood is a fluid of so complex a nature that it is not easy to ascertain the changes produced in it by exposure to different gases out of the body; and even if that could be done, we have no method of proving that the effects of these gaseous bodies upon the coagulated blood are the same as they would be on the blood in its natural state, circulating in the vessels of a living animal. The facts which have been ascertained are the following:

1 Oxygen, 1st. It appears from the experiments of Priestley, Girtanner, and Hassenfratz, that when venous blood is exposed to oxygen gas confined over it, the blood instantly assumes a scarlet colour. Davy could not perceive any sensible diminution of the bulk of the gas.

2. Air, 2d. The same change of colour takes place when blood is exposed to common air. In this case a quantity of carbonic acid gas is formed, and a quantity of oxygen gas, exactly equal to it in bulk, disappears; making allowance for the small quantity of carbonic acid, which we may suppose to be absorbed by the blood itself.

3. Azote. 3d. Venous blood exposed to the action of azotic gas

continues unaltered in colour; neither does any perceptible diminution of the gas ensue.

4th. Venous blood exposed to the action of nitrous gas becomes of a deep purple, and about $\frac{1}{8}$th of the gas is absorbed.

5th. Venous blood exposed to nitrous oxide becomes of a brighter purple, especially on the surface, and a considerable portion of the gas is absorbed.

6th. Venous blood exposed to carbonic acid gas becomes of a brownish-red colour, much darker than usual, and the gas is slightly diminished in bulk.

7th. Carbureted hydrogen gas gives venous blood a fine red colour, a shade darker than oxygen gas does, as was first observed by Dr. Beddoes, and at the same time a small portion of the gas is absorbed. This gas has the property of preventing, or at least greatly retarding, the putrifaction of blood, as was first observed by Mr. Watt.*

8th. When arterial blood is put in contact with azotic gas, or carbonic acid gas, it gradually assumes the dark colour of venous blood, as Dr. Priestley found. †. The same philosopher also observed, that arterial blood acquired the colour of venous blood when placed *in vacuo.* ‡ Consequently this alteration of colour is owing to some change which takes place in the blood itself, independent of any external agent.

The arterial blood becomes much more rapidly and deeply dark coloured when it is left in contact with hydrogen gas placed above it. § We must suppose therefore that the presence of this gas accelerates and increases the change, which would have taken place upon the blood without any external agent.

9th. If arterial blood be left in contact with oxygen gas, it gradually assumes the same dark colour which it would have acquired *in vacuo,* or in contact with hydrogen; and after this change oxygen can no longer restore its scarlet colour.‖ Therefore it is only upon a part of the blood that the oxygen acts; and after this part has undergone the change which occasions the dark colour, the blood loses the power of being affected by oxygen.

* Davy's Researches, p. 380.   † Priestley, iii. 363,
‡ Priestley, iii. 363, and Ann. de Chim. ix. 269.
§ Fourcroy, ibid. vii. 149.   ‖ Ibid. ix. 268.

10th. Mr. Hassenfratz poured into venous blood a quantity of chlorine; the blood was instantly decomposed, and assumed a deep and almost black colour. When he poured common muriatic acid into blood, the colour was not altered.*

Theory of
Priestley.

2. Dr. Priestley, the first of the modern chemists who turned his attention to respiration, concluded from some of his earliest experiments, that the blood, as it passed through the lungs, gave out phlogiston to the air, which was expired loaded with that substance; and of course that the purpose of respiration was to free the blood of phlogiston. Lavoisier soon after ascertained with more precision the changes which the air undergoes during respiration; and he formed a theory in order to explain that function, assuming as its basis that all the changes on the air inspired are produced in the lungs; and of course, that all the new sub-

Modified
by Lavoi-
sier.

stances expired are formed in the lungs. According to him, the blood absorbs no air in the lungs; but it gives out hydrogen and carbon, which, combining with the oxygen of the air inspired, form water and carbonic acid. This theory was adopted by Laplace, Crawford, Gren, and Girtanner, with a small variation. Indeed it does not differ, except in detail, from the original hypothesis of Dr. Priestley, that the use of respiration is to rid the blood of phlogiston; for if we substitute carbon and hydrogen for phlogiston, the two theories precisely agree. Mr. Lavoisier attempted not to prove its truth; he only tried to show that the oxygen absorbed corresponds exactly with the quantity of oxygen contained in the carbonic acid and the water emitted.

Theory of
La Grange.

A different theory was afterwards proposed by Mr. De La Grange. According to this philosopher, the oxygen gas, which disappears, combines with the blood as it passes through the lungs; and at the instant of this combination there is set free from the blood a quantity of carbonic acid gas and of water, which are thrown out along with the air expired. This theory was adopted and illustrated by Mr. Hassenfratz. But as the carbonic acid formed is exactly equal to the bulk of the oxygen which disappears, this oxygen must be changed into carbonic acid in the lungs;

* Fourcroy, ix. 268.

for oxygen, when changed into carbonic acid, does not sensibly alter its bulk. The blood, then, must emit carbon in the lungs to the extent of about ¾ths of a pound in the day. This, I conceive, is all that happens in the lungs. The watery vapour, indeed, is doubtless secreted from the blood to mix with the air inspired; but probably the secretion takes place in appropriate organs. By the loss of carbon the venous blood is changed into arterial. The very same thing happens when venous blood is presented to the air.

The change of the chyle into blood, I presume, takes Chyle con-place in the blood-vessels. Indeed the blood is a liquid verted into blood. which is constantly running through a suite of changes. Hence it is kept of a similar nature only by the constant influx of new matter, which is as constantly manufactured into blood. It appears, from the most accurate observations hitherto made, that neither chyle nor lymph contain fibrin, which forms a very conspicuous part of the blood. This fibrin is employed to supply the waste of the muscles; the most active parts of the body, and therefore in all probability, requiring the most frequent supply. Nor can it be doubted that it is employed for other useful purposes. The quantity of fibrin in the blood, then, must be constantly diminishing, and therefore new fibrin must be constantly formed. But the only substances out of which it can be formed are the chyle and lymph, neither of which contain it. There must therefore be a continual decomposition of the chyle and lymph going on in the blood-vessels, and a continual new formation of fibrin. Other substances also may be formed; but we are certain that this *must* be formed there, because it does not exist previously. Now, one great end of respiration must undoubtedly be to assist this decomposition of chyle and complete formation of blood.

In what manner the chyle, or a part of it, is converted into fibrin, it is impossible to say: we are not sufficiently acquainted with the subject to be able to explain the process. But we can see, at least, that carbon must be abstracted from that part of the chyle which is to be converted into fibrin. Hence, as the process of blood-making advances, there must be a greater and greater redundancy of carbon in the liquid. Unless this redundancy were re-

moved, the process could not go on, and probably the whole would run into putrifaction. We may conclude, then, that one great use of respiration is to abstract this carbon, by forming with it carbonic acid. How this is performed, indeed, it is impossible at present to explain; but the fact is undoubted.

Animal heat.

But the abstraction of carbon is not the only advantage gained by respiration : the *temperature* of all animals depends upon it. It has been long known, that those animals which do not breathe have a temperature but very little superior to the medium in which they live. This is the case with fishes and many insects. Man, on the contrary, and quadrupeds, which breathe, have a temperature considerably higher than the atmosphere : that of man is 98°. Birds, which breathe in proportion a still greater quantity of air than man, have a temperature equal to 103° or 104°. It has been proved, that the temperature of all animals is proportional to the quantity of air which they breathe in a given time.

These facts seem sufficient to demonstrate that the heat of animals depends upon respiration. But it was not till Dr. Black's doctrine of latent heat became known to the world, that any explanation of the cause of the temperature of breathing animals was attempted. That illustrious philosopher, whose discoveries form the basis upon which all the scientific part of chemistry has been reared, saw at once the light which his doctrine of latent heat threw upon this part of physiology, and he applied it very early to explain the temperature of animals.

Dr. Black's theory.

According to him, part of the latent heat of the air inspired becomes sensible; and of course the temperature of the lungs, and the blood that passes through them, must be raised; and the blood, thus heated, communicates its heat to the whole body. This opinion was ingenious, but it was liable to an unanswerable objection : for if it were true, the temperature of the body ought to be greatest in the lungs, and to diminish gradually as the distance from the lungs increases; which is not true. The theory, in consequence, was abandoned even by Dr. Black himself; at least he made no attempt to support it.

Theory of Crawford.

Dr. Crawford, who considered all the changes operated by respiration as taking place in the lungs, accounted for

the origin of the animal heat almost precisely in the same way with Dr. Black. According to him, the oxygen gas of the air combines in the lungs with the carbon emitted by the blood. During this combination, the oxygen gives out a great quantity of caloric, with which it had been combined; and this caloric is not only sufficient to support the temperature of the body, but also to carry off the new-formed water in the state of vapour, and to raise considerably the temperature of the air inspired. According to this philosopher, then, the whole of the caloric which supports the temperature of the body is evolved in the lungs. His theory accordingly was liable to the same objection with Dr. Black's; but Dr. Crawford obviated it in the following manner: He found that the specific caloric of arterial blood was 1·0300, while that of venous blood was only 0·8928. Hence he concluded, that the instant venous blood is changed into arterial blood, its specific caloric increases; consequently it requires an additional quantity of caloric to keep its temperature as high as it had been while venous blood. This addition is so great, that the whole new caloric evolved is employed : therefore the temperature of the lungs must necessarily remain the same as that of the rest of the body. During the circulation, arterial blood is gradually converted into venous; consequently its specific caloric diminishes, and it must give out heat. This is the reason that the temperature of the extreme parts of the body does not diminish.

But this theory, ingenious and plausible as it is, has not been able to stand the test of subsequent investigations. Dr. John Davy has shown that the difference between the specific caloric of arterial and venous blood is much smaller than Dr. Crawford had estimated it. According to Dr. Davy, the specific caloric of these liquids is as follows :

Arterial blood .... 0·913
Venous blood .... 0·903

Delaroche and Berard have shown that the specific caloric of oxygen gas and carbonic acid gas differs much less than Crawford had supposed. According to these philosophers, the specific heats of these gases are as follows :

Oxygen gas .... 0·8848
Carbonic acid gas .... 0·8280

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Now such minute differences would hardly admit the application of Dr. Crawford's explanation. But the most formidable objections result from the experiments of Mr. Brodie. He found that when artificial respiration is kept up in the lungs of animals, after decapitation, the usual proportion of carbonic acid gas is formed, and the circulation continues nearly as usual. Yet in these animals the heat diminishes more rapidly than in a dead animal, in which artificial respiration is not kept up.* From these experiments Mr. Brodie concludes that the production of animal heat is owing to the action of the brain, and not to respiration.

I think it must be admitted that these experiments have entirely destroyed the foundations on which Dr. Crawford's theory was built. But I am disposed to think that Mr. Brodie has gone rather too far in his consequences when he conceives that respiration has no connection whatever with the production of animal heat. The fact that all animals which respire regularly are hot-blooded, while amphibious animals and fishes are cold-blooded, seems to me to establish a connection between respiration and heat. Though we are unable to explain in what way the heat is evolved.

SECT. III.

OF THE ACTION OF THE KIDNEYS.

Thus we have reason to suppose that chyle and lymph are converted into blood during the circulation : but besides the lungs and arteries, there is another organ, the sole use of which is also to produce some change or other in the blood, which renders it more complete, and more proper for the various purposes to which it is applied. This organ is the KIDNEY.

A very great proportion of blood passes through the kidneys; indeed we have every reason to conclude that the whole of the blood passes through them very frequently.

* Phil. Trans. 1812, p. 378.

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These organs separate the urine from the blood, to be after-
wards evacuated without being applied to any purpose use-
ful to the animal.

The kidneys are absolutely necessary for the continuance
of the life of the animal; for it dies very speedily when they
become by disease unfit to perform their functions: there-
fore the change which they produce in the blood is a change
necessary for qualifying it to answer the purposes for which
it is intended.

As the urine is immediately excreted, it is evident that
the change which the kidneys perform is intended solely for
the sake of the blood. It is not merely the abstraction of
a quantity of water and of salts, accumulated in the blood,
which the kidney performs. A chemical change is certainly
produced, either upon the whole blood, or at least on some
important part of it; for there are two substances found in the
urine which do not exist in the blood. These two sub-
stances are urea and uric acid. They are formed, therefore,
in the kidneys; and as they are thrown out, after being
formed, without being applied to any useful purpose, they
are certainly not formed in the kidneys for their own sake.
Some part of the blood, then, must be decomposed in the
kidney, and a new substance, or new substances, must be
formed; and the urea and uric acid must be formed at the
same time, in consequence of the combined action of the
affinities which produce the change on the blood; and being
useless, they are thrown out together with a quantity of
water and salts, which, in all probability, were useful in
bringing about the changes which take place in the arteries
and in the kidneys, but which are no longer of any service
after these changes are brought about.

The changes operated upon the blood in the kidneys are
at present altogether unknown; but they must be impor-
tant. Provided the method of analysing animal substances
were so far perfected as to admit of accurate conclusions,
considerable light might be thrown upon this subject, by
analysing with care a portion of blood from the emulgent
vein and artery separately, and ascertaining precisely in
what particulars they differ from each other.

SECT. IV.

OF PERSPIRATION.

THUS we have seen that the principal changes which the blood undergoes, as far at least as we are at present acquainted with them, take place in the lungs, in the kidneys, and in the arteries. In the lungs, a quantity of water and carbonic acid gas is emitted from the blood; and in the kidneys, the urine is formed and separated from it. There seems also to be something thrown out from the blood during its circulation in the arteries, at least through those vessels which are near the surface of the body : for it is a fact, that certain substances are constantly emitted from the skins of animals. These substances are known in general by the name of *perspirable matter*, or *perspiration*. They have a great resemblance to what is emitted in the lungs; which renders it probable that both excretions are owing to the same cause; namely, to the decomposition produced in the blood by the effects of respiration.

Quantity perspired.

Many experiments have been made to ascertain the quantity of matter perspired through the skin. For the first set, and not the least remarkable, we are indebted to Sanctorius; who continued them for no less than 30 years. He ascertained his own weight and the weight of his food; and whatever weight he lost over and above that of his excrements, he ascribed to perspiration. A similar set of experiments was afterwards made in France by Dodart; in England by Keil; in Ireland by Bryan Robertson and Rye; and in Carolina by Lining. The result of all these experiments has been collected by Haller; but it gives us no precise estimate of the amount of the transpiration, since these philosophers have not distinguished between what is lost by the skin and by the lungs. Lavoisier and Seguin alone have attempted to ascertain the amount of the matter perspired through the skin. A bag composed of varnished silk, and perfectly air-tight, was procured, within which Seguin, who was usually the subject of experiment, was enclosed, and the bag was closed exactly over his head. There was a slit in the bag opposite to his mouth, and the edges of this slit were accurately cemented round the mouth by means of a mixture of turpentine and pitch. Thus

every thing emitted by the body was retained in the bag, Chap. III. except what made its escape from the lungs by respiration. By weighing himself in a delicate balance at the commencement of the experiment, and again after he had continued for some time in the bag, the quantity of matter carried off by respiration was ascertained. By weighing himself without this varnished covering, and repeating the operation after the same interval of time had elapsed as in the former experiment, he ascertained the loss of weight occasioned by perspiration and respiration. By subtracting from this sum the loss of weight indicated by the first experiment, he obtained the quantity of matter which made its escape by perspiration in a given time. The following facts were ascertained by these experiments:

1. The maximum of matter perspired in a minute amounted to 26·25 grains troy; the minimum to nine grains: which gives 17·63 grains at a medium in the minute, or 52·89 ounces in the 24 hours. This quantity differs less than might have been expected from the result of former experiments made by·Dodart, Keil, Rye, &c.

2. The quantity perspired is increased by drink, but not by solid food.

3. Perspiration is at its minimum immediately after a repast. It reaches its maximum during digestion.*

The quantity of matter perspired differs very considerably according to circumstances. It has been shown to be greatest in hot weather, and in hot climates, and after great exercise; and its relation to the quantity of urine has been long known. When the matter perspired is great, the quantity of urine is small, and *vice versa.*

To ascertain the substance thus emitted by perspiration Substances is a difficult task, because it passes off invisibly, and in small perspired. quantities at a time. It has, notwithstanding, been ascertained, that water, carbon, and an oily matter are emitted; and that an acid, phosphate of lime, and even urea, are sometimes emitted through the skin.†

It has been supposed that the skin has the property of *absorbing moisture* from the air; but this opinion has not been confirmed by experiments, but rather the contrary.

The chief arguments in favour of absorption of the skin Whether

* Fourcroy, ix. 198. † See the preceding Chapter, Sect. 25.

have been drawn from the quantity of moisture discharged by urine being, in some cases, not only greater than the whole drink of the patient, but even than the whole of his drink and food. But it ought to be remembered that, in diabetes, the disease here alluded to, the weight of the body is continually diminishing, and therefore part of it must be constantly thrown off. Besides, it is scarcely possible in that disease to get an accurate account of the food swallowed by the patients; and in those cases where very accurate accounts have been kept, and where deception was not so much practised, the urine was found not to exceed the quantity of drink.* In a case of diabetes, related with much accuracy by Dr. Gerard, the patient was bathed regularly during the early part of the disease in warm water, and afterwards in cold water: he was weighed before and after bathing, and no sensible difference was ever found in his weight.† Consequently, in that case, the quantity absorbed, if any, must have been very small.

It is well known that thirst is much alleviated by cold bathing. By this plan Captain Bligh kept his men cool and in good health during their very extraordinary voyage across the South Sea. This has been considered as owing to the absorption of water by the skin. But Dr. Currie had a patient who was wasting fast for want of nourishment, a tumor in the œsophagus preventing the possibility of taking food, and whose thirst was always alleviated by bathing; yet no sensible increase of weight, but rather the contrary, was perceived after bathing. It does not appear, then, that in either of these cases water was absorbed.

Farther, Seguin has shown that the skin does not absorb water during bathing, by a still more complete experiment: He dissolved some mercurial salt in water, and found that the mercury produced no effect upon a person that bathed in the water, provided no part of the cuticle was injured; but upon rubbing off a portion of the cuticle, the mercurial solution was absorbed, and the effects of the mercury became evident upon the body. Hence it follows irresistibly, that water, at least in the state of *water*, is not absorbed by the skin when the body is plunged into it, unless the cuticle be first removed.

* See Rollo on Diabetes.   † Ibid. ii. 73.

This may perhaps be considered as a complete proof that no such thing as absorption is performed by the skin; and that therefore the appearance of carbonic acid gas, which takes place when air is confined around the skin, must be owing to the emission of carbon. But it ought to be considered, that although the skin cannot absorb water, this is no proof that it cannot absorb other substances; particularly that it cannot absorb oxygen gas, which is very different from water. It is well known that water will not pass through bladders, at least for some time: yet Dr. Priestley found that venous blood acquired the colour of arterial blood from oxygen gas, as readily when these substances were separated by a bladder as when they were in actual contact. He found, too, that when gases were confined in bladders, they gradually lost their properties. It is clear from these facts, that oxygen gas can pervade bladders: and if it can pervade them, why may it not also pervade the cuticle? Nay, farther, we know from the experiments of Cruickshanks, that the vapour perspired passes through leather, even when prepared so as to keep out moisture, at least for a certain time. It is possible, then, that water, when in the state of vapour, or when dissolved in air, may be absorbed, although water, while in the state of water, may be incapable of pervading the cuticle. The experiments, therefore, which have hitherto been made upon the absorption of the skin are insufficient to prove that air and vapour cannot pervade the cuticle, provided there be any facts to render the contrary supposition probable.

Now, that there are such facts cannot be denied. I shall not indeed produce the experiment of Van Mons as a fact of that kind, because it is liable to objections, and at best is very indecisive. Having a patient under his care who, from a wound in the throat, was incapable for several days of taking any nourishment, he kept him alive during that time by applying to the skin, in different parts of the body, several times a-day, a sponge dipped in wine or strong soup.* A fact mentioned by Dr. Watson is much more important, and much more decisive. A lad at Newmarket,

* Phil. Mag. vi. 95.

Book V. who had been almost starved in order to bring him down to such a weight as would qualify him for running a horse race, was weighed in the morning of the race day; he was weighed again an hour after, and was found to have gained 30 ounces of weight; yet in the interval he had only taken half a glass of wine. Here absorption must have taken place, either by the skin or lungs, or both. The difficulties in either case are the same; and whatever renders absorption by one probable, will equally strengthen the probability that absorption takes place by the other.*

SECT. V.

OF ASSIMILATION.

WE have now seen the progress of digestion, and the formation of blood, as far at least as we are acquainted with it. But to what purposes is this blood employed, which is formed with so much care, and for the formation of which Blood an- so great an apparatus has been provided? It answers two swers two purposes. The parts of which the body is composed, bones, purposes: muscles, ligaments, membranes, &c. are continually chang-
1. Supplies the waste of ing. In youth they are increasing in size and strength, and the system. in mature age they are continually acting, and consequently continually liable to waste and decay. They are often exposed to accidents, which render them unfit for performing their various functions; and even when no such accident happens, it seems necessary for the health of the system that they should be now and then renewed. Materials therefore must be provided for repairing, increasing, or renewing all the various organs of the body; phosphate of lime and gelatin for the bones, fibrin for the muscles, albumen for the cartilages and membranes, &c. Accordingly all these substances are laid up in the blood; and they are

* Watson's Chemical Essays, iii. 101. The Abbé Fontana also found that, after walking in moist air for an hour or two, he returned home some ounces heavier than he went out, notwithstanding he had suffered considerable evacuation from a brisk purge purposely taken for the experiment. This increase, indeed, might be partly accounted for by the absorption of moisture by his clothes.

drawn from that fluid, as from a storehouse, whenever they are required. The process by which the different ingredients of the blood are made part of the various organs of the body is called ASSIMILATION.

Over the nature of assimilation the thickest darkness still hangs : there is no key to explain it, nothing to lead us to the knowledge of the instruments employed. Facts, however, have been accumulated in sufficient numbers to put the existence of the process beyond the reach of doubt. The healing, indeed of every fractured bone, and every wound of the body, is a proof of its existence, and an instance of its action.

Every organ employed in assimilation has a peculiar office; and it always performs this office whenever it has materials to act upon, even when the performance of it is contrary to the interest of the animal. Thus the stomach always converts food into chyme, even when the food is of such a nature that the process of digestion will be retarded rather than promoted by the change. If warm milk, for instance, or warm blood, be thrown into the stomach, they are always decomposed by that organ, and converted into chyme; yet these substances are much more nearly assimilated to the animal before the action of the stomach than after it. The same thing happens when we eat animal food.

On the other hand, a substance introduced into an organ employed in assimilation, if it has undergone precisely the change which that organ is fitted to produce, is not acted upon by that organ, but passed on unaltered to the next assimilating organ. Thus it is the office of the intestines to convert chyme into chyle. Accordingly, whenever chyme is introduced into the intestines, they perform their office, and produce the usual change; but if chyle itself be introduced into the intestines, it is absorbed by the lacteals without alteration. The experiment, indeed, has not been tried with true chyle, because it is scarcely possible to procure it in sufficient quantity ; but when milk, which resembles chyle pretty accurately, is thrown into the jejunum, it is absorbed unchanged by the lacteals.*

* Fordyce on Digestion, p. 189.

Again, the office of the blood-vessels, as assimilating organs, is to convert chyle into blood. Chyle, accordingly, cannot be introduced into the arteries without undergoing that change; but *blood* may be introduced from another animal without any injury, and consequently without undergoing any change. This experiment was first made by Lower, and it has since been very often repeated.

Also, if a piece of fresh muscular flesh be applied to the muscle of an animal, they adhere and incorporate without any change, as has been sufficiently established by the experiments of Mr. J. Hunter; and Buniva has ascertained, that fresh bone may, in the same manner, be engrafted on the bones of animals of the same or of different species.*

Foreign substances may be incorporated with the body.

In short, it seems to hold, at least as far as experiments have hitherto been made, that foreign substances may be incorporated with those of the body, provided they be precisely of the same kind with those to which they are added, whether fluid or solid. Thus chyle may be mixed with chyle, blood with blood, muscle with muscle, and bone with bone. The experiment has not been extended to the other animal substances, the nerves, for instance: but it is extremely probable that it would hold with respect to them also.

On the other hand, when substances are introduced into any part of the body which are not the same with that part, nor the same with the substance upon which that part acts, provided they cannot be thrown out readily, they destroy the part, and perhaps even the animal. Thus foreign substances introduced into the blood very soon prove fatal; and introduced into wounds of the flesh or bones, they prevent these parts from healing.

Powers of the assimilating organs limited.

Although the different assimilating organs have the power of changing certain substances into others, and of throwing out the useless ingredients, yet this power is not absolute, even when the substances on which they act are proper for undergoing the change which the organs produce. Thus the stomach converts food into chyme, the intestines chyme into chyle, and the substances which have not been converted into chyle are thrown out of the body. If there hap-

* Phil. Mag. vi. 308.

pen to be present in the stomach and intestines any sub-stance which, though incapable of undergoing these changes, at least by the action of the stomach and intestines, yet has a strong affinity, either for the whole chyme and chyle, or for some particular part of it, and no affinity for the sub-stances which are thrown out, that substance passes along with the chyle, and in many cases continues to remain che-mically combined with the substance to which it is united in the stomach, even after that substance has been com-pletely assimilated, and made a part of the body of the animal. Thus there is a strong affinity between the co-louring matter of madder and phosphate of lime. Accord-ingly, when madder is taken into the stomach, it combines with the phosphate of lime of the food, passes with it through the lacteals and blood vessels, and is deposited with it in the bones, as was proved by the experiments of Bechier * and Duhamel.†I n the same manner, musk, indigo, &c. when taken into the stomach, make their way into many of the secretions.

These facts show us that assimilation is a chemical pro-cess from beginning to end; that all the changes are pro-duced according to the laws of chemistry; and that we can even derange the regularity of the process by introducing substances whose mutual affinities are too strong for the organs to overcome.

It cannot be denied, then, that the assimilation of food consists merely in a certain number of chemical decompo-sitions which that food undergoes, and the consequent formation of certain new compounds. But are the *agents* employed in assimilation merely chemical agents? We cannot produce any thing like these changes on the food out of the body, and therefore we must allow that they are the consequence of the action of the animal organs. But this action, it may be said, is merely the secretion of parti-cular juices, which have the property of inducing the wished-

* Phil. Trans. 1736, p. 287.
† Ibid. 1740, p. 390. The fact was mentioned by Mizaldus in a book published in 1566, entitled, Memorabilium, utilium ac jucundorum Centuriæ novem.

for change upon the food : and this very change would be
produced out of the body, provided we could procure these
substances, and apply them in proper quantity to the food.
If this supposition be true, the specific action of the vessels
consists in the secretion of certain substances ; consequently
the cause of this secretion is the *real* agent in assimilation.
Now, can the *cause* of this secretion be shown to be merely
a chemical agent? Certainly not. For in the stomach,
where only this secretion can be shown to exist, it is not
always the same, but varies according to circumstances.
Thus eagles at first cannot digest grain, but they may be
brought to do it by persisting in making them use it as
food. On the contrary, a lamb cannot at first digest animal
food, but habit will also give it this power. In this case,
it is evident that the gastric juice changes according to cir-
cumstances.

But the a-
gent not
chemical.

The presence of some agent, different from a mere che-
mical power, will be still more evident, if we consider the
immunity of the stomach of the living animal during the
process of digestion. The stomach of animals is as fit for
food as any other substance. The gastric juice, therefore,
must have the same power of acting on it, and of decompo-
sing it, that it has of acting on other substances; yet it is
well known that the stomach is not affected by digestion
while the animal retains life; though, as Mr. Hunter
ascertained, the very gastric juice which the living stomach
secretes, often dissolves the stomach itself after death.*
Now what is the power which prevents the gastric juice
from acting on the stomach during life? Certainly neither
a chemical nor mechanical agent, for these agents must still
retain the same power after death. We must, then, of ne-
cessity conclude, that there exists in the animal an agent
very different from chemical and mechanical powers, since
it controuls these powers according to its pleasure. These
powers, therefore, in the living body, are merely the ser-
vants of this superior agent, which directs them so as to
accomplish always one particular end. This agent seems
to regulate the chemical powers, chiefly by bringing only

* Phil. Trans. 1772, p. 447.

certain substances together which are to be decomposed, and by keeping at a distance those substances which would interfere with, or diminish, or spoil the product, or injure the organ ; and we see that this separation is always attended to even when the substances are apparently mixed together : For the very same products are not obtained, which would be obtained by mixing the same substances together out of the body, that are produced by mixing them in the body ; consequently all the substances are not left at full liberty to obey the laws of their mutual affinities. The superior agent, however, is not able to exercise an unlimited authority over the chemical powers ; sometimes they are too strong for it : some substances, accordingly, as madder, make their way into the system ; while others, as arsenic, decompose and destroy the organs of the body themselves.

But it is not in digestion alone that this superior agent makes the most wonderful display of its power; it is in the last part of assimilation that our admiration is most powerfully excited. How comes it that the precise substances wanted are always carried to every organ of the body? How comes it that fibrin is always regularly deposited in the muscles, and phosphate of lime in the bones ? And, what is still more unaccountable, how comes it that prodigious quantities of some one particular substance are formed and carried to a particular place, in order to supply new wants which did not before exist ? A bone, for example, becomes diseased and unfit for the use of the animal; a new bone therefore is formed in its place, and the old one is carried off by the absorbents. In order to form this new bone, large quantities of phosphate of lime are deposited in a place where the same quantity was not before necessary. Now, who informs this agent that an unusual quantity of phosphate of lime is necessary, and that it must be carried to that particular place? Or, granting, as is most probable, that the phosphate of lime of the old bone is partly employed for this purpose, who taught this agent that the old bone must be carried off, new-modelled, and deposited and assimilated anew? The same wonders take place during the healing of every wound, and the renewing of every diseased part.

But neither in this case is the power of this agent over

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the chemical agents which are employed absolute. We may prevent a fractured bone from healing, by giving the patient large quantities of acids. And unless the materials for new-wanted substances be supplied by the food, they cannot in many cases be formed at all. Thus the canary bird cannot complete her eggs unless she be furnished with lime.

Nature of this agent.

As this agent which characterises living bodies does not appear to act according to the principles of chemistry, any inquiry into its nature would be foreign to the subject of this work. Physiologists have given it the name of the *living* or *animal* principle; and to them I beg leave to refer the reader.

2. Blood furnishes the materials of secretion.

Besides the different organs of the body, the blood is also employed in forming all the different secretions which are necessary for the purposes of the animal economy. These have been enumerated in the last chapter. The process is similar to that of assimilation, and undoubtedly the agents in both cases are the same: but we are equally ignorant of the precise manner in which secretion is performed as we are of assimilation.

Animals decay and die.

After these functions have gone on for a certain time, which is longer or shorter according to the nature of the animal, the body gradually decays, at last all its functions cease completely, and the animal dies. The cause of this must appear very extraordinary, when we consider the power which the animal has of renewing decayed parts; for it cannot be doubted that death proceeds, in most cases at least, from the body becoming incapable of performing its functions. But if we consider that this power is limited, and that it must cease altogether when those parts of the system begin to decay which are employed in preparing materials for future assimilation, our surprise will, in some measure, cease. It is in these parts, in the organs of digestion and assimilation, accordingly, that this decay usually proves fatal. The decay in other parts destroys life only when the waste is so rapid that it does not admit of repair.

What the reason is that the decay of the organs causes death, or, which is the same thing, causes the living principle either to cease to act, or to leave the body altogether,

it is perfectly impossible to say, because we know too little of the nature of the living principle, and of the manner in which it is connected with the body. The last is evidently above the human understanding; but many of the properties of the living principle have been discovered: and were the facts already known properly arranged, and such general conclusions drawn from them as their connection with each other fully warrant, a degree of light would be thrown upon the animal economy, which those who have not attended to the subject are not aware of.

No sooner is the animal dead, than the chemical and mechanical agents, which were formerly servants, usurp the supreme power, and soon decompose and destroy that very body which had been in a great measure reared by their means. But the changes which take place upon animal bodies after death, are too important to be passed over slightly. They shall therefore form the subject of the next chapter.

CHAP. IV.

OF THE DECOMPOSITION OF ANIMAL BODIES.

The rapidity with which animal bodies undergo decomposition, and the disgusting fetor which accompanies this decomposition, have long been considered as some of their most striking peculiarities. This spontaneous destruction is denominated *putrifaction*. Considerable attention has been paid to it by chemists. Beccher and Stahl have described with fidelity the phenomena with which it is attended, and the circumstances necessary for its taking place. Several curious remarks on it were made by Boyle and Beale.* To Sir John Pringle we are indebted for some important experiments on the method of retarding putrifaction;† neither are the experiments of Dr. Macbride less valuable, though the consequences which he drew from them were erroneous. We are indebted also to Crell and

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* Phil. Trans. iv. 1735.			† Ibid. xlvi. 480, &c.

Priestley for many valuable facts; and to Berthollet and Lavoisier for the first attempts to determine the real changes which takes place, and the manner in which the new products which appear during putrifaction are formed. But notwithstanding the labours of these philosophers, and of many others, much is still wanting to enable us to trace the complicated changes which take place during putrifaction, and to account for them in a satisfactory manner.

Conditions requisite for putri-faction.   It has been ascertained long ago, that putrifaction never takes place in those animal substances which contain only two or three ingredients, such as oils, resins, sugar; they must always be more complicated in their texture: and perhaps in all cases a mixture of two or more compound bodies is necessary for speedy decomposition. But however complicated the animal substance may be, it does not putrify unless moisture be present; for dry animal substances are not susceptible of alteration. A certain degree of heat is also necessary. Animal bodies may be kept without decomposing for any length of time at the freezing temperature. In general, the higher the temperature the more rapid is the putrifaction, provided the heat be not great enough to reduce the animal body to dryness. It has been observed, too, that putrifaction advances with more rapidity in the open air; but exposure to the air is not necessary, though it modifies the decomposition.

Putrifac-tion in air.   When these conditions are observed, and dead animal matter is left to itself, its colour becomes gradually paler, and its consistence diminishes: if it be a solid part, such as flesh, it softens, and a serous matter sweats out, whose colour quickly changes; the texture of the part becomes relaxed, and its organization is destroyed; it acquires a disagreeable smell; the substance gradually sinks down, and is diminished in bulk; its smell becomes strongly ammoniacal. If the subject be contained in a close vessel, the progress of putrifaction at this stage seems to slacken; no other smell but that of a pungent alkali is perceived; the matter effervesces with acids, and converts syrup of violets to a green. But if the communication with the air be admitted, the urinous exhalation is dissipated, and a peculiar putrid smell is spread around with a kind of impe-

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tuosity; a smell of the most insupportable kind, which lasts a long time, and pervades every place, affecting the bodies of living animals after the manner of a ferment, capable of altering the fluids : this smell is corrected, and as it were confined by ammonia. When the latter is volatilized, the putrifactive process becomes active a second time, and the substance suddenly swells up, becomes filled with bubbles of air, and soon after subsides again. Its colour changes, the fibrous texture of the flesh being then scarcely distinguishable ; and the whole is changed into a soft brown or greenish matter, of the consistence of a poultice, whose smell is faint, nauseous, and very active on the bodies of animals. The odorant principle gradually loses its force, the fluid portion of the flesh assumes a kind of consistence, its colour becomes deeper, and it is finally reduced into a friable matter, rather deliquescent: which, being rubbed between the fingers, breaks into a course powder like earth. This is the last state observed in the putrifaction of animal substances ; they do not arrive at this term but at the end of a considerable time.*

During this decomposition a variety of gaseous bodies Products. are emitted : these vary according to the substance exposed to putrifaction ; but they consist chiefly of hydrogen gas, holding sulphur, phosphorus, and carbon in solution ; of ammonia, water, and carbonic acid, and perhaps also of azotic gas. Nitric acid seems in some cases to be formed and emitted. The earthy-like residuum, which remains after the decomposition is completed, consists of the fixed parts of the animal substance, mixed with charcoal, oil, and ammonia. Thus it appears that putrifaction consists in a total decomposition of the animal body ; the elements of which combine together two and two, and thus form a new set of less complicated bodies. But any attempt to explain the manner in which these changes take place would be exceedingly imperfect indeed; not only because we are ignorant of the strength of the affinities of the different elementary parts of animal bodies for each other, but because we do not even know the manner in which these elements are combined,

* Fourcroy.

and consequently we cannot know by what particular forces these compounds are destroyed.

Putrifaction under ground.

In carcases buried in the earth, putrifaction takes place much more slowly; but it is scarcely possible to observe its progress with accuracy. The abdomen is gradually dilated with elastic fluids, which make their appearance in it, and at last it bursts and discharges a horribly fetid and noxious gas; at the same time a dark coloured liquid flows out. If the earth be very dry, and the heat considerable, the moisture is often absorbed so rapidly, that the carcase, instead of putrifying, dries, and is transformed into what is called a *mummy*.

Putrifaction of accumulated animal matter.

Such are the phenomena when dead bodies are left to putrify separately: but when great numbers of carcases are crowded together in one place, and are so abundant as to exclude the action of external air and other foreign agents, their decomposition is entirely the consequence of the reciprocal action of their ingredients themselves upon each other, and the result is very different. The body is not entirely dissipated or reduced to mould, but all the soft parts are found diminished remarkably in size, and converted into a peculiar *saponaceous matter*. This singular change was first accurately observed in the year 1786.

Converted into a saponaceous matter.

The burial ground of the Innocents in Paris having become noxious to those who lived in its neighbourhood, on account of the disagreeable and hurtful odour which it exhaled, it was found necessary to remove the carcases to another place. It had been usual to dig very large pits in that burial ground, and to fill them with the carcases of the poorer sort of people, each in its proper bier; and when they were quite full, to cover them with about a foot deep of earth, and to dig another similar pit, and fill it in the same manner. Each pit held between 1000 and 1500 dead bodies. It was in removing the bodies from these pits that this saponaceous substance was found. The gravediggers had ascertained, by long experience, that about thirty years were required before all the bodies had undergone this change in its full exent.* Every part of the

* Fourcroy, Ann. de Chim. v. 154.

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body acquired the properties of this substance. The intestines and viscera of the thorax had completely disappeared; but what is singular enough, the brain had lost but little of its size or appearance, though it was also converted into the same substance.

This saponaceous matter was of a white colour, soft and unctuous to the touch, and melted, when heated, like tallow. It exhibited all the properties of a *soap*, containing, however, an excess of fatty matter. Fourcroy, who analysed it, found that it was composed of a fatty matter combined with ammonia, and that it contained also some phosphate of lime and ammonia. Diluted acids decomposed it, and separated the fatty matter: alkalies and lime, on the other hand, drove off the ammonia. When exposed to the air it gradually lost its white colour; the ammonia, in a great measure, evaporated; and what remained had something of the appearance of wax. It absorbed water with great avidity, and did not part with it readily. Its white colour was owing to the presence of that liquid. The oily matter, when separated by means of a diluted acid, was concrete, and of a white colour, owing to the mixture of a quantity of water. When dried, it acquires a greyish-brown colour, a lamellar and crystalline texture, like that of spermaceti; but if it has been rapidly dried, it assumes the appearance of wax.* It melts when heated to 126°; when properly purified, by passing it through a linen cloth while fluid, it has scarcely any smell. Alcohol does not act upon it while cold, but at the temperature of 120° it dissolves it: when the solution cools, the fatty matter precipitates, and forms a gritty mass. With alkalies it forms a soap; and when set on fire it burns precisely like oil or fat, only that it exhales a more unpleasant odour.†

Dr. Smith Gibbes found the same substance in the pit

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* Chevreul has shown that it is a compound of two substances, one having nearly the properties of margaric acid, the other of fluid fat. Ann. de Chim. xcv. 25.

† Fourcroy, Ann. de Chim. viii. 17. A set of experiments on a similar substance have been published by Dr. Eimke. See Gehlen's Jour. iv. 439.

Book V. into which animal matters are thrown at Oxford after dis-
section.   A small stream of water constantly passes through
this pit; a circumstance which induced him to try whether
animal muscle exposed to the action of a running stream
underwent the same change.   The experiment succeeded
completely: he attempted, in consequence, to render this
substance, to which he gave the name of *spermaceti*, useful
in those manufactures which require tallow; but the fetid
odour which it constantly exhales was an unsurmountable
objection.*   Attempts were indeed made to get over it;
and a manufacture of Dr. Smith Gibbes's spermaceti was
even established near Bristol.

Substances   Many attempts have been made to retard the destructive
which re-   progress of putrifaction, in order to preserve animal bodies
tard putri- either as food or for other useful purposes; and several
faction.   methods have been ascertained which prevent it from
operating for a considerable time.

1. The freezing temperature is a complete preservative
from putrifaction, as long as the animal substance is ex-
posed to it.   Hence the common practice of keeping meat
in snow in the frozen climates of the north; and of packing
fish in ice, and sending them in that state from Scotland
to the London market.

2. Almost all bodies which have a strong affinity for
water retard putrifaction for a longer or shorter time,
doubtless by depriving the animal substances of their water,
or preventing that liquid from acting upon these bodies in
its usual manner.   In this way the acids, sugar, alcohol,
&c. seem to prevent or retard putrifaction.

3. It is well known that common salt is a powerful anti-
septic.   Hence the practice of salting meat, and the length
of time which meat that has undergone this operation may
be kept.   Several other salts, especially nitre, possess the
same property.   In what manner these bodies act has not
been ascertained; but they undoubtedly produce some
chemical change upon the meat; for they alter its taste, its
colour, and other sensible properties.

4. Many aromatics, such as camphor, resins, volatile

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* Phil. Trans. 1794, 1795.

oils, bitumens, and other similar bodies, act with consi- Chap. IV.
derable efficacy in preserving animal bodies from putri-
faction. Hence their utility in embalming. In what the
action of these substances consists has not been ascertained.
Part of their efficacy is doubtless owing to the rapidity with
which the animal substances to which they are applied lose
their moisture; and something may be ascribed likewise to
their odour, which keeps insects at a distance, and thus
prevents the lodging of excrementitious matter, which
always acts powerfully as a putrifactive ferment.

PARAGRAPHS OMITTED.

The two following paragraphs have been omitted by
mistake.

1. Glass of Antimony.

(Should have come in Vol. I. p. 532.)

The protoxide of antimony has the property of dissolving Glass of
different proportions of sulphuret when in a state of fusion. antimony.
The resulting compound is a semitransparent substance of
a brownish-red colour, differing considerably in its appear-
ance according to the proportion of its ingredients. When
it is composed of about eight parts of oxide and one part
of sulphuret, it has a red colour, and is semitransparent.
It is then called *glass of antimony.* When it contains eight
parts oxide and two sulphuret, it is opaque, and of a red
colour inclining to yellow. This is the *crocus metallorum* of
apothecaries. Eight parts of oxide and four of sulphuret
form an opaque mass of a dark-red colour. This is the *liver
of antimony* of apothecaries.*

When sulphur is heated with either of the oxides, it re-
duces them to the metallic state, if sufficient in quantity;
if too small for that, it deoxidizes a portion, combines with
it, and the sulphuret formed unites with the remaining
oxide, always converted to a protoxide. Hence the reason
that these different compounds may be formed by a great

* Proust, Jour. de Phys. lv. 334.

variety of processes.   The glass of antimony is usually pre-
pared by exposing sulphuret of antimony in powder to a
gentle heat for a considerable time in an open vessel.   By
this process, which is called *roasting*, the greater part of the
sulphur is driven off, and the metal is reduced to a protox-
ide.   In this state it is put into a crucible, and melted by a
sudden heat into glass.   If the roasting has been carried so
far as to drive off the whole of the sulphur, only dark-co-
loured scoriæ are obtained; but on the addition of a little
sulphur or sulphuret of antimony, the glass may be easily
formed.*   The glass sold by apothecaries is seldom or never
pure, containing almost always, as Vauquelin has demon-
strated, about 0·09 † parts of silica; derived undoubtedly
from the crucibles in which the oxidized sulphuret is fused;
for these crucibles contain a very great proportion of silice-
ous earth.

The peroxide of antimony is incapable of dissolving any
sulphuret.   Of course it does not form a glass.

3. Black Ore of Antimony.‡

(Should have come in Vol. III. p. 535.)

This ore is found in Cornwall.   Colour iron-black.
Crystallized in four-sided rectangular tables, truncated on
the edges.   Planes of the crystals smooth.   Internal lustre
shining, metallic.   Fracture small conchoidal.   Fragments
indeterminate.   Soft.   Rather sectile.   Heavy.

* Bergman, iii. 166.   † Ann. de Chim. xxxiv. 139.
‡ Jameson, ii. 425.

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THE END.