WATER

ITS ORIGIN AND USE

Mrs Aubrey Le Blond.

THE INN RIVER, NEAR ST MORITZ–EARLY MORNING.

(A typical picture of water, in the form of water, ice, snow, hoar-frost, and mist.)

[*Frontispiece.*

WATER

ITS ORIGIN AND USE

BY

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Illustrations of Mountain and Glacier Scenery from the original pictures of

MRS. AUBREY LE BLOND
(MRS. MAIN)

"The lapse of time which is herein indicated, fills the mind of man with awe; but nature has no need to consider time; has she not eternity to work in?"—LORD AVEBURY.

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PREFACE

Being professionally interested in the finding and distribution of water, as engineer to an important waterworks, I have naturally been led to give this subject some attention and study, and I have derived no little pleasure in gathering together into the present volume the notes and memoranda which I have accumulated during a number of years, in the hope that my readers may find in it some matter of interest, and may be led to the contemplation of the wonders of nature.

Water in its various forms has been dealt with by some of the most eminent of scientists.

The subject, like the boundless ocean, is so wide, that there are few branches of scientific research in which it does not claim attention.

This book, however, does not pretend to be a scientific record; it is simply an ordinary person's interpretation of what he sees in nature, and represents his best efforts to describe the same.

Of such sources of information as were at my disposal, I have made free use: originality on such a theme was not contemplated, nor is it possible.

It is a truism that we know least about the common things we see and use every day of our lives. There are writers on such subjects who have the happy gift of imparting useful information in a pleasant and agreeable way. In such company I have added to my slender store of knowledge of the marvels of nature, and have derived from their works much profitable amusement; so I set out to write down in simple language, and in proper sequence, the results of my recreative studies and personal experiences.

That others may be encouraged to a greater curiosity about such things, and find therein both greater interest and reverence for the Great Author of all, is the purpose of this story.

With this special object in view, I have freely introduced verses bearing upon the various subjects; and I hope that these may help to awaken the interest of those who are not generally attracted to such subjects as this work treats of, and in this manner may make the scientific facts mentioned appear in a more acceptable form, for poetry and nature are ever closely allied.

Many of the scientific facts mentioned in this book are recorded in various works of note, but they have never before been brought together in this manner.

Where I have quoted verbatim from any writer, I have endeavoured faithfully to mention the fact. Should I have omitted to do this in any instance, I trust that the author will generously regard it as an oversight, and accept this as my apology.

In making this request I am but copying one of the minor poets of the last century, Peter Coxe, who in 1825 brought out a poem which he had "strengthened" considerably by quotations from poets greater than himself. "Distinguishing," says Joseph Bennet, "the larger extracts in the usual way, he left the smaller to the unaided perceptiveness of his subscribers; but, fearing the critics, he indited an apology, which concluded:—

> "'When we with proper caution weigh,
> And stealing, meditate our prey;
> And this we state lest any look
> For plagiary to spurn the book,
> And cautious mention at the starting
> To bar all quarrel at the parting.'"

I wish to express my thanks to Mrs Aubrey Le Blond for the beautiful Alpine illustrations which adorn this volume, and to my friend Mr R. Keith Johnston for the help he has given me in revising the manuscript and in seeing my book through the Press; also to Mr George F. Deacon, for his kind assistance in connection with the illustrations of the Vyrnwy Dam.

Should those who read my book derive as much pleasure and profit from its perusal as I have found in its compilation, the time and labour given to it will find sufficient compensation, and I shall be amply rewarded.

W. COLES-FINCH.

WATERWORKS HOUSE,
LUTON, CHATHAM, KENT,
June 1908.

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WATER
ITS ORIGIN AND USE

CHAPTER I

HEAT

In the Beginning

"Before the hills in order stood,
Or earth received her frame."

To trace the story of water and its work we must go back to the very beginning of the earth's history.

The word "beginning" is not intended to carry the mind of the reader back to that period at which it pleased God to create and disperse into space the marvellous elements of the material world, the Biblical description of which is so familiar to us, and no verse of the Scriptures is more pregnant with mystery than the first: "In the beginning God created the heavens and the earth." This is not true, says Dr Harley, because it is found in the Bible, but it is found in the Bible because it is true.

According to Ruskin, "there are, broadly, three great demonstrable periods of the earth's history. That in which it was crystallized, that in which it was sculptured, and that in which it is now being unsculptured or deformed.

These three periods interlace with each other—as the periods of human life do; of their length we know as yet nothing, except that it has been greater than any man has imagined."

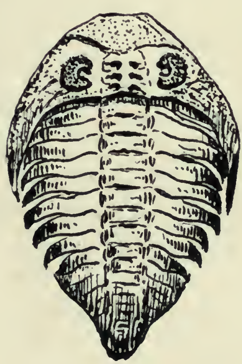
It will therefore be well to commence our story from the period of its crystallization, the study of which will unlock the past history of our planet, and, as Hugh Miller says, "will acquaint us with God's doings upon it, as the Creator of all, for myriads of ages ere He had first breathed the spirit of life into human nostrils, or man had become a living soul."

This part of the Creator's work preceded all the divine accounts of the Creation which we read in the book of Genesis; it is also beyond the comprehension of the greatest astronomers and geologists that have ever lived. Of this period Dr Buckland writes: "It is nowhere affirmed that God created the heaven and the earth in the first day, but in the beginning. This beginning may have been an epoch at an unmeasured distance, followed by periods of undefined duration, during which all the physical operations disclosed by geology were going on."

The evolution of our solar system from the original elements, as generally understood from the nebular theory of the renowned Laplace, is, as far as man is concerned, all we know of the beginning. But this is only a hypothetical theory, "it cannot be demonstrated by observation or established by mathematical calculation, but, from the study of other systems, astronomers have generally regarded this theory with considerable approval."

According to Sir Norman Lockyer, a nebula consists of vast swarms of meteorites moving in different directions, and dashing against each other with such force as to generate sufficient heat to dissolve themselves into luminous vapour.

THE NEBULA IN ANDROMEDA.



A TRILOBITE.

To face p. 2.

This globe was, then, but a nebula, or a mass of gaseous matter, a fluid haze of light. The whole of our solar system, in fact, was evolved out of this immense nebula, which must have been thousands of millions of miles in diameter, similar to many now adorning the heavens.

This rotating nebula, cooling by radiation of its heat into space, contracted and condensed towards the centre, leaving behind successive rings, in this manner giving birth to the planets, of which our earth is one of the smaller, and at last solidifying into and forming the sun as we see it to-day.

Other astronomers, however, believe that the parent nebula assumed a pear-shaped form, and that the smaller end became detached, forming a planet with independent existence, and, as was the case with our own planet in its early days, self-luminous.

The mass of solid matter now forming the sun and all the planets is said to represent only about one five-thousandth part of the mass of the original nebula.

A study of this story will tell us how worlds like ours were so marvellously formed, and are now in the process of formation. Beginning with a state of gaseous vapour, we pass next to one of a mass of liquid matter of intense heat, and thence to the solidification of this molten mass. Throughout the gaseous period the immense body of matter surrounding the globe must have been millions of miles in thickness, and during this period water was present only in the form of vapour; but, after a lapse of time, with the solidification there came a cooling, the reduced temperature was insufficient to maintain in a state of vapour the vast amount of moisture in the atmosphere, and the oxygen and hydrogen combined, giving birth to the water which now forms the oceans, seas, lakes, and rivers.

Whether water was existing in the atmosphere during the molten period, in the form of rarefied steam, or as its constituent gases, oxygen and hydrogen, in an uncombined state, is unknown. It is certain that no water could have rested on this molten surface, the temperature of which must have been at least 10,000° F., a degree of heat almost beyond our comprehension, but one which we dare not question, for Sir William Crooks tells us that in the manufacture of diamonds it is necessary to raise the temperature of the electric furnace to 7200° F.

According to Professor Sollas, liquid water (or, as I have seen it called, "wet water") could not have begun to accumulate until the surface of the earth had cooled to 716° F. When it had cooled sufficiently, the water condensed and remained upon the earth, covering the whole surface.

Owing to the heat of the earth, the evaporation and condensation were enormous. Rain fell upon the earth: but it was not cool, refreshing rain, with which we are familiar. It was a deluge of boiling water, described by one eminent scientist as red-hot rain, with a ceaseless accompaniment of thunder, lightning, and steam. How long this fierce battle between fire and water continued, we cannot say. Probably hundreds of thousands of years elapsed before the contest ended in water being victorious.

It is certain that at this period there was a total absence of organic life upon the earth. None of the forms of life with which we are acquainted, or the remains of which have from time to time been discovered, could have existed in or survived the intense heat of this period.

Many millions of years must have passed before the Creator of the universe saw fit to provide even the most primary form of organic life, and innumerable forms of both animal and vegetable life had existed and passed away into geological history before it was deemed a fitting habitation for man.

The preparation of the globe for all forms of life was impossible without water; thus in these remote ages water had commenced its useful and necessary work—a work, we shall see, it has never ceased to perform.

"Of all physical agents," says Dr Buckland, "that have at any time and in any manner affected the surface and interior of the earth, in the foremost rank we find fire and water—those two universal and mighty antagonistic forces, which have most materially influenced the condition of the globe, and which man has also converted into most efficient instruments of his power."

"During the earlier ages of our globe," says Louis Figuier, "waters covered a great part of its surface, and it is in them that we find the first appearance of life. When the waters had become sufficiently cool to allow the existence of organised beings, creation was developed and advanced with great energy, for it manifested itself by the appearance of numerous and very different species of animals and plants."

The crust of the earth is variously stated to be 30 or 40 miles thick, under which is a layer of molten matter 60 to 100 miles thick, the whole centre of the earth being gas, but under such pressure and of such great density as to be three times heavier than granite and as incompressible as steel.

Further research, however, into the question of the thickness of the earth's crust has caused a much higher figure than the above to be stated. It is assumed that a thickness of at least 2000 to 2500 miles would be necessary to enable the earth to maintain its shape, the tide-producing force exerted by the sun and moon on our globe being sufficient to cause a deviation from its present shape, were it only, say, 100 miles thick.

With the consolidation and buckling of the earth's surface, mountains were thrust up from the deeps, and vast continents began to appear above the heated waste of the waters, and it is apparent that—

"Then began the gathering together of the waters called seas, and the dry land appeared."

The struggle for the mastery between fire and water continued intermittently; for the earth was still passing through great convulsive changes, accompanied by earthquakes and eruptions of internal fires, the crust of the earth gradually thickening. During these eruptions metamorphic rocks and mountains were in process of formation. In all this water played, as we have seen, an important part, and practically "laid the foundation of the earth, that it never should move at any time."

"We have traced back," says Dr Buckland, "the history of the primary rocks, which composed the first solid materials of the globe, to a probable condition of universal fusion incompatible with the existence of any forms of organic life, and have seen reason to conclude that, as the crust of the globe became gradually reduced in temperature, the unstratified crystalline rocks and stratified rocks produced by their destruction were disposed and modified, during long periods of time, by physical forces, the same in kind with those which actually subsist, but more intense in their degree of operation; and that the result has been to adapt our planet to become the receptacle of divers races of vegetable and animal beings, and finally to render it a fit and convenient habitation for mankind."

Probably neither the greatest geographical or geological scholar, nor even the greatest living astronomer, is sufficiently acquainted with the universe, or the structure of our earth, to speculate, without fear of contradiction, as to its age, or the duration of any of its previous forms.

Referring to this subject, Sir Oliver Lodge remarks that "he did not know why it had taken so long to produce man upon the earth. That was a mystery of which he could only speak with bated breath, but he supposed that in a sense it could not be done any quicker with the same completeness or thoroughness. In the early years of existence the world contained only the lower forms of life, but it gradually improved, until it became what it is, and man attained his present state. But lower and higher forms still exist on the planet."

Hugh Miller considers that the vast series of long geologic ages and their successive creations, each placed in advance of that which had gone before, are more worthy of their Divine Author than had the whole work been huddled into a few literal "days," "and thus convert the incalculably ancient universe which we inhabit into a hastily run-up erection of yesterday."

The story of the successive geological periods and the gradual evolution of life, of the fossil remains of marine vegetation, of fishes, insects, land vegetation and terrestrial animals, is too vast a subject for further investigation here, and we must leave them to the geologist and the chemist, and proceed to the simpler wonders of creation, in which the work of water can be more easily traced than in the period just considered.

It is, however, more than probable that life first had its being in these more or less heated waters; and it is in this respect that the waters of the globe have been considered by many to be the cradle of the world.

The first dawn of life is variously stated as having taken place some forty or fifty million years ago. How this first germ of life (or protoplasm), the structural unit and basis of all organic bodies, came into being, and began its vital and endless function of evolution, culminating in man, none can tell.

We can only believe that this life must have had a divine origin, or, as we term it, creation; for it can only be begotten of life, and reproduced only by living organisms;—by no conceivable process could living matter arise from dead matter; but we do know that rocks formed of the sediment of the ancient seas have yielded the fossil remains of some of the earliest forms of life, which were of marine origin, but by no means the first life.

One of the creatures referred to is the trilobite, a widely distributed family of extinct palæozoic crustacea, comprising more than fifty genera, which are found in the Cambrian and Silurian strata. They are so named from their bodies being divided into three lobes. These little creatures, which nature has preserved to us in fossil form, are probably 12,000,000 years old, and represent a very low form of life. Their marvellous construction will well repay the reader for any time he may spend in learning more of them.

Solar Heat

We have seen that, in the beginning, the atmosphere was heated principally by the earth itself. Continuing the history of our globe, there came a time when this heat was, for purposes of evaporation, practically insufficient.

It has been ascertained that the amount of internal heat now escaping from the earth each year would be only sufficient to melt a shell of ice one-fifth of an inch thick over the whole surface of the globe. The atmosphere, therefore, found itself compelled to rely solely on the sun for its warmth.

It will be necessary, therefore, for the purposes of this story, to consider as concisely as possible heat and its relation to water.

The heat of the sun is inseparable from any description of water and its origin. The sun controls the solar system. It is really the cause of water in all its forms. In short, the whole of nature depends for its very existence upon the energy imparted by the sun. It has been rightly called "the grand prime mover in all that circulation of matter which goes on, and has gone on for untold ages."

In following water, therefore, through its varied and interesting phases, we must understand more fully the source from which all this power and work originates. The ancient inhabitants of our earth had a most erroneous idea of these matters. "They believed," says Sir Oliver Lodge, "that the earth was the centre of the universe, the world to which everything else was an appendage,—a world with a sort of sky over it, in which there were lights which regulated our seasons. What is the earth to us? A round globe, flying through space 19 miles every second of time around the sun; one of a family—the solar system; smaller than most of the others, larger than some. Spinning round the sun, that sun only one of a myriad of smaller suns."

We cannot do better in connection with this than quote the words of Sir Robert Ball: "To thoroughly obtain some conception of the intensity of the heat of the sun, we must imagine a temperature of molten steel, of such heat that it will run like water. Multiply this by seven, and we have then something approaching the fearful intensity of the celestial furnace that we see in the heavens.

"The earth is a mighty globe, yet what are the dimensions of our earth in comparison with those of the sun? If we represent the earth as a grain of mustard seed, then, on the same scale, the sun should be represented by a cocoanut. Again, look at the moon, which revolves round the heavens at a distance from the earth of 244,000 miles; yet the sun is so large that if there were a hollow globe equally great and the earth were placed in its centre, the entire orbit of the moon would lie completely within it.

"The solar heat is scattered through space with boundless prodigality. The earth receives but an infinitesimal fraction of what the sun emits. The heat and light daily lavished by the sun would suffice to warm and illuminate 2,000,000,000 globes, each as great as the earth."

Thus the earth receives only $\frac{1}{2,000,000,000}$ part, and the earth and the whole of the planets receive only $\frac{1}{227,000,000}$ part of the whole heat and light dispersed by the sun; the rest is lost in interstellar space. Should the heat of the sun's rays be utilized as a mechanical force, it has been calculated that, on a bright summer's day, the heat is equal to five thermal units per minute to each square foot of surface, if placed so as to receive the rays perpendicularly.

A simpler comparison may perhaps help us to form an idea of the immensity of the sun. The diameter of our earth at the equator is 7926 miles; that of the sun is 866,000 miles. The mean distance of the earth from the sun is 93,080,000 miles. Sir George Airy, from the transit of Venus (1874), made it 93,300,000 miles. It may be mentioned that its determination has been attempted in four ways, with the following results:—

		Miles.
By parallax . . .	Distance	92,908,000
,, velocity of light .	,,	93,075,480
,, motions of the moon	,,	92,958,000
,, mass of earth compared with the sun	,,	93,113,000

The mean distance of the earth from the sun in winter is 93,950,000 miles; in summer, 90,950,000 miles. The surface area of the earth would have to be multiplied by 11,946 to get the area of the sun's surface; and the volume of the sun is 1,252,700 times greater than our earth, and its mass exceeds that of the earth 316,000 times, its mean density being only one-fourth of the earth's.

That is to say, its weight is not in equal ratio, being only equal to 316,000 earths, whereas, if its density were the same as the earth's, it would equal 1,252,700 earths.

The sun's mass or weight, however, is also equal to 750 times the united masses of all the planets which gravitate around it; thus we see that what it lacks in weight it makes up for in size, and by its attraction keeps the earth and all the planets whirling round in space at their respective distances, warming and lighting them through "space": a simple word, but conveying much; for Mercury, the planet nearest to the sun, is 35,393,000 miles distant, while Neptune, the most distant, is 2,746,271,000 miles away!

Marvellous as these astounding figures are, Lord Kelvin estimates that there are 1000 millions of such suns in the heavens, each being the centre of a universe having earths perhaps like ours.

In order to comprehend these immense distances, we may express them by a simple arithmetical calculation. Taking the diameter of the moon as 1, the earth would be represented by 4, and the sun by 400, and 619,000 full moons would be required to equal the light of the sun.

The enormous size of the sun seems to be hardly possible, for when the moon comes between the sun and our earth, its outline and the sun's surface seem to be about of equal diameter; the one appears just to cover the other, as one would cover one coin by another of the same kind or value. This equality is indeed only apparent; the moon's shadow covers that of a body four hundred times its size because of the distance of the sun, which is about four hundred times farther away from the moon than the latter is distant from the earth. That the reader should really grasp the magnitude of the sun is so essential to the following of our story, that, at the risk of perhaps wearying him, I would suggest that he should construct a model of simple articles.

We will take the peel of half an ordinary orange, and call this the sun (866,000 miles diameter). We next find a small glass bead equal in diameter to, say, one-hundredth of that of the orange; we will call that the earth. Our next difficulty will be to find a bead small enough in diameter to equal one-fourth of that representing the earth; this minute article will represent the moon (2159 miles in diameter). Suspend these two beads on a piece of cotton or wire across the centre of the orange-peel, placing the larger bead (earth) in the centre; the moon revolves round our earth at a mean distance of 238,818 miles, or, roughly, about one-fourth of the diameter of the sun.

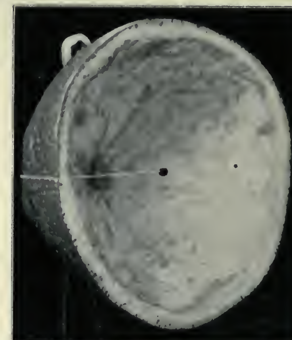
Therefore, the smaller bead must be placed halfway between the centre bead (earth) and the edge of the orange-peel. We shall then see at a glance the relative proportions of the sun and of this world on which we live.

What do we not owe to the sun?

Dr Fitchett says: "The white of the lily, the purple of the violet, comes from the sun; the crimson of the poppy was eight minutes ago actually in the sun, 93,000,000 miles distant.

"The waves of light smite the flower; by some unknown process of vital chemistry, the flower disintegrates the ray, it selects and absorbs some colour-element, and reflects others.

A PIECE OF CHALK MAGNIFIED.



TO ILLUSTRATE THE IMMENSITY OF THE SUN

"The miracle goes on while we gaze, under our very eyes. The tiny flower, it may be said, interprets the ultimate elements of light to our consciousness."

Professor Tyndall also writes: "The purple colouring of the mountains encountered on looking down the valley was indescribable. Oxygen and nitrogen could not produce the effect; some effluence from the earth, some foreign constituent of the atmosphere, developed by the sun, must sift the solar beams, abstracting a portion, and blending their red and violet to that incomparable hue."

The temperature of the surface of the sun has not yet been accurately ascertained. It is, however, agreed that the temperature and radiation have remained constant for a long period.

> "Tradition holds this ball of fire,
> Must burn for ever, nor expire."

How the sun's heat is sustained is not within the scope of our story. Should the reader be sufficiently interested, let him read *The Earth's Beginning*, by Sir Robert Ball, where this most interesting subject is treated; but the reader must not feel alarmed if he finds that the sun, in order to send forth the grateful heat we so much appreciate, is contracting, and is smaller in diameter by one mile every twenty-five years. This diminution is practically insignificant when compared with its enormous size.

Solar Constant of Heat

If we have thoroughly conceived, as far as human mind can conceive, the size and mass of the sun, the next and not less important task will be, to get a similar comparative idea of its heat, both at its surface and here on our earth: the former that we may better be able to account for its warmth reaching us, so far distant as we are from it; and the latter that we may better comprehend some of the marvellous works it accomplishes here.

"The solar constant is the number of units of heat which fall in one minute on one square foot of a surface placed at right angles to the sun's rays, and situate at the mean distance of the earth from the sun. We shall suppose the loss due to atmospheric absorption is allowed for, so that the result will express the number of units of heat that would be received in one minute on a square foot turned directly to the sun, at a distance of 93,000,000 miles. This amount has been found to be sufficient to raise 1 lb. of water 14° F. in one minute. The total radiation from the sun must suffice to convey in each minute, to a sphere whose radius is 93,000,000 miles, 14 units of heat per square foot of that surface. This radiation comes from the surface of the sun. Now it is easily shown that the heat from each square foot on the sun will have to supply an area of 46,000 square feet at the distance of the earth. Hence the number of units of heat emerging each minute from a square foot on the sun's surface must be about 640,000, which in the course of a year would be equivalent to the heat generated in the combustion of 11,000 tons of best coal" (Sir Robert Ball).

The highest temperature with which we are acquainted is said to be that of the "electric arc," viz. 3500° C.

It is calculated that all the coal on the earth would not supply the sun's heat for one-tenth of a second, and that this heat is maintained by the shrinking of the sun, its particles developing heat by falling together. In this way the amount of heat expended by the sun for the past 24,000,000 years can be accounted for.

It is also estimated that the sun's radiation would melt a coating of ice, covering its own surface to a depth of 40 feet, in one minute. To measure the sun's heat, an ingenious instrument called the pyrheliometer is used, this being the invention of M. Pouilett.

Lord Kelvin concludes that the amount of heat which the earth radiates from its surface and loses would in 20,000 million years be sufficient to melt the entire bulk of the earth, if the rate of loss had always been what it is now, and the earth had consisted throughout of the same materials as its surface rocks.

At times of a total eclipse of the sun, long coronal streamers are seen; these mighty tails of light shine with an intrinsic light of their own, consisting, it is believed, of hydrogen of such high temperature as to be self-luminous.

These streamers are of enormous length; in the eclipse of 1898 they were ascertained to be equal in length to six times the diameter of the sun.

Distribution of Heat

The next interesting point of the study of our luminary will naturally be the distribution of its genial warmth. We are now concerned with a matter of which we really have definite knowledge, each of us personally, without having to lean quite so heavily on the scientists to whom we owe so much.

Shakespeare says: "All the world is cheered by the sun." In some parts of the earth he not only cheers, but seems determined to make his presence rather uncomfortably apparent.

The highest temperatures occur in India, North Africa, Red Sea, Persian Gulf, and Australia. In the centre of the Sahara Desert, 130°; New South Wales, 120°. Paris once recorded 106°. London has seldom recorded more than 96°.

It is in these regions of extreme heat that the terrestrial radiation is greatest, the cooling effect of which produces nights of comparatively intense cold.

It is, of course, known to most readers that summer occurs in the northern hemisphere when the earth is at the greatest distance from the sun, and winter when it is nearest to us. In the northern hemisphere the difference is about 3,000,000 miles. Further reference will be made to this subject in a future chapter.

It is curious also to note that from 31st May to 16th July more heat falls on the North Pole than on any other part of the earth. "This heat is mainly employed in melting the Arctic ice and raising the temperature of the water, and not in raising the atmospheric temperature, and so, even in these cold regions, again equalising the temperatures" (Archibald).

Effect of Heat on Land, etc.

If the same amount of sun-heat were to fall upon an equal area of land and water, it would raise the temperature of the former four or five times as much as that of the latter. The rays which fall on the land are absorbed by the thin surface layer exposed to them; the temperature of the surface increases; a wave of heat passes downwards through the soil, the intensity of the wave varying with the conductivity of the soil; but it generally ceases to be measurable at a depth of 4 feet. Part of the heat of the surface layer is reflected upwards, heating the lower stratum of air with which it comes in contact.

Rays falling on the water are not arrested at the surface, but penetrate to a considerable depth. In clear water the heat of the sun is perceptible at a depth of 500 to 600 feet. Therefore, the heat being diffused downwards, the surface of the water is heated by day less than the surface of the land, and, as will be apparent, it also cools less during the night, by terrestrial radiation. This is the explanation of the fact that the sea maintains a more uniform temperature than the land. These differences in radiation of heat from land and sea help in the general circulation of the atmosphere.

The rays of the sun, in passing through the air, affect the vapour particles 764 times more than the dry ones. In passing through stellar space but little of the sun's heat is lost.

Thermal Unit of Heat

The reader will probably wonder why he is asked to consider the thermal unit of heat here; but heat changes the dimensions of all bodies. Increase of volume is the normal effect, although the reverse is observed in water between 0° C. and 4° C. Without some short reference to this matter, we cannot possibly grasp many of the interesting phenomena to which we shall refer; and the aim of the writer is not only to state facts, but to enable the reader to understand their causes.

The thermal unit of heat is the quantity of heat required to raise 1 lb. of water 1° F. (from 60° to 61° F.), utilising energy equivalent to that required for raising 772 lbs. through 1 foot, or 1 lb. through a height of 772 feet, called foot-lbs.; or, taking the thermal unit as the energy required, to raise a pound of water 1° C., the equivalent must be increased by four-fifths, amounting to 1390 foot-lbs.

If a pound of good coal were burned and no heat wasted, it would produce at its full theoretical equivalent 14,000 thermal units of heat, which would raise 14,000 lbs. of water 1° C., or 140 lbs. of water 100°, or 70 lbs. of water 200°. A pound of coal theoretically contains heat sufficient to boil 7 gallons of water, so the energy contained in 1 lb. of good coal expressed in foot-lbs. is 14,000 (units of heat) $\times$ 772 = 10,808,000 lbs. raised 1 foot. By a trial of ninety-eight samples of good English coal, a mean of 14,112 thermal units was obtained, so 1 unit of heat equals—

772 foot-lbs.
0·000388 horse-power per hour.
0·00087 lb. of water evaporated at 212° F.
(Boiling point of water.)

The British thermal unit (B.T.U.) was first determined by Joule, who gave its mechanical equivalent as 772 foot-lbs. or units of work at 60° F. This has been modified by subsequent experimenters, and the dynamic equivalent of heat is generally accepted as being 778 foot-lbs.

Heat of Combustion of Various Fuels

This may at first appear to have no connection with our story, but it is of great importance that we should know something of the comparative heats of combustion of various fuels, also the air consumed by each in the process, and its power for evaporating water, as frequent reference will be made to these powers in the following chapters.

	Total heat of combustion of 1 lb. of fuel.	Cub. ft. of air at 62° chemically consumed.
Coal of average composition	14·700 heat units	140
Coke	13·548 ,,	142
Wood, desiccated . .	10·974 ,,	80
Peat ,, . .	12·297 ,,	99

Temperature

Before leaving this subject, it will be as well to bear in mind that a thermometer measures temperature, and not heat directly.

Temperature is that energy with which one body seeks to impart its heat to another, and is no real indication of heat in the body, *e.g.* equal weights of mercury and water may have the same temperature, and yet the water will contain really thirty times more heat than mercury.

Temperature implies that the condition of heat in a body may be compared with some standard, and the means of such comparison is the thermometer.

The construction and use of the thermometer is so well known, that a general description is unnecessary, but it may be of some interest to know that mercury was not always used in its construction.

Air has been used for this purpose: it was the substance first used by Sanctorius of Padua in 1590. His instrument consisted of a simple glass tube, having attached to it at one end a bulb, the other dipping into some liquid contained in a vessel below; as the bulb became heated the air expanded, and forced down the liquid in the tube. Mercury, however, is found to be the most suitable substance; and as the same body at the same temperature always has the same volume, and always suffers the same change in volume with the same change of temperature, we can easily understand how the change of temperature causes the mercury in the bulb to expand or contract, and so stand higher or lower in the tube, the amount of variation in the height depending upon the proportion which the diameter of the tube bears to the capacity of the bulb.

Though the boiling-point of water varies according to atmospheric pressure, ice practically always melts at a fixed temperature of 32° F., so the zero of the F. scale is fixed 32° below this point. The interval between the points of freezing and boiling (212°) is divided into 180 equal parts or degrees ($32+180=212$). In the centigrade scale the interval (32 – 212 F.) is divided into 100°, and the zero placed at the freezing-point. Mercury freezes at 39° or 40° below zero F., or 71° or 72° F. of frost.

Glass is admirably suited for the bulb and tube of a thermometer, for it is found by experiment that the dilatability or expansive power of mercury is greater than that of glass in the proportion of nearly 20 to 1.

It is also necessary that the tube should be made of some transparent material, so that the position of the mercury can be seen.

If glass be heated from 32° to 212° F., the increase in volume is only ·00001434, but mercury would be represented by ·00014000.

Where the heat to be measured is beyond the range of the mercurial thermometer, an instrument called the pyrometer is used.

Internal Heat of the Earth

The internal heat of the earth commands consideration here, as it is the principal agent in the formation of thermal springs, geysers, etc., to which we shall refer later on. It is found in temperate regions that at a depth of about 80 to 100 feet in the earth there is an unvarying temperature. All the world over, from the Arctic region to the tropics, varying of course with latitude, etc., there is a constant temperature at a certain depth. For instance, if it were possible to sink a shaft into the bed of the ocean to this depth, the result would be the same, the solar rays having no power to raise the temperature here.

It is stated by Lord Avebury that "the variation of temperature due to the seasons, etc., does not extend to a greater depth than 5 feet into the surface of the earth."

As in all things, however, there are exceptions to this rule, and although the depth to which the seasonal variations penetrate depends also partly on the thermal conductivity of the soil, rocks, etc., without doubt the cold of winter and the heat of summer are transmitted downward in successive waves, disappearing at the constant limit above referred to.

In extreme climates, as we might expect, this zone of invariable temperature, however, reaches extreme depths.

At Yakutsk, Eastern Siberia (Lat. 62° N.), in sinking a well the soil was found to be permanently frozen to a depth of 700 feet. The researches of Sir William Thomson prove how these apparently phenomenal conditions are possible. He says: "Any considerable area of the earth's surface, covered for several thousand years by snow or ice, and retaining, after the disappearance of that frozen covering, an average surface temperature of 13° C., would, during 900 years, show a decreasing temperature for some depth down from the surface, and 3600 years after the clearing away of the ice would still show residual effect of the ancient cold."

In Java at 2 to 3 feet, and in India at a depth of 12 feet from the surface, the thermometer is constant all the year round.

From observations made in the catacombs at Paris, which are situated at about a depth of 100 feet from the surface, there was no change of temperature; this depth is called the invariable stratum, and is taken as having a temperature of 52° F.

From observations taken all over the world, below the limit of the influence of the seasonal changes we have described, the temperature has in no single instance been found to diminish downward; it always rises. Of course volcanic regions are excepted.

Beyond the constant limit the temperature is influenced solely by the internal heat of the earth; the difference between the temperature at 100 feet and at the surface is caused by what is called radiation.

Below this depth there is an increase of 1° F. for each 66 feet, or 80° F. at the depth of a mile; or at a depth of a little over 2 miles below the earth's surface the temperature would be 212° F. It is supposed that at a depth of 20 miles the temperature would be 1760° F., and at 50 miles 4000° F., at which point every known solid substance would melt. Some authorities give 1° F. for every 45 feet, others 52 feet, 55 feet, 60 feet, and 90 feet, but 66 feet appears to be generally accepted, the highest being 1° F. for each 41 feet at Glasgow, in the coal measures.

These minor differences are no doubt due to local conditions: the kind of rock through which the heat has to pass, no doubt, has some little influence on the results.

If this rate were kept up, the temperature at the centre would surpass the imagination of the most fertile brain; but the increase cannot be as great as this would show, for if it were so, according to some estimates the temperature would be not far short of 200,000° C. We only really know the condition of heat at a depth of from six to seven thousand feet.

The hot springs which issue from the earth prove the existence of great heat within the earth, as also do active volcanoes. With our knowledge of these slumbering powers, there is little room to wonder when we hear of an eruption; it is indeed more wonderful that they should not be even more frequent and numerous, and of greater magnitude, than any we have records of.

"The agency of central heat," says Dr Buckland, "and the admission of water to the metalloid bases of the earths and alkalies, offer two causes which, taken singly or conjointly, seem to explain the production and state of the mineral ingredients of the crystalline rocks, and to account for many of the grand mechanical movements that have affected the crust of the globe."

From observations by the writer, the temperature of water in wells in the chalk formation 150 feet deep was found to be 53° F.; in a well 250 feet deep, 56° F.; and in an artesian well in the same locality, 650 feet deep (taken at the same time), 65° F., or an increase of 12° F. between 150 and 650 feet; the difference between the two depths being 500 feet, giving an increase of 1° F. for each 41·66 feet in depth.

In making the Simplon tunnel (12¼ miles long), the tunnelling began from both sides simultaneously. The greatest obstacles encountered were springs of water yielding 3700 gallons per minute; finally, in the last section of the Swiss advance, a number of hot springs were met with, pouring out 600 gallons of water per minute at a temperature ranging from 104° to 117° F. The men at this point had 1¼ miles of rock over their heads.

During the progress of this work careful observation was made, and it was found that the increase in temperature was 1° F. to 71·5 feet, the figure being 97·7° F. at 2135 metres below the summit. At another position the vertical gradient worked out at 1° F. to 67·5 feet.

This proves that though the increase of the internal heat of the earth is, as we have seen, 1° F. for each 66 feet all the world over, it will not account for the above temperature, which bears out the statement that where the heat is considerably in excess of these figures, it must be due to volcanic agency.

It is, however, hardly satisfactory to take the temperature of the water from springs, as in the above and similar instances, for comparison with the depth from which it is drawn; for, though apparently coming from the level at which it is found, it is probable that it may really have its origin at either a higher or a lower level, and so carry an apparently inaccurate temperature. It must also be remembered that at some places both hot and cold springs issue from the earth within a few feet of each other.

In the boring of the Ox-bow tunnel in Idaho, similar hot springs were met with, the temperature of which progressed from 95° to 132° F. at the hottest point; this difficulty was only overcome, and the work enabled to proceed by the usual method of spraying the walls with cold water.

If we study the foregoing figures, a simple calculation will tell us what little distance we have to penetrate into the earth to come to temperatures such as that of our domestic fire (1100° F.), of the melting-point of wrought iron (2912° F.), of platinum (3080° F.), of a Bessemer furnace (4000° F.), and to that point at which the granite rocks would melt (20–30 miles).

Such depths as these, compared with the diameter of the earth (7926 miles), are insignificant, and can be compared to the prick of a pin in the earth's crust.

We who live on the surface of the earth would hardly give a thought to the existence of the enormous heat beneath us, were it not for the presence of volcanoes, geysers, etc., which remind us by occasional eruptions of their slumbering forces.

CHAPTER II

ATMOSPHERE

"The great instrument of communication between the surface of the sea and that of the land is the atmosphere, by means of which a perpetual supply of fresh water is derived from an ocean of salt water, through the simple process of evaporation."—Dr Buckland.

Let us now consider briefly the atmosphere of air which envelops the globe, without which nothing could live, nothing could burn, nothing could grow; without which no sound could be heard, and there could be no rain. The more we think of this marvellous envelope, the more interesting and fascinating it becomes.

Air is a mixture of two gases without chemical change, unlike water, which is two gases chemically compounded and forming a liquid.

Dr Saleeby says: "For many centuries air was regarded as a single thing, like water.

"It had occurred to no one that air might be, as we now know it to be, a mixture of gases. This discovery was the work of Joseph Black, a Scotchman, the outcome of which was a revision of the doctrine of heat, the discovery of latent heat, and the universal acceptance of the fact that there is not only one kind of air."

Impossible though it may appear to us, it is nevertheless a fact that, by a wonderful provision of nature, wet air is lighter than dry.

One cubic foot of ordinary air at normal pressure (62° F.)

weighs, when dry, 532·5 grains; but if saturated, it weighs only 529 grains, or 3½ grains less per cubic foot.

Twenty thousand cubic feet of saturated air at 60° contain 17 lbs. of water; if the temperature of saturated air were 90°, the same quantity would contain 47 lbs. of water.

The presence of this water vapour in the air has the effect of making a temperature of 30° to 40° feel raw and cold, 60° comfortable, 100° close and heavy as in a steaming hot-house.

These same temperatures of dry air would not cause such extreme sensations.

When the atmosphere is charged with vapour, and contains, in this form, all the water that is to become rain, etc., it is lighter than dry air; hence one of the minor causes of the difference in pressure shown by the mercury in a barometer, which then indicates rain, but actually shows reduced pressure. The probability of rain, of course, depends upon the presence of more or less vapour in the atmosphere, and in the progress of such changes as ultimately lead to its condensation.

This is the secret of all the wondrous works accomplished by the atmosphere, beside which all other of nature's mysteries sink into insignificance. Were this not so, the whole existence of this globe would have been different; and on this fact hang all the mysteries of the air, a few only of which we will try to trace.

Maury says: "It feeds and nourishes the earth, it is more simple, more grand, more majestic than the world of waters, more varied and changeful in its moods of storm and calm, of ebb and flow, of brightness and gloom.

"The carbonic acid with which to-day our breathing fills the air, to-morrow seeks its way round the world. The date-trees that grow around the falls of the Nile will drink it in by their leaves, the cedars of Lebanon will take of it and add to their stature, and the palms and bananas of Japan will change it into flowers.

"The oxygen that we are breathing was distilled for us some short time ago by the magnolias of the Susquehanna, and the giant rhododendrons of the Himalaya contributed to it.

"It is an envelope or covering for dispersing light and heat over the surface of the earth; it is a sewer into which, with every breath we draw, we cast vast impurities; it is a laboratory for purification; it is the machine for pumping up all rivers from the sea, and conveying the waters from their fountains in the ocean to their sources in the mountains."

We will therefore devote a considerable portion of our story of water to trying to follow some of the methods by which the atmosphere fulfils these many duties, and acts as one of the principal of nature's agents, raising, purifying, and supplying to the world pure water and air, two of the things most necessary to our existence, and on which two things the whole universe lives and grows, and without which all other necessaries of life could never exist.

The atmosphere is far older than the earth which it surrounds, consisting, as we have seen, of the remaining uncondensed gases left after the complete consolidation of the thin crust enveloping the earth, having, like the earth itself, gradually cooled down, until at last it has become capable of supporting life.

Composition of the Atmosphere

When we feel the breeze gently fanning our cheek, do we ever realise that the sensation is caused by molecules of air, so small that 25,000,000 of them, placed in a straight line, would only measure one inch, which are beating against our face although we cannot see them.

The composition of air is as follows:—

	By volume.	By weight.
Oxygen . . .	20·84	23·141
Nitrogen . . .	79·16	76·859
	100·000	100·000

It also contains ·03 to ·04 per cent., by volume, of carbonic acid. When dry it is 819 times lighter than water. The average proportion of aqueous vapour contained in air is 1·4 per cent. by volume. It is estimated that the total weight of the entire atmosphere of the world is 300,000 million tons. Sir John Herschel estimates it to weigh 11¾ trillion pounds, and to equal in mass $\frac{1}{1,200,000}$ part of that of the earth itself.

Fire could not be kindled without air, and to consume 1 lb. of coal 11½ lbs. or 150 cubic feet of air are necessary to combine with it.

Oxygen is a gas which is the most widely distributed of all the elements; respiration, burning, and the production of light (electric light excepted) are only possible in its presence. (*See* Composition of Water.)

It is the oxygen in the atmosphere that destroys metals, setting up rust or oxidation on iron; mercury (quicksilver) cannot withstand its influence under certain conditions. Iron rust weighs more than the amount of metal destroyed; this additional weight is found to consist of oxygen, which by a chemical process can be re-converted into gas. It was by carrying out this experiment with red mercurial powder that Priestley, in 1774, discovered oxygen.

The nitrogen which forms four-fifths of the atmosphere represents the inert negative element which, though not actively hostile to life, by diluting the oxygen, lessens the activity and rapidity of the energy developed by its combustion, and thus tends to prolong life. Nitrogen is a colourless, inodorous, tasteless, incombustible, invisible gas, incapable of supporting life.

Dr Schofield says that the human being, while resting, requires about 480 cubic inches of air per minute; if walking at the rate of 3 miles per hour, 1550 cubic inches; if running at the rate of 6 miles per hour, 3260 cubic inches. The average man requires, to replace the waste of his body, 7000 grains of oxygen and 300 grains of nitrogen daily.

The other properties of these gases are of equal interest, but for the purpose of our story this must suffice.

Analysis of Atmosphere

The average composition of the atmosphere is:—

Oxygen		20·61
Nitrogen		77·95
Carbonic acid		·04
Aqueous vapour		1·40
Nitric acid		trace
Ammonia		,,
Carburetted hydrogen		,,
In towns	Sulphuretted hydrogen	,,
	Sulphurous acid	,,
		100·000

(According to Lord Rayleigh, air contains 1 per cent. of argon.)

Specific Gravity of Elastic Fluids

In order that we may be better able to trace some of the wonders of the atmosphere, it is necessary that we should know the specific gravity of air; and for our guidance and comparison the S.G. of a few elastic fluids are given.

One cubic foot of dry atmospheric air, at 62° F., at normal pressure weighs 532·5 Troy grains; its assumed gravity of 1 is the unit for elastic fluids. Therefore the specific gravity of—

Atmospheric air	1·000
Hydrogen	·068
Oxygen	1·102
Nitrogen	·971
Carbonic anhydride	1·520
Steam at 212° F.	·488
Vapour of water	·623

Carbonic Acid in Atmosphere

This is more properly known as carbonic anhydride, or carbon dioxide, and is composed of 12 parts by weight of carbon and 32 of oxygen; it is a colourless gaseous compound, without smell, 22 times as heavy as hydrogen. It is incapable of supporting animal life; in fact, if it exists in the atmosphere to an extent of only 4 or 5 per cent., it acts as a narcotic poison; it however exists there in a harmless proportion of 1 volume to 2500.

This compound plays such an important part in our story that we may with interest trace it a little further. It is disengaged from fermenting liquors, from decomposing animal and vegetable matter. It exists in large quantities in all limestones and marbles, and is also found to emanate from the earth, constituting the choke-damp of the mines, the dangerous gas in our wells, vaults, and caves.

From its weight it tends to subside into low-lying places, rendering them uninhabitable, as in the Upas Valley of Java.

Thus we see that it is fatal to breathe carbonic acid; it has its redeeming features, however, when taken into the stomach with our food. It exists in all aerated waters and beverages, from ginger beer to champagne, all of which owe their refreshing qualities to this gas.

The amount of carbonic acid in the atmosphere has been found to be, in the London parks, ·0301 ; London streets in summer, ·0380 ; Manchester fog, ·0679 ; worst parts of a London theatre, ·3200 ; while in a mine in Cornwall 2·5000 was found to exist.

The extremely luxuriant forests that covered the face of the earth millions of years ago, before man's appearance, and which, by their rapid growth and decay, were destined to provide our present coal-fields, flourished and grew with great rapidity, covering the ground with their carbonaceous trunks, leaves, and branches. This prolific production of vegetable life was mainly due to the higher temperature then existing, and the greater proportion of carbon dioxide in the air; it must have greatly exceeded what we find at the present day.

In the accumulation and gradual decay of the luxuriant vegetable growth in the forests of past ages, which in course of time were buried and overwhelmed by floods, undergoing chemical changes, and suffering the loss of certain gases, we find a most interesting cycle of transformation, which, aided by gradual compression, resulted in the formation of coal.

Evaporation

The first process in the formation of cloud and atmospheric water is evaporation, or the conversion by heat of a liquid or a solid into vapour, which becomes dissipated in the atmosphere in the form of an elastic fluid.

We will consider only the passing of water by natural process into the atmosphere, where it remains, generally invisible.

If water be spilled upon the ground on a hot day, it dries up; that is to say, it is quickly converted into invisible vapour. The small pool by the roadside, lakes, the mighty ocean, the fields of snow and ice, are all evaporating, eventually forming clouds and rain.

Newly-fallen snow is at times the sport of the wind, and is frequently wafted from the summit of a mountain in the form of a vast banner. Professor Tyndall tells us he has seen it gradually melt away in the air, and again, by condensation, curdle up into true white cloud; this in turn would be pulled asunder like carded wool, and reduced a second time to transparent vapour.

The effect of evaporation is always to reduce the temperature of the evaporating surface. The lowest artificial temperature ever produced was obtained by the evaporation of volatile liquids such as ether.

The evaporation from our bodies is one of the most obvious causes of diminution of temperature. We possess 2,000,000 perspiration glands, in connection with 10 miles of ducts. It is calculated that the available energy derived from oxidation of the organic matters of the food of a well-fed man equals about 2,700,000 units of heat (the unit being the amount of heat required to heat 1 gram of water 1° C.). Bodily heat is diminished by the skin, lungs, etc. By radiation and evaporation from the skin, about 75 per cent. is lost. In cold weather the loss by radiation is increased, and that by evaporation is proportionately decreased; and under reverse climatic conditions we find a greater increase in the evaporation and a decrease in the radiation. The loss of bodily heat by the lungs is equal to 20 per cent., and is fairly constant at all temperatures. This accounts for 95 per cent.; the remainder, 5 per cent., is disposed of in other ways.

When a man is not exerting himself in any way, nature

Mrs Aubrey Le Blond.

SNOW (NOT CLOUD) BLOWN FROM A MOUNTAIN SUMMIT, ENGADINE.

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dissipates the heat from the body in the following manner :—

	Units of heat.		Per cent.
In raising the temperature of food .	70,157	or	2·6
In warming inspired air . . .	70,032	,,	2·6
In vaporising the water of the lungs .	397,536	,,	14·7
Lost by radiation, conduction, and evaporation from the skin .	2,162,275	,,	80·1
	2,700,000		100·0

Here we see nature's system of evaporation and radiation at work in our bodies.

If we apply this principle to the heat absorbed in the evaporation of water to form the vapour in the atmosphere, and set free in the re-condensation of the vapour into rain, it may perhaps help us to grasp this part of nature's wonders in connection with our subject.

One other practical example of the reduction of temperature by evaporation. In hot climates water is made to freeze during clear, cold nights by leaving it overnight in porous vessels or bottles wrapped in moistened cloth. This is entirely due to the cold produced by the evaporation from the porous vessel or by the evaporation of the water in the moistened cloth surrounding the bottle.

Water requires a greater expenditure of heat to evaporate it than any other liquid. As much heat is required to evaporate a pound of water as would raise 966·6 lbs. 1° F., or about 5⅓ lbs. from freezing to boiling. (*See* Latent Heat of Steam.)

This heat is stored up in the vapour, and given out again when the vapour is converted into water. In cold, cloudy weather we often hear the expression used, "It will be warmer after the rain"; and there is more in this remark than a casual observation would lead us to think, for, "every gallon of rain that falls has yielded to the atmosphere that surrounds the place where it was condensed as much heat as would raise $5\frac{1}{3}$ gallons from freezing to boiling."

Evaporation varies with the distance from the equator, and from many other causes. The glaciers, ice, and snow on the mountain summits, where the temperature is far below freezing, are continually evaporating.

The sun pours its heat on the water in the tropics and evaporates it. Stored with this heat the vapour is borne away and converted into rain, giving up its store of heat when it encounters a lower temperature.

Hartwig says: "Neither storms nor ocean currents, nor ebb and flood, however great their influence, cause such considerable movements of the waters, or force them to wander so restlessly from place to place as the silent and imperceptible action of the warming sunbeam." He considers that the whole of the aerial and terrestrial migrations of the waters of the globe are due to evaporation, and the counter-currents thus induced in both air and water.

"To liquefy ice, a large quantity of heat is necessary.

"To vaporise water a still larger quantity is necessary, as this heat does not render water warmer than ice, nor steam warmer than the water.

"To convert a pound weight of tropical ocean into vapour, the sun would require to expend 1000 times the amount of heat necessary to raise 1 lb. of water 1 degree in temperature."

This same quantity of heat which would raise 1 lb. of water 1 degree, would raise the temperature of 1 lb. of iron 10 degrees; thus to convert 1 lb. of the tropical ocean into vapour, the sun must expend 10,000 times as much heat as would raise 1 lb. of iron 1 degree in temperature.

"This quantity of heat would raise the temperature of 5 lbs. of iron 2000°, which is the fusing point of cast iron, when passing into the molten condition.

"Imagine the mighty glaciers, etc., to be, instead of ice, a mass of molten iron, white hot and of quintuple the weight, and you get some notion of the enormous heat paid out by the sun to produce the present glacier.

"This is as clear as day, and a diminution of the sun's rays would not produce an extension of our glaciers, but the reverse.

"More heat instead of less, and the corresponding condensation alone could produce a 'Glacial Epoch'" (Tyndall).

Vapour

Vapour is really the term applied to designate the gaseous form which a solid or liquid substance assumes when heated. Vapour is therefore essentially a gas, and most gases are now proved to be liquefiable.

There is no physical difference between steam and vapour; but for the purpose of our story we shall associate vapour with the natural passing of water into the atmosphere invisibly.

Aqueous vapour formed on the surface of the land and water is always present, mixed with the atmosphere, and when it meets with a sufficient reduction in temperature, it condenses into water in the form of rain or dew, etc.

If the air were perfectly dry, the heat radiating from the surface of the earth, as well as the solar radiation, would pass through it without it being sensibly warmed thereby—add vapour and its diathermancy is diminished. So with an increase of vapour or with increase of humidity both solar and terrestrial radiation are much less felt on the surface of the earth.

"Vapour is perfectly transparent to light, or luminous heat rays. It does not occupy more perhaps than $\frac{1}{200}$ of the space occupied by air: that is, it is present in very small proportion; yet it stops more than 100 times as much heat as all the air together—20,000 times as much as an equal quantity of air.

"So impervious is it to heat, that no inconsiderable portion of the heat radiated from the earth is stopped within the first thirty or forty feet, probably not less than half.

"Vapour water acts as glass; lets the heat of the sun through, but will screen you from the heat of the fire. It also admits and then detains the heat of the sun.

"The temperature of our planet is higher and much more equable than it would be but for this singular property of vapour" (J. M. Wilson).

If vapour existed alone, and not in combination with air, as is fortunately the case, cloud would form only at one level. There would be only one temperature at which vapour could change into a liquid, and form rain. The level and temperature would alter with the time of day and season.

Weight of Vapour

"In pure dry air at sea level, with the barometer at 30 inches, we shall find that at 32° F. the column of mercury 30 inches high, resting on 1 square inch, weighs 14·7 lbs., mercury being 13·6 times as dense as water, air only $\frac{129}{100,000}$ as dense. The weight of a cubic foot of dry air under these conditions will be about 565 grains (Troy). On the top of a mountain 18,000 feet high it would weigh only half as much.

"The weight of a cubic foot of watery vapour, under the same conditions, would be only 352 grains; so when vapour is mixed with dry air, the resulting compound is lighter: that is, damp air is lighter than dry air" (D. Archibald).

The elasticity of vapour varies with the temperature. At 0° F. it is capable of sustaining a pressure of 0·044 inches of the mercurial bar; at 32° F., 0·181; at 60° F., 0·518; at 80°, 1·023; at 100° F., 1·918, which is nearly $\frac{1}{15}$ of the average pressure of the atmosphere.

"The quantity of the atmosphere which covers the globe must be practically unchangeable. On the other hand, the amount of aqueous vapour in the air is constantly varying.

"A cubic foot of dry air at sea level and 50° F. temperature weighs nearly 547 grains; a cubic foot of vapour the same temperature weighs only 4·1 grains. The air is 133 times heavier than the vapour. Hence the more moisture distributed through the atmosphere, the less pressure shown by the mercury in the barometer tube.

"We cannot at any moment tell how much the fall of the barometer is due to the presence of vapour or precipitation of rain, or actual removal of the air by cyclonic movements; but water in one form or another must have a notable influence" (Science Notes—*Daily Telegraph*).

At a height of 23,000 feet, the amount of vapour in the air is only $\frac{1}{10}$ of that which exists at sea level; while at 46,000 feet it would be only $\frac{1}{100}$.

Cirrus clouds have been seen at this altitude. Long before water vapour has reached 37 miles a great deal is lost by being condensed into rain.

At a height of 9 miles above the surface, the actual amount of vapour present is only $\frac{1}{30}$ of what would exist if it were incondensible.

It is the water vapour in the atmosphere that causes it to rise, as it is lighter than the air (*see* Specific Gravity of Elastic Fluids, p. 29—Atmosphere).

"When a mass of air containing only a small proportion of vapour rises, it cools at the rate of 1·6° F. for every 300 feet it ascends, or about 5·2° in 1000 feet.

"When the air contains as much as it can hold invisibly, or is fully saturated, it is different; it ascends, cools, condenses into cloud, and finally falls as rain, giving out the heat which it absorbed in the act of conversion from water into vapour.

"This heat is latent so long as it is vapour, becomes patent as it condenses, and retards the cooling of such a mass of air; it only cools $\frac{3}{4}$° F. in ascending 300 feet" (Archibald).

Saturation of Air

Saturation is the term used when the air is saturated with aqueous vapour, when, if the temperature is slightly lowered, condensation takes place. The degree of saturation is measured by an instrument called the hygrometer.

Air at a temperature of 32° can contain, in the state of vapour, the $\frac{1}{160}$ part of its own weight, and that amount is doubled with every 27° rise in temperature; so that at 59° the air can contain $\frac{1}{80}$ part, and at 86° $\frac{1}{40}$ part; but it is seldom that it is so fully saturated.

A given space can only contain a certain amount of vapour. When it can hold no more it is said to be fully saturated. Whether there be air or not in the space does not affect the quantity of vapour.

If the space be a vacuum, it is immediately filled; if there be air in it, the evaporation goes on slowly. Just as hot water can contain more salt than cold water, so hot air can contain more vapour than cold.

TYPICAL NATURAL WATERWORKS.

The sun has raised the moisture up into the cloud. The mountain forms a natural condenser; the snowfields and glaciers act as storage reservoirs holding the water "locked to solidity" in reserve. The small glacier stream conducts a continuous supply into the little lake, which forms a service reservoir, whence a stream acts as nature's distributing agent.

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Condensation of Vapour

The condensation of vapour is frequently referred to in the following chapters; it is the turning of steam or vapour back into water. Thus when a cold east wind meets a warmer current, the moisture which this latter contains is condensed, and we have rain, or natural atmospheric condensation.

The artificial condensation of steam and the formation of a vacuum by the injection of cold water to condense the exhaust steam into water, now in general use, was first applied to the steam engine in 1705 by Thomas Newcomen, a locksmith of Dartmouth, Devon, but this is somewhat outside the scope of our subject.

Vapour and its Effects

Atmospheric water exists in three states: vapour (gaseous), water (liquefied, as rain), solid (ice, snow, hail). It is, however, only in the form of vapour that we shall consider it here.

Were it not for the particles of vapour and dust in the air, there would be no refraction of light, no twilight or dawn.

Where the air is very rarefied, as at Quito and Lima, twilight is said to last only twenty minutes.

In India there is but little of this beautiful phenomenon to be seen.

> "The sun's rim dips, the stars rush out,
> At one stride comes the dark."
>
> COLERIDGE.

There can be no twilight on the moon, for, as we have seen, this luminary possesses no air.

Now the sun is apparently visible, and its rays continue to reach us for some considerable time after it has set, for though the rays of light cannot reach us directly they do so by refraction.

Light from the sun travels through millions of miles of pure ether, and suffers no refraction until it strikes our atmosphere.

It is a well-known fact that the setting sun has actually sunk completely beneath the horizon at the moment when it appears to us to be first in contact with it, and when the upper limb is just about to disappear it is actually 36′ below the horizon.

Atmospheric refraction is the apparent angular elevation of the heavenly bodies above their true places, causing them to appear higher than they really are.

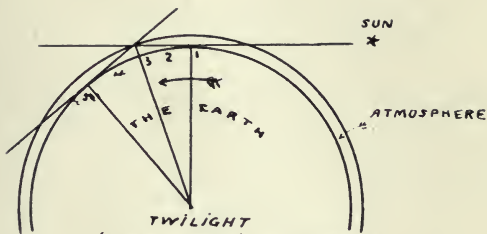
Therefore, the more obliquely the light enters the atmosphere, the greater will be the refraction. It is from this cause that the sun, when near the horizon, either at sunrise or sunset, appears to be elliptical, the long axis being horizontal, from the fact that the light from the upper part of the disc is not so strongly refracted as that from the lower part.

Therefore refraction is greatest when the body is on the horizon, and diminishes all the way to the zenith, where it disappears.

In passing through the upper layers of air, the rays get bent and reflected, and, in spite of the curvature of the earth, we get brilliant skies after the sun has set.

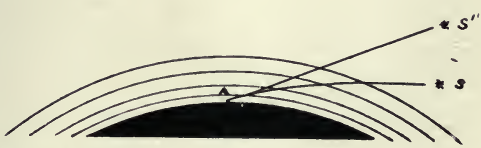
As an illustration of the fact that floating particles of vapour and dust in the air reflect light, we may instance a ray of light penetrating into a dark room through a hole in the shutter, which diffuses sufficient light to illuminate feebly the apartment.

Were it not for this, the sun would set, and darkness immediately overshadow all, where now we get twilight until the sun is 18° below the horizon, and night approaches gradually.



TWILIGHT
(FROM YOUNG'S ASTRONOMY.)

"With the sun as shown, it will just have set to an observer at 1, but all the air within his range of vision will still be illuminated. When by the earth's rotation he has been transported to 2, he will see the 'twilight bow' rising in the east. When he reaches 3, the western half only of the sky remains bright. When he reaches 4, only a glow remains in the west; and when he come to 5, night closes in upon him. Nothing remains in sight which the sun is shining."



ATMOSPHERIC REFRACTION (Dr Mill, *The Realm of Nature*).

A observer. *s*, true position. *s'*, apparent position of sun.
The denseness of the atmosphere is indicated by the closeness of the lines

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For the same reason, we have the gentle daybreak, and gorgeous coloured skies, both morning and evening, instead of an immediate transition from light to darkness or darkness to light.

Nearly all the celestial phenomena arise from this refraction of light. Chambers, in his *Story of the Solar System*, attributes even the twinkling of the stars to this cause.

The word twilight is of Saxon origin; it implies the presence of twin or double light, and applies to the dawn (break of day) as well as to the approach of evening, generally known by the name of twilight.

The sun having set, it still continues to light the clouds, and when thus illuminated they reflect some of the sun's light, producing these half-lights.

"The duration of this light depends on the position of the observer, the season of the year, and the condition of the atmosphere. In the tropics 16° or 17° puts an end to the phenomenon. At the equator the duration is about seventy minutes; at the latitude of Greenwich two hours; and so on towards the Pole. At each pole in turn the sun is below the horizon for six months; but as it is less than 18° below for three and a half of those six months, it may be said that there is a continual twilight for three and a half months.

"At the latitude of Greenwich, from 22nd May to 21st July there is no true night, but constant twilight from sunset to sunrise, or two months' twilight in all" (Chambers).

I often wonder how many of my readers, when they see the glorious colours of the sky, think of the manner in which nature enables us to realise their beauty and variation.

Light and colour are impressions produced by vibrations of the ether on the retina of the eye. When 700 millions of millions of vibrations strike the eye in a second we see violet; 400 millions of millions give us the impression of red.

The optical illusion called mirage is, like the coloured skies, caused by the reflection of the light through masses of air of various density.

In this manner apparent elevations, coasts, mountains, and phantom ships are formed; in deserts the illusion takes the form of lakes. At times it appears to invert existing objects, or to repeat an object above its true position.

The Fata Morgana seen on the Calabrian coast is a phenomenon of this kind, men and animals of enormous size being represented in the air.

Without vapour or minute particles of water in the air, these would be impossible.

Temperature of Atmosphere

The air resting on the earth becomes warmed by contact with it, and by the radiation from its surface; but in the temperate zone, as we ascend above the earth's surface, the temperature diminishes.

The rate of diminution decreases as we rise, from 7° in every 140 feet near the surface to 1° in every 400 feet at a height of 10,000 feet, the total diminution from sea level up to 10,000 feet being 34°, or an average of 1° in 300 feet. In India at 10,000 feet the rate is 1° in 270 feet.

The lowest air temperature recorded was registered in a free balloon ascent from St Louis in December 1905, when −122·1° F. was found. This was almost equalled at Vienna on 2nd March 1905, when −121·7° F. (154° of frost) was registered at a height of 31,880 feet. At greater heights up to 37,300 feet, the temperature, though more than 100° below zero, was not quite so low as that quoted.

The mean temperature of London is 46·9° F.; the mean summer temperature 62° F.; and the mean winter temperature is 40° F.

If we take the mean temperature of London as being, say, 50°, snow-line would be reached at about 4500 feet.

At the earliest period of the earth's history, the temperature of the atmosphere depended principally on the mass of molten matter forming the earth. As this cooled the temperature was governed more and more by the radiation of the sun's heat from the land and sea, and not from the rays of the sun passing through the atmosphere, and internal heat now suffices to raise the temperature no more than $\frac{7}{100}$ of a degree.

Tyndall says: "Solar beams, powerful enough to fuse the snows and blister the human skin; nay, it might be added, powerful enough when concentrated to burn up the human body itself, may pass through the air, and still leave it an icy temperature."

The altitude of the sun also has considerable effect on the amount of heat radiated.

When the sun's rays are vertical, we get nearly its full power; but when the rays are inclined we get proportionately less, the same rays having to cover a larger area of the earth's surface. The power of light also varies in like proportion. This is in fact the cause of the variation of light and heat in different seasons, and on different portions of the globe.

This will be strikingly apparent if we call to mind the fact that at the end of December, when we in England are experiencing the severe conditions of winter, the earth is 3,000,000 miles nearer the sun than it was at the end of June.

This is due to the earth's describing an ellipse and not a circle round our luminary, and proves that a few millions of miles either nearer or further away is of minor importance compared with the angle at which the sun's rays strike the earth; for we get the maximum heat when the rays fall directly on us, and a minimum of heat when they are most inclined.

Twenty-five per cent. of the heat falling vertically on the upper surface of the atmosphere is absorbed thereby, and 75 per cent. only reaches the earth. When, therefore, the sun's rays are inclined at an angle of 50°, only 64 per cent. reaches us; if at an angle of 10°, only 16 per cent. At sunrise and sunset the sun has only $\frac{1}{1345}$ part of its brilliancy at midday, when directly overhead. In the same manner, in winter (speaking of the northern hemisphere) the earth is nearest to the sun, and in summer the furthest from it, the difference being occasioned not by the distance, but by the more or less oblique direction of the sun's rays.

We have seen that the earth receives the sun's heat direct, while the air receives it by radiation from the earth's surface; therefore, the further we get above the earth, the colder the air becomes.

We have also seen that in England we can, by varying our altitude by 300 feet either way, gain or lose say 1° F.

To obtain a like result from travelling north or south, taking the temperature of the North Pole as 0° F., and that of the equator as 80° or 90° F., we should have to take a journey 70 or 80 miles.

The greatest ranges of temperature of the lowest atmospheric stratum, between day and night, occur in the driest parts of the earth. In the interior of the continents, such as the Sahara, Desert of Gobi, etc., the difference often amounts to 40° F. The smallest ranges of temperature

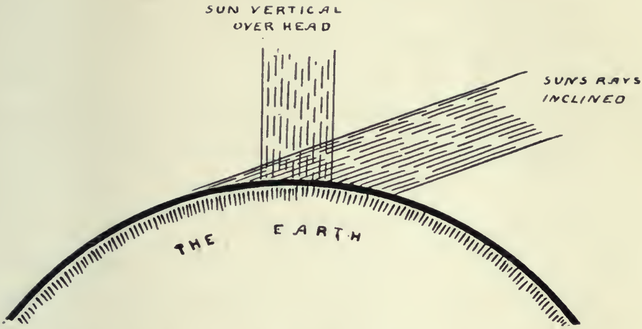

DIAGRAM SHOWING THE AREA COVERED BY A CERTAIN WIDTH OF SUN'S RAYS AS THEY FALL EITHER VERTICALLY OR INCLINED.

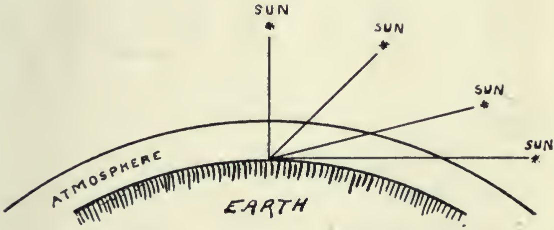

DIAGRAM SHOWING THE THICKNESS OF THE ATMOSPHERE TRAVERSED BY THE SUN'S RAYS WHEN VERTICAL OR INCLINED

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occur in small oceanic islands, such as Madeira, Bermuda, etc., where the difference between day and night does not exceed 5° F.

Were the earth deprived of its atmosphere, the temperature at the equator would be 94° F. below zero, and that at the Poles would be 328° F. below zero, and the mean temperature of the whole globe 138° F. below zero—a terrible frost. With the protection of our atmosphere, the average temperature near the surface is about 60° F.—a delightful temperature.

Thus we see this atmospheric mantle supports life, acts as a blanket keeping the earth warm, and it also protects us from falling meteorites.

Many planets have not progressed towards solidification so far as our earth. Jupiter has not yet cooled to the same extent, and is supposed to be partly self-luminous, having an atmosphere containing all the substances which have, on the earth, long since been condensed into liquids and solids. This is due to its enormous size, its diameter being nearly eleven times that of the earth, and it would therefore take longer to cool.

In the moon, however, we see a picture of the more advanced stages of this wonderful transformation of vapour into liquids and solids. Here the smaller body has cooled more quickly; not only is there no gas, but no liquids, no air, therefore no life—all has been absorbed into the solid substance of the moon.

Sir Robert Ball gives us a graphic description of the mountain scenery in the moon, where the disintegrating influences of the atmosphere are not at work. "The absence of air and water from the moon explains the ruggedness of the lunar scenery. The cloud-capped towers, the gorgeous palaces, the solemn temples have but a brief career on earth. It is chiefly the incessant action of water and of air that makes them vanish like the 'baseless vision.' On the moon these causes of disintegration and decay are absent. It seems probable that on the moon a building would remain for century after century just as it was left by the builders. There would be no need for glass in the windows, for there is no wind and no rain to keep out; there need not be fireplaces in the rooms, for fuel cannot burn without air. Dwellers in a lunar city would find that no dust could rise, no odours be perceived, no sounds be heard."

Professor Günther of Freiburg University predicts that the time will come when there will not be sufficient water on this globe to support human life, and that it will eventually disappear into the cavernous interior, as in the case of the moon. Both the former and the latter are mere speculations and are not accepted as facts, but their ingenuity makes them worth repeating.

I trust my readers will not think this a digression, for it has a distinct bearing on our story, as it tells us that the source of all our water (the atmosphere) will not always remain in its present apparently permanent condition, though there are scientific reasons given to lead us to believe that our earth will never be so absolutely devoid of atmosphere as the moon; and although it will never concern us, we may at least be gracefully thankful.

Compression of Atmosphere

Air may be compressed almost indefinitely; the pressure of one atmosphere will halve the volume of air. By the time pressure equal to three atmospheres has been put on, it will be found to occupy only one-third of its space, and so on.

Another example will perhaps make it clearer. If

6 cubic feet of air at ordinary atmospheric pressure be compressed until they occupy only 3 cubic feet of space, the pressure of the air would rise to that of two atmospheres, or the barometer at the commencement would register 30 inches, and after the compression 60 inches.

Compressed air has been used as a motive power for many years. A French engineer, Papin, first put it to this useful purpose about two hundred years ago.

In 1843 passenger trains were by this means run at a speed of 70 miles per hour between London and Croydon. Compressed air was, however, abandoned for this and other similar large purposes, but we still have parcel and letter delivery by its means. Pneumatic tools of the most useful and ingenious kind are now used for many purposes, including the work of boring for water.

There are also air lift-pumps, where water is raised from deep wells by the force of compressed air only, no pump valves being necessary. We also use compressed air for inflating our bicycle and motor-car tyres, and many other purposes.

We should also remember that most pleasant of all uses that compressed air is put to, viz. the production of music; above all in the king of instruments, the organ. Any person who is not moved by the grandeur of our cathedral organ cannot possess a soul.

This calls to mind an anecdote related by that well-known *raconteur*, the late Dean Hole.

As a chorister I had attended the choir festival, which was followed by the usual spread, to which, as might be imagined, we choir boys did ample justice. Among several stories related for our edification and amusement, one impressed me more than any. At a certain church the Dean gave out the number of the hymn and waited for the playing of the same, but there was no sound from the organ. He again repeated the number, and again. At last the organ-blower thrust his head through the oak screen and called out aloud, "Please, sir, she's bust!" The Dean probably told us how the congregation received the news, but I have forgotten it.

Only those who have been organists can fully appreciate the pranks played by the vapour in the atmosphere on the mechanism of the organ. With certain alterations of the temperature the delicate parts of the organ are affected, and before the days of pneumatic organs the "trackers" would often hang up, causing the pipes to continue to pour forth sound longer than was desired. It was a common occurrence to find notes cyphering, and little did the congregation think that, shortly before the service, the organist had been crawling all over the dusty interior of his instrument, fixing elastic bands with pins on the defective trackers to help them to "shut up."

Expansion of Air

Dry air expands or contracts uniformly ·002039 its volume, per degree Fahrenheit, under constant pressure, or but one volume for each 493° of temperature through which it is raised, and, like all other elastic fluids, this expansion is uniform at all temperatures.

If air be heated in a confined chamber, its pressure increases in direct proportion to its rise of temperature.

If air be suddenly compressed, its temperature rises in proportion, and if suddenly allowed to expand, the temperature falls.

The suddenness is only necessary to enable the alteration of temperature to be detected before it escapes.

One thousand volumes of air at 0° C. become 1·3665 volumes at 100°, *i.e.* 1 volume of air at 0° C. increases to 1·003665 at 1° C.

The amount of increase in volume for 1° C. is ·003665, and approximately equals $\frac{1}{273}$, this fraction being the co-efficient of expansion for air.

Thus, for every increase of 1° C., the volume of the gas is increased $\frac{1}{273}$ of its volume.

Therefore, 273 volumes at 0° C. are changed into 274 volumes at 1° C., and 275 volumes at 2° C.

It likewise contracts uniformly on the reduction of temperature.

For every degree which gas is cooled below 0° C. it should lose $\frac{1}{273}$ of its volume; therefore, if cooled through 273° C. below zero, it would occupy practically no space whatever.

This is called the absolute zero of temperature, viz. −273° C. (−459° F.).

Such temperature has never yet been reached, and in such extreme cold gas would not exist as such.

The greatest artificial cold ever produced was 330° below zero F. This was accomplished by Professor Dewar.

If there were no expansion and diffusion of air, the separate gases of which it is composed would all lie in layers one above another, the lightest at the top. This would be the water vapour; next, the nitrogen, then the oxygen; at the bottom next the earth the carbonic acid. Result to us, death.

It will no doubt be asked why all these points are considered here; but air and vapour, under the influence of these laws of compression and expansion, due to the action of heat and cold, are really the cause of wind, storms, cloud, rain, snow, ice, and all the varieties of atmospheric phenomena.

Height of Atmosphere

The height of the atmosphere is not known. Probably we shall never know exactly where air ceases to exist and the boundless region of space or vacuum commences.

Some idea of the thickness of this sea of air is obtained from the point at which meteorites become visible. This interesting phenomenon has always attracted the attention of the poets. From Tennyson we get—

> "Now slides the silent meteor on, and leaves
> A shining furrow."

And Byron sings—

> "As stars that shoot along the sky
> Shine brightest as they fall from high."

Though they may have fallen millions of miles, they are invisible until they come in contact with our atmosphere, at about 100 miles from the earth, when by friction through it they become incandescent, and we can then see them, usually at a height of from 40 to 80 miles.

They generally burn out and disappear at an altitude of about 25 miles; but portions of their bodies frequently reach the earth. When this happens it is usually a single aerolite or meteoric stone; but frequently several have been known to fall. In several instances thousands have been obtained: as in the fall of L'Aigle in 1803, at Knyahinya in 1866, and Pultusk in 1868.

Meteorites consist principally of iron and siliceous matter. Some are of large dimensions. One mentioned by Pliny and seen in his day fell at Ægospotami in 467 B.C., and is described as being as large as a waggon.

These stones have been seen to break up into several pieces when about 90 miles from the earth. Some are known as detonating meteors. The explosion of one that fell in Kansas, U.S.A., was heard 60 miles off, and was supposed to have been heard 150 miles distant.

Their velocity is rarely under 10 miles per second; seldom over 40 or 50 miles; the average being about 30 miles per second.

On 27th January 1906 a very brilliant meteor was seen to pass over East Lincolnshire, at an altitude of 40 to 50 miles, and its velocity was about 24 miles per second. Its brightness was equal to the full moon, and its trail of light lasted for several minutes.

From similar observations it is concluded that the height of the atmosphere is at least 120 miles; but in an extremely attenuated form it may reach 200 miles.

Observations made at twilight, on account of reflection of air and vapour and dust particles in suspension, give about 50 miles.

It is supposed that the atmosphere of the sun is 500,000 miles deep; but we must bear in mind the size of this body, compared with that of our earth, as it probably accounts to some extent for the great difference in depth.

Height Penetrated

The atmosphere has been penetrated to a height of 37,000 feet, at which point the ordinary person becomes insensible.

This is probably the greatest height to which man will ever be able to ascend without an artificial supply of oxygen. In September 1862 Messrs Glaisher and Coxwell made an ascent from Wolverhampton, reaching an elevation of 37,000 feet (7 miles), which is the greatest altitude yet attained.

Mr Glaisher became insensible. His companion's hands were so severely frozen that he was compelled to use his teeth to open the valve and so enable them to descend.

Dr Berson of Strassfurt found the temperature at about 20,000 feet to be practically constant at all seasons of the year, varying from $-14°$ to $-19°$ F. On 4th December 1894 he ascended to 22,000 feet, feeling some discomfort from reduced pressure; but by the assistance of a cylinder of compressed oxygen, fitted with a tube for breathing through, he attained an altitude of 31,800 feet without serious discomfort. The temperature here was $-54°$ F.

On 31st July 1901 another ascent was made, Dr. Berson reaching 33,790 feet. Up to 29,000 feet no unusual sensations were experienced. Up to 33,600 feet observations were continued regularly, though consciousness was temporarily lost for brief intervals. Soon after this one of the observers resisted all efforts to arouse him; his companion opened the valves, so as to bring about a descent, and then himself became unconscious through the exertion of this action. Neither of them awoke for one hour, the balloon being then at about 16,000 feet.

When the above altitude (33,790 feet) was reached, the balloon was still ascending and would have gone higher. The thermometer registered freezing point at 12,470 feet; at 33,600 feet $-40°$ (*Geographical Journal*, 1901).

Self-registering instruments affixed to balloons in France gave the following temperatures :—

Altitude	49,000 feet	$-90°$ F.
„	59,000 „	$-101°$ F.

Major B. F. S. Baden-Powell (20th March 1907), in an address to the members of the Royal Meteorological Society on "The Exploration of the Air," tells us that small balloons carrying self-recording instruments had ascended to the enormous altitude of 82,000 feet, or nearly 16 miles, above the surface of the earth.

On 17th May 1907 balloons were liberated from the Physical Observatory at Pavia (near Milan), when the recording instruments they carried indicated a height of 74,150 feet, and the thermometers registered a temperature of 77·8° below zero F.

The highest kite ascent as yet made was accomplished in Lindenberg Observatory on 25th November 1905. By a team of six kites an elevation of 21,096 feet was attained, 9 miles of wire being paid out.

The pressure at the highest point was 12·99 inches, and the temperature −13° F., the temperature at the surface being 40·8° F.

For permanent habitation, it is found to be prejudicial to live at a greater altitude than 15,000 feet, our respiratory and other organs not being constituted to withstand the conditions of temperature and reduced pressure that would be encountered above this height; though we would not be affected by any chemical alteration in the properties of the air, for its composition is quite as suitable for man at great heights as at sea-level.

Dr W. N. Shaw, F.R.S., tells us that the greatest cold yet discovered at high altitudes was over the equator, where the fall of temperature was found to be continuous as the balloon ascended; so the coldest spot known on earth, or rather off the earth, is the air 9 or 10 miles above the equatorial belt, where the temperature is lower than any yet reached in the atmosphere within the Arctic Circle.

Pressure of Atmosphere

The weight of air = $\frac{1}{851}$ times that of water. A cubic foot of air = ·07646 lb. at 62° F., and 13·0777 cubic feet of air = 1 lb. A column of air at 32° F. and 1883 feet high = 1 lb. pressure per square inch. A column of water, to exert a similar pressure, would only require to be 27·727 inches high (62° F.), and mercury at 32° F. only 2·036 inches high.

The barometer was discovered through the failure to draw water from a deep well in Florence, where, after infinite pains, it could be made to rise no higher in the pump than 33 feet.

Galileo was consulted, and concluded that the atmosphere had weight, and that a column of water 33 feet in height was as much as the weight of the atmosphere could balance.

It was Evangelista Torricelli, an Italian (born 1608, died 1647), who discovered that a column of water 32 feet high balanced the pressure of a column of atmosphere of equal diameter, and that 2 feet 4 inches of mercury produced a similar result.

Pascal discovered that, in ascending the Puy de Dome in Auvergne, the mercury fell to 24·7 inches, and in descending again rose to 28 inches, proving that there was less pressure at the top of a mountain than at the base, and that the mercury was really supported by the weight of the atmosphere.

A cubic inch of mercury weighs ·49 lb., and $30 \times \cdot 49 = 14 \cdot 7$, which figure represents the weight of the atmosphere over 1 square inch of surface. Therefore, it exerts a pressure of 14·7 lbs. on every square inch of mercury, which is 13·6 times heavier than water, so we have $\frac{30 \times 13 \cdot 6}{12}$ feet = 34 feet, or the theoretical limit beyond which water refuses to rise. In practice 25 feet is the figure commonly considered as the workable limit.

The outcome of this discovery was the barometer. There are two kinds of mercurial barometers—the "syphon" and the "cistern." The familiar instrument with dial and pointer, commonly called the weather-glass, the Fitzroy barometer, and others, are but modifications of these two.

Although in the present day mercury is almost universally used in the construction of the barometer, some of my readers may not be aware that all liquids will answer this purpose, though not equally well, one point in favour of mercury being that it does not give off vapour at moderate temperatures; if it did so the space in the tube above the column would fill with vapour, and so cause the instrument to be inaccurate. Again, the specific gravity of mercury is greater than that of any other liquid, and therefore a shorter column is required (say 30 inches) to balance the atmosphere.

If made of water the tube would require to be about 34 feet high, the specific gravity of mercury being 13·6 times greater than water ($13·6 \times 2·5 = 34$).

If made of glycerine the tube would require to be 27 feet high, and so on, according to the specific gravity of the liquid employed.

The aneroid barometer consists of a circular metallic chamber, partly exhausted of air and hermetically sealed; it has corrugated concentric circles on its upper and under surfaces. The varying pressure of the air depresses or elevates the surface of this chamber. An arrangement of levers and springs moves the pointer on the dial.

Solid bodies press downwards only, but fluids equally in all directions. The ocean of fluid air enveloping our globe, weighing 14·7304, or nearly 15 lbs. to a square inch, is pressing on the human body with an enormous weight.

When a man lies down, he has a pressure of about 30,000 lbs. above him, and he would be unable to get up were it not for the fact that an equal pressure is exerted in all directions, inside as well as outside the whole body. For this reason the weight or pressure is not apparent.

It is from the same cause, viz. equal pressure inside and out, that the delicate soap-bubble withstands this pressure, rising in the air through being filled with slightly lighter air from the lungs.

I once saw a photograph of a simple object lesson on the pressure of the atmosphere.

An ordinary china hot-water plate had been partly filled with boiling water and then corked tightly. As the water cooled and the steam condensed, a partial vacuum was formed; the dish could not withstand the pressure of 15 lbs. to the square inch, and the plate was forced in with a crash.

At sea-level, with the barometer at 30 inches, the pressure would be 14·7 lbs. per square inch (generally spoken of as 15 lbs. to the square inch), therefore a column of air 1 inch square, 45 miles high, weighs 15 lbs. Seven miles above the surface of the earth the air is 4 times lighter than on the ground. Fourteen miles above the earth it is 16 times lighter. Twenty-one miles above the earth it is 64 times lighter.

The pressure of the atmosphere at sea-level is used as the unit of pressure, and is called an atmosphere; 29·905 inches of the mercurial column at 32° F. (London).

The capital of our country is here given for a definite reason. This unit of pressure is not universal; the unequal distribution of land and water influences the figure, which varies from 30·400 inches in the centre of Asia to 29·304 inches on the coast of Iceland.

The time of day, seasons, and many other considerations also influence the pressure and upset its uniformity.

At 18,000 feet above the sea-level, under the same conditions, the pressure would only be half the above.

A fall of 1 inch of mercury (30° to 29°) shows an increase in altitude of 910 feet; but it is not at this ratio throughout, as the pressure is lighter in a cumulative degree as we ascend. Were it not so, the pressure at 16 inches would be 30 to $16 = 14 \times 910 = 12{,}740$ feet altitude. This is not correct, and it is in reality 16,000 feet, the proportion increasing with the height.

The following table will show the decrease of pressure, with the corresponding altitude, when the barometer marks 30 inches at sea-level (air of average temperature and dampness).

Altitude in feet.	Pressure in inches.
0	30
910	29
1,850	28
2,820	27
3,820	26
4,850	25
5,910	24
7,010	23
8,150	22
9,330	21
10,550	20
13,170	18
16,000	16

Were the ratio of 1 inch to 910 feet of air preserved all the way up, we should reach the limit of our atmosphere at about 5 miles.

By a glance at this table, the difficulty to be encountered in cooking at high altitudes will at once be apparent, the degree of heat necessary for this purpose not being obtainable in these heights with the ordinary utensils.

Darwin, in his *Voyage of the Beagle*, tells an amusing anecdote of an occurrence which happened to his party while crossing the Andes in 1835.

They had attained so great an altitude, and the boiling point was, as we have seen, so low, that "our potatoes after remaining some hours in the boiling water, were nearly as hard as ever. The pot was left on the fire all night, and the next morning it was boiled again; but yet the potatoes were not cooked.

"I found out this by overhearing my two companions discussing the cause. They had come to the simple conclusion that the potatoes were bewitched, or that the pot, which was a new one, did not choose to boil them."

It is possible to tell the altitude by boiling water.

If the temperature of the vapour of boiling water and of air be taken at a lower and higher station, and the difference noted and reference made to tables provided for the purpose, the difference in the altitude between the two stations can be correctly obtained.

To give some idea of this reduction of boiling points:—

At	500 ft.	below sea-level,	boiling point is	213° F.
,,	1,013	,,	,,	214°
,,	sea-level,		,,	212°
,,	509 ft.	above sea-level,	,,	211°
,,	1,021	,,	,,	210°
,,	5,185	,,	,,	202°
,,	10,053	,,	,,	193°

From these figures we also see that, if we go down into a mine below sea-level, a greater degree of heat is necessary before water will boil.

Contamination and Purification of Atmosphere

All animals, including man, consume oxygen, and in respiration exhale carbonic acid. The latter is not allowed to accumulate, for, by the wonderful provision of nature, it is arranged that the trees and vegetation should feed on it; they remove the carbon it contains, building it into their structures, and setting free again the oxygen which was united with it in the gas.

Charles Kingsley, in writing on this subject, refers to a sickly geranium in the window of a slum cottage where death had been rampant among the children through vitiated air: "It spreads its blanched leaves against the cellar panes, and peers up, as if imploringly, to the narrow slip of sunlight at the top of the narrow alley," and he tells how the little geranium did its best, like a heaven-sent angel, to right the wrong which man's ignorance had begotten, and drank in, day by day, the poisoned atmosphere, forming it into fair green leaves, and breathing into the children's faces, whenever they bent over it, the life-giving oxygen for which their festered lungs were craving in vain.

There are air-plants (Epiphytes) found in the damp tropical forests of Africa, Asia, and America, which live entirely on the nutriment obtained from the atmosphere.

"What is fraught with health," says Hugh Miller, "to the existence of the vegetable kingdom, is in many instances a deadly poison to those of the animal.

"The grasses and water-lilies of the neighbourhood of Naples flourish luxuriantly amid the carbonic acid gas which rests so densely over the pools and runnels out of which they spring, that the bird stoops to drink and falls dead into the water—the two kingdoms exist under laws of life and death so essentially dissimilar."

Man exhales 16 cubic feet of carbonic acid gas per day when at rest, and correspondingly more in proportion to the amount of work performed, up to about 30 cubic feet.

One ordinary gas-burner consuming 5 feet per hour contaminates the atmosphere at the same rate as five men by respiration, producing about an equal amount of carbon dioxide per hour.

Winds also remove the vitiated air from the towns, replacing it continually by purer air. The sea is also acting in a similar capacity, churning, washing, and cleansing the air by its waves and breakers. The benefits to be derived from breathing such air around our coasts has no doubt been experienced by us all; its invigorating effect on the human system is one of nature's greatest physicians, and succeeds when man's ingenuity has failed to restore health.

There is food for thought in the wholesale manner in which we contaminate the atmosphere by pouring soot and smoke into it from our chimneys and factory shafts. To some extent of course this is necessary to the conditions of our life; but it is out of all proportion to what it would be if our furnaces consumed the fuel properly. Let us see what soot is. Most persons would describe it, and in general correctly, as "unburnt carbon." But this reply would be inadequate for Manchester, which possesses a fatty description of soot, quite peculiar to this town. Professor E. Knecht has found it to comprise 50 per cent. of substances that are not carbon. "Among them were snow-white samples of ammonium chloride, ammonium sulphate, calcium sulphate, and a beautifully crystallised paraffin hydrocarbon, similar in properties to one that exists in beeswax. The amount of heavy hydrocarbon oils in household soot was found to be no less than 13 per cent." From these strange components that float in the breathing mixture—sometimes called fresh air—the Professor manufactured a dye-stuff, which was capable of producing absolutely fast shades of brown on cotton. Professor Knecht is of the opinion that unless more efficient fire-grates are made compulsory, we must continue to breathe our soot-and-air mixture.

Contamination of atmosphere by the combustion of coal in private houses is much greater than that of the smoking chimneys of manufacturing and business premises. It is estimated, says a correspondent of the *Daily Telegraph* "that half to 75 per cent. of the smoke in London comes from this source." As indicating the great amount of smoke discharged from domestic chimneys, it has been noticed that some of the densest London fogs have arisen on days when the great bulk of business premises have been closed, and a massive bank of smoke in London has been seen to rise to a height of at least 3000 feet or 4000 feet and to be carried by the wind in a sunlight-obscuring trail to a distance of 50 miles. Dr W. N. Shaw, of the Meteorological Office, states that he found from comparison of records that, owing to its smoke, London loses half of the sunshine in winter and one-sixth in summer, and there can be no doubt that domestic grates contribute largely towards the evil.

If the lungs of a Londoner be examined (after death), they will be found to be of a greenish black, while those of a countryman are fresh pink and quite clean, although the respiratory organs of the former may not be seriously impaired.

At the earlier period of the earth's history (the carboniferous), the amount of carbonic acid in the atmosphere is supposed to have been much greater, thus causing the luxuriant growth of vegetation that went to form our present coalfields.

Velocity and Impulse

The circulation of the atmosphere called wind is in no small degree due to the vapour it contains. The heat given out in the process of evaporation reappears in the process of condensation of vapour into cloud or rain; the saturated air, being lighter than dry air, ascends, giving rise to aerial movements.

"If one portion of the universe," says Professor Tyndall, "be hotter than another, a flux instantly sets in to equalise the temperatures, while winds blow and rivers roll in search of a stable equilibrium."

The visible effect of the work of the atmosphere on the geological formation of our globe is not at first sight very apparent; it is, however, a mighty agent—so mighty as to be beyond our conception.

When moving rapidly, it agitates the sea; sets in motion the mighty waves, with all their attendant works of destruction, transportation, and reconstruction.

Were it not for the fact that the air surrounding us travels with us (1000 miles per hour at the equator), the enormous velocity of the earth's rotation would be apparent to an alarming extent. The gently falling snow-flakes would appear to (and really would under those conditions) fly past us with a velocity of several times that of the greatest tornado ever experienced.

To find the direct impulse of the wind in pounds on one square foot, square the velocity in statute miles per hour × ·005016, or square the velocity in knots per hour × ·006667.

Velocity, miles per hour.	Pressure, lbs. sq. ft.	
3	·045	Light air.
5	·125	Light wind.
7	·246	Light breeze.
9	·406	Moderate breeze.
14	·983	Fresh breeze.
20	2·00	Strong breeze.
24	2·89	Moderate gale.
30	4·51	Fresh gale.
36	6·50	Strong gale.
40	8·02	Heavy gale.
50	12·5	Storm.
100	50·2	Hurricane.

This last velocity is 12 in the Beaufort scale. It is a familiar joke, says Dr Mill, that force 12, the maximum of the scale, can only be recorded when observer and observatory have both been blown away!

Stellar Space

Two short words, certainly; but what a mystery they imply! How little we know of it! It can only be compared with time, having no end; both go on and on, *ad infinitum.* It forms the blue vault or heavens, covering us like a mighty dome; and it contains our solar system, in which the sun, the earth, the moon, the stars move, everything moves, nothing stands still.

It is in this space that our earth is so marvellously suspended, in which it revolves on its axis, and the marvellous envelope of air with it; and we are practically unaware that we are being whirled round at the rate of 17 miles per minute; and in addition there is the velocity in orbit of 1100 miles per minute.

It is through this space that we receive our light and heat, and without the latter there would be no water to write about.

Outside the limits of our known universe are the stars, which Carlyle calls the "street lamps of the city of God."

The self-luminous, apparently small, bright objects of the heavens, are suns similar to our sun; probably each is the centre of a solar system like our own. Their size, owing to their distance, cannot be calculated, as in the case of the planets of our system; the nearest fixed star being that of *a Centauri* (a double star), one of the brightest in the southern hemisphere, is 20 billions of miles distant; its light would take 3½ years to reach us. Dr Gill gives this period as 4 years and 4 months, and its distance from the earth 275,000 times that of the sun. There is little cause for wonder that David should contemplate them and remark: "When I consider the heavens, the work of thy fingers, the moon and the stars, which thou hast ordained; what is man, that thou art mindful of him? and the son of man, that thou so regardest him?"

The stars visible to the eye are beyond numbering correctly, and the telescope reveals thousands more; then there are the myriads beyond its reach, beyond our comprehension.

Chambers, in the *Story of the Stars*, tells us that Sir William Herschel saw through his stationary telescope 258,000 stars pass before his view in 41 minutes, and that 20,000,000 stars are within the range of an 18-inch reflector.

> "From star to star, from kindred sphere to sphere,
> From system on to system without end."

Such wonders as these should surely raise our thoughts to the great Controller of the universe, for the Creator is greater than His works.

J. C. Sharp, LL.D., says: "Nature and her works are employed by Scripture as a proof of the goodness of God. When, therefore, in the light of these thoughts, we study nature, we may well feel that we are engaged in no trivial employment. Even the most common acts of minutely observing nature's handiwork may in this way partake of a religious character, and become, as it were, the steps of a stair ascending towards the Eternal."

However anxious one may be to keep rigidly to the scientific and practical side only of these things, the higher and religious connection between them will force itself upon one. An apology or excuse for this is unnecessary, for, as the Rev. Robert Harley, F.R.A.S., remarks:

"Science without devotion is defective; science without religion is a corpse; religion without science is a ghost."

The temperature of stellar space is hardly within the scope of our study, but a few remarks on this subject cannot fail to be of interest. It is variously estimated as 90° F. below zero, or 122° below freezing point, and 60° F. below zero. These figures differ considerably; but of this we are certain—it is colder than any temperature experienced on any part of the earth. In the upper atmosphere, as we have seen, −122° F. has been recorded, so there is reason to suppose that stellar space is even colder than this.

Compare these figures with the mean temperature at the Poles, which is below 13° zero F., and we shall be able to form some vague idea of the awful cold of stellar space. It is through 93,000,000 miles of this intensely cold space that the sun's rays travel to reach us and dispense their generous warmth.

CHAPTER III

CLOUDS

"The clouds may stoop from heaven and take the shape
With fold to fold of mountain or of cape."

TENNYSON.

CLOUDS consist of visible vapour or watery particles suspended in the atmosphere. They differ only from fogs by their height, and less degree of transparency.

How Formed

In hot weather moisture is quickly taken up, and converted into vapour. The drier the air the greater the amount of cloud or moisture that can be dissolved.

Clouds, when first formed, contain more moisture than the air is able to maintain in an invisible state. As the cloud gradually mixes with a larger mass of air, it is more and more dissolved, finally passing altogether from the condition of finely divided liquid into transparent vapour.

This process will be more easily understood by comparing it with breathing. The moisture from the lungs on a fine, dry, warm day is invisible; on a cold, damp day little clouds of aqueous vapour appear to issue from the mouth, gradually dispersing as they mix with the surrounding air.

Nature but elaborates on this simple process, and we have moisture transformed into vapour, clouds, condensation, rain; then the streams and rivers, and at last the boundless ocean.

So clouds, like fog and mist, are produced by the partial condensation of vapour in the higher regions of the atmosphere.

How do these watery vapours rise to such heights to form the clouds? The reason has already been given and the cause explained: watery vapour is lighter than air.

The minute globules of water which compose a cloud, which is the middle stage between vapour and rain, are only about $\frac{1}{3000}$ of an inch in diameter, and have been expressively called by Professor Tyndall "water dust."

They were at one time supposed to be hollow, and for this reason able to float in the air; but the secret of their suspension lies in their minuteness. The slightest upward motion of the air will keep them suspended, as we see them, for a considerable time.

The particles grow by the adhesion of fresh coatings of water as the condensation continues, and the larger ones fall and absorb the smaller particles, increasing in size to, say, one-twentieth to one-tenth of an inch in diameter, when they can no longer remain suspended.

From whence does all this vapour arise? The sunbeams falling upon the sea warm it, though not so much as the land, sending up aqueous vapour; thus both from land and sea we have ascending currents of vapour which are eventually formed into clouds.

Hartwig says: "In every zone evaporation is constantly active; but the chief seat of its powers is in the equatorial regions, where the vertical rays of the sun plunge day after day into the bosom of the ocean and perpetually saturate the burning air."

These currents, on reaching a certain elevation, divide and flow part towards the north and part towards the south.

Colder air flows in to take their place. Circulation is thus established, and the air, laden with vapour, commences to form into cloud, and condenses, falling as rain or snow.

Cloud-banner

A cloud-banner is sometimes seen flying from a mountain top. The streamer of cloud appears to be steady, though a strong wind may be blowing; but it is only apparently permanent; its extremity is continually being dissolved by the atmosphere, the other end being incessantly renewed by partial condensation at the peak. The cloud-banner of the Matterhorn is described by Professor Tyndall in the following words: "The Matterhorn appeared to be divided in two halves by a vertical line drawn from its summit half-way down, to the windward of which we had the bare cliffs of the mountain, and to the lee of it a cloud which appeared to cling tenaciously to the rocks. In reality, however, there was no clinging; the condensed vapour incessantly got away, but it was ever renewed, and thus a river of cloud had been sent from the mountain. The wind, charged with moisture, rubbed against the cold cone of the Matterhorn; the vapour was chilled and precipitated in his lee. The summit seemed to smoke sometimes like a burning mountain; for immediately after its generation, the fog was drawn away in long filaments by the wind. As the sun sank lower the ruddiness of his light augmented, until these filaments resembled streamers of flame."

Moisture in Clouds

"There, floating in the blue expanse,
The watery clouds we view,
Whence fruitful showers, at His command,
The thirsty soil bedew."

From the Latin.

When we see clouds, whether high or low, in the air, we are looking at nature's process of preparing rain for the

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THE CLOUD-BANNER OF THE MATTERHORN.

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earth—first invisible vapour, cloud, rain; then, at 32°, snow and hail. Even at this temperature the air will gather moisture by evaporation. A cubic foot of air at zero F. will hold ½ grain of vapour; at 60° F., 5½ grains. At 80° F. 11 grains will remain invisible in the space of a cubic foot.

It has often been remarked, "I wonder what it is like to be in the clouds." Probably all of us have experienced it; for it is not necessary to ascend in a balloon to satisfy a wish in that direction. It is not a pleasant experience. When condensation occurs near the surface of the earth, we get clouds, but we call it fog, and dislike it accordingly. There is little difference between fog, mist, and cloud, except the place of origin.

We can at times climb above the clouds in our own country; even our hills under certain atmospheric conditions make this possible. It is an experience not easily forgotten, to climb for a considerable time through a drenching mist, and at last to come, dripping wet, through the clouds into clear, bright sunshine. Here nothing meets the eye but an endless sea of clouds, rolling like waves, breaking round the peaks and rolling round their massive sides, as their more substantial prototype, the ocean, rolls around our coasts; and we see, above, the blue dome of heaven, the vast expanse of clouds and space.

Re-evaporation

Sometimes condensation occurs among the clouds, rain falling from an upper stratum, but not reaching the ground, for on coming into a warmer temperature it is re-evaporated on its downward journey.

> "A little gale will soon disperse that cloud
> And blow it to the source from whence it came;
> The very beams will dry those vapours up."
>
> SHAKESPEARE.

The writer has frequently watched an isolated mass of noble white cumulus cloud in a clear sky, as it slowly sails across the blue heavens, like a snow-clad mountain, and has seen it slowly evaporate and almost disappear, leaving but a few stray filaments to guide the eye to its actual position; then slowly condense, become visible again, but altered in form to that of a frothy sea, or indescribable feathery moving mass of exquisite beauty. It slowly changes into the most beautiful forms, disappears and reappears in another shape unceasingly, never retaining the same density or form for any length of time. It is a marvellous and inspiring sight.

Professor Tyndall refers to condensation and evaporation of cloud as seen in the Alps:—

"As the sun sank the shadow of the Finsteraarhorn was cast through the adjacent atmosphere, which, thus deprived of the direct rays, curdled up into visible fog. The condensed vapour moved slowly along the flanks of the mountain, and poured itself cataract-like into the valley of the Rhone. Here it met the sun again, which reduced it once more to the invisible state. Thus, though there was an incessant supply from the generator behind, the fog made no progress. As in the case of the moving glacier, the end of the cloud river remained stationary, when condensation was equal to the supply."

Those in our crowded cities whose gardens and yards are so small as to be scarcely worthy of either name, can, under certain atmospheric conditions, obtain most restful and interesting views in the heavens above by watching the form, speed, and colour of the clouds: a sight that few of us ever contemplate, unless in a critical, grumbling mood, caring only whether they foretell rain and its consequent inconvenience to our anticipated work or pleasure.

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SEA OF CLOUD OVER THE LAKE OF ST MORITZ WHILE FREEZING (THE ENGADINE, SWITZERLAND).

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A CLOUD STUDY, ENGADINE.

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Clouds were of course designed by the Creator primarily for rain, but surely also for man's pleasure; for all the beauties of nature must be considered as gifts to man for his enjoyment and study, which, if we will only take delight in them, will lift us above the everyday troubles that come to all at all times.

Dew-point

When air is warm and moist, a slight lowering of temperature produces condensation, and clouds are formed. The ordinary expression "dampness" does not therefore give a comparative idea of the amount of vapour present in the air; for warm air may hold more vapour and yet feel drier. The degree of humidity is determined by the nearness of the dew-point to the existing temperature, and is governed by the amount of moisture present, and the temperature of the air in which it is dissolved.

As the air becomes cooler and cooler, it can contain less and less vapour. When it can hold no more it is said to be saturated, and the temperature then reached is called the dew-point.

Forms of Clouds

There are three primary forms of clouds—stratus, cumulus, and cirrus. They are usually seen in the same relative altitudes—low, intermediate, and high.

These primary forms of clouds are subdivided into cirro-cumulus, cirro-stratus, cumulo-stratus, nimbus, cumulo-cirrus-stratus, or rain-cloud. The last is the least attractive-looking, but it is only when the dark surface of this cloud forms its background that the splendid phenomenon of the rainbow is exhibited in perfection.

Altitude and Velocity

The average height of cloud is greater in summer than in winter. This fact calls to mind the well-known lines of Lord Tennyson:—

> "It was the time when lilies blow
> And clouds are highest up in air."

From a series of observations near Skiddaw, it was found that clouds were generally above 3000 feet; only ten times in five years were they below 300 feet from the ground.

Of all clouds, cirrus has the least density, greatest elevation, and the greatest variety of figure.

Clouds travel more slowly in summer than in winter.

From observations made at Blue Hill Observatory, Boston, U.S.A., the following interesting particulars were obtained:—

Description of cloud.	Height in feet.	Average velocity, miles per hour.
Stratus	1,676	19
Cumulus	5,326	24
Alto-cumulus	12,724	34
Cirro-cumulus	21,888	71
Cirrus	29,317	78

In winter the velocity of the wind is twice as great at the upper levels as in summer. At this period cirrus clouds have been known to travel at the rate of 96 miles per hour.

The upper half of the air, above 16,000 feet, is calculated to possess six times the energy of the lower half. Of this latter we utilise but little; only the merest strip or layer. The whole of the remainder is wasted.

The enormous force provided by nature is now employed to a much smaller extent than in former years. Sailing

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ABOVE A SEA OF CLOUD, ARCTIC NORWAY.

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CLOUDS BREAKING LIKE A GIANT WATERFALL OVER THE FURGGEN RIDGE, MATTERHORN.

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vessels and the once familiar windmills have been practically supplanted by steam.

The force and velocity of the wind is measured by an instrument called the anemometer, from the Greek *anemos*, wind; *metron*, measure.

The enormous speed attained by the air in a tornado has been stated at 500 miles per hour. This is, however, an exaggeration.

The pressure exerted by the wind on all that stands in its way varies according to its velocity.

The circulation of the atmosphere, which we call wind, is a current of air induced first by the heat of the sun, which expands the air and causes it to rise, its place being taken by the cooler and heavier air, and, in the next place, by the rotation of the earth.

The winds have been divided into fixed or constant, as trade winds; periodical, as monsoons, etc.; and variable winds.

Trade winds, so called, are perpetual or constant winds which occur in all open seas on both sides of the equator, their origin being the great heat of the torrid zone, which causes the air to rise to high regions, and the colder air from north and south flows in to take its place.

Calms, so called, are the tracts in the Atlantic and Pacific Oceans between the trade winds, where long periods of calm prevail.

Hartwig calls this "the dreaded zone of the equatorial calms, where long calms alternate with dreadful storms, and the sultry air weighs heavily upon the spirits"; and it was in this region that the phantom ship of the *Ancient Mariner* lay becalmed:

"Day after day, day after day
We stuck, nor breath nor motion,
As idle as a painted ship
Upon a painted ocean."

Etesian winds, which blow during the summer in the Mediterranean, towards North Africa, take the place of the heated air which rises from the Sahara and other African deserts.

Egypt owes a great part of its fertility to these winds, carrying, as they do, the vapours of the Mediterranean across that country to the Abyssinian Mountains, where they are condensed in torrential rains, flooding the Nile, and so producing fertility where otherwise sterility and arid wastes only would be found.

The simoom, a hot, suffocating wind that blows occasionally in Africa and Arabia, is generated by the extreme heat of the deserts. The air, heated by contact with these burning sands, ascends, and the colder air rushes in, forming a whirlwind which carries with it clouds of dust. The sirocco of South Italy and the kamsin in Egypt and Syria are similar to the simoom:

> "The red-hot breath of the most lone simoom,
> Which dwells but in the desert, and sweeps o'er
> The barren sands, which bear no shrubs to blast,
> And revels o'er their wild and arid waves.
>
> BYRON.

Harmattan—a hot, dry wind, which, coming from the interior of Africa, prevails at times on the coast of Guinea in December, January, and February, withers and destroys vegetation.

Mistral—violent, cold north-east winds experienced in autumn, winter, and spring in Provence and the neighbouring districts on the borders of the Mediterranean.

Monsoon is the name given to a certain disturbance of the regular course of the trade winds in the Arabian and Indian Seas, or similar alternating winds in any region.

Typhoon—a violent hurricane experienced on the coasts

H.M.S. "PHŒNIX" DRIVEN ASHORE OFF KOWLOON.

WRECKED BY THE TYPHOON, KOWLOON.

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of China and Japan and in the Archipelago. It is most frequent and disastrous in July, August, and September.

"So wrecked the tempest, as the sea
Engulfs a vessel, grasp'd a tree,
Wrench'd from wide-spreading roots, and laid
The giant on the hillside dead;
So rushed the torrent, small at first,
Then, gathering strength in moving, burst
In deluge streams of rain and snow
Upon the hills and plains below.
So wreck'd the wind, so swept the rain
Of that tornado hurricane."

Whirlwinds are caused by the meeting of violent winds, moving in opposite directions, and setting up a whirling spiral motion in the atmosphere.

On land they carry dust and sand with them, lifting it up and scattering it broadcast. At sea they give rise to waterspouts. They are most frequent and violent in tropical climates.

Colour of Clouds

Sunset

"Those evening clouds, that setting ray,
And beauteous tints serve to display
  Their great Creator's praise;
Then let the short-lived thing called man,
Whose life's comprised within a span,
  To Him his homage raise.
We often praise the evening clouds,
  And tints so gay and bold,
But seldom think upon our God,
  Who tinged these clouds with gold."

Scott.

The colour of clouds is most apparent when the sun is near the horizon; its rays falling on the watery vapours produce the glorious tints of sunrise and sunset, which tints may be used as a guide in forecasting the changes in the weather that may be expected to follow.

The quantity and condition of the watery vapour have great influence in the production of the hues. The red rays are caused by having to pass through about 900 miles of atmosphere, instead of 50 miles when the sun is overhead. The blue rays are absorbed first, the yellow rays next; the red rays have the greatest penetrating power, and therefore reach us most readily. It is owing to the enormous depth of the atmosphere which the light from bodies on the horizon has to penetrate that no star is ever visible there.

I recollect vividly the glorious dawn of the last day of the year 1905. It was, without doubt, the most gorgeous spectacle I have ever seen; for if ever "the heavens declared the glory of God, and the firmament showed his handiwork," it was this last Sabbath morn of the year.

It was a little past 6 A.M., two hours before sunrise, when the eastern horizon became brightly illuminated. Though of intense brightness, it was not the angry red betokening a wet and cheerless day. Presently the whole sky became coloured with what I can only compare to an ocean of golden brightness, and every separate wave had a crest of a still brighter hue; even on the extreme western horizon, where it disappeared in a space of purest blue, the rose-pink reflection of the still hidden sun was strongly apparent.

It called to my mind the well-known words of Bishop Heber:—

> "Till, like a sea of glory,
> It spreads from pole to pole."

This canopy of golden waves was to be seen until about 8 A.M., giving two hours for the enjoyment of this sublime spectacle. Truly the old year left us with a graceful grandeur.

At last the sun appeared above the horizon, and slowly the light of day dispersed those lovely tints, melting them into every conceivable shade of red, blue, and violet, leaving us a bright, crisp, clear day with which to close the year.

Dust Particles in Clouds

Dust particles, suspended in the atmosphere by the small globules of watery vapour, assist greatly in the glorious effects I have just described.

The dust ejected by the eruption of Krakatoa in 1883 was sufficient to spread a mantle of particles in the air over the whole world, causing beautiful and phenomenal skies, which often lasted 1½ hours after sunset; a huge corona, of all the colours of the spectrum in turn, was also observed round the sun.

These beautiful colours are always present more or less, and are due to the diffraction by suspended particles of water; but the dust from Krakatoa intensified and prolonged these effects all over the world.

These particles remained suspended for a long time: some years elapsed before they all settled and our skies resumed their usual appearance.

One of the most gorgeous spectacles the eye can rest on is a sunset at sea, where sky and sea are illuminated with every imaginable tint, and—

> "The sea is but another sky,
>   The sky a sea as well,
> And which is earth and which is heaven,
>   The eye can scarcely tell."
>
> LONGFELLOW.

CHAPTER IV

RAIN

Cause of Rain

"At last
The clouds consign their treasures to the fields,
And softly shaking on the dimpled pool
Prelusive drops, let all their moisture flow
In large effusion o'er the freshened world."

RAIN, the water that falls from the heavens, is the final stage of the condensation of the vapour in the air. In the process of condensation the small particles of water gradually grow larger and larger, until their size prevents them from being suspended any longer, and they fall as rain.

We have seen the process by which liquids and solids assume the gaseous state. The rate at which the evaporation of the same takes place is controlled by the temperature of the liquid or solid, the extent of its exposed surface, and the condition of the atmosphere; and by means of the latter facility is given to the gaseous particles to escape.

The atmosphere will continue to absorb the particles of vapour until it is fully saturated, when, if the temperature remains the same, evaporation will be arrested, there being no further opportunity for the vapour to escape.

Thus, at a temperature of 50° F., evaporation goes on until the vapour pressure reaches 0·361 inches. If the temperature be raised to 60° F., evaporation will be resumed until the vapour pressure rises to 0·518 inches, and so on in proportion to the temperature. If the temperature were to fall from 60° F. back to 50° F., the air would not retain the whole aqueous vapour; the surplus would condense and fall as rain, until the previous condition (50° F., 0·361 inches) were attained, and, with the formation of the rain, the air would yield up the latent heat contained in the vapour so condensed.

If the reduced temperature be caused by the introduction of a cold solid body, the condensation will take place in the layer of air next that body, forming dew upon its surface, and if it is sufficiently cold it will run with water.

We have all seen this simple object lesson. If on a hot summer day a bottle of cold water be brought into the room, it quickly becomes covered with drops of moisture, which eventually trickle down its sides.

Some might imagine that this water came from the inside of the bottle; but it is simply the action of the cold bottle cooling the warm air which is in immediate contact with it, so that it cannot retain the moisture invisibly, and deposits it on the side of the bottle. If the bottle were not colder than the atmosphere in the room, this depositing of the moisture would not occur.

The moisture on the window-pane which makes the pretty frost pictures is another instance—the exterior cold on the glass condenses the atmosphere in the room.

This is the manner in which nature forms dew, rain, hail, snow, and all atmospherical precipitation; it is the natural result of any refrigerating influence on the air.

When warm air-currents are transported to colder regions, the moisture condenses into small globules, but little heavier than the atmosphere, forming cloud; if the condensation be continued, rain results. Those upward currents, therefore, carrying away the heat, which at times, especially in the tropics, would be insupportable, render hot climates habitable.

Rain does not always of necessity fall from clouds. If the invisible vapour of the atmosphere suddenly comes into contact with cold air, the vapour passes immediately into rain.

It is in this manner that mountains receive more rain than plains. The atmosphere strikes the sides of the mountain and is quickly carried up into higher regions and rapidly condensed.

"The cold crags," says Tyndall, "which had lost their heat by radiation the night before, acted like condensers upon the ascending vapour, and caused it to curdle into visible fog. The current, however, continued ascending, and the clouds were slowly lifted above the tallest peaks, where they arranged themselves in fantastic forms as they gradually melted away."

Dr Shaw, Director of the Meteorological Office, states that there is a remarkable parallelism between the winds of St Helena and our rainfall, and that any excess or deficiency of the wind velocity is often followed by a similar excess or shortage in our rainfall in the succeeding month.

The size of the rain-drops depends upon the thickness, density, and elevation of the clouds out of which they are condensed. Minute particles of vapour composing the clouds increase in number as the temperature decreases, and begin to fall. The largest fall fastest, and in their descent unite with the smaller ones they encounter, and thus increase their size:

"But, lo! while I listened, down heavily dropt
  A few tears from a low-sailing cloud;
Large and few they descended; then thickened; then stopt;
  Then poured down abundantly loud.

Oh! the rapture of beauty, of sweetness of sound,
  That succeeded that soft gracious rain!
With laughter and singing the valley rang round
  And the little hills shouted again."

CAROLINE SOUTHEY.

Mrs Aubrey Le Blond.

THE MATTERHORN, FROM THE ZMUTT SIDE.

Illustrating how the cold crests of the mountains aid in the work of condensation.

The two white crosses indicate the probable course followed by the bodies of the victims of the Matterhorn disaster in their fall of 4000 feet on to the Matterhorngletscher. See Chap. IX.)

[*To face p.* 80.

Time of Greatest Fall

"Thou comest, Autumn, heralded by rain."—LONGFELLOW.

The heaviest rainfall is in the autumn throughout the greater part of England. More rain falls by night than by day. The cold at night condenses and cools the air, thus diminishing its capacity for retaining moisture.

Seathwaite, a village of Borrowdale, Cumberland, is in almost the wettest spot of the British Isles, the average yearly rainfall being about 137 inches. On several occasions the daily fall has exceeded 6 inches; and on one occasion 8 inches were reached. Dr Mill's results seem to show that "the rainfall at Seathwaite in an average year indicates a tendency to be greater during the hours of darkness than in daylight; that rather less than half the time during which rain is falling it continues without intermission for at least six hours at a time; and that rather more than half the total amount of rain is deposited in such long showers."

Accumulated evidence seems to point to the fact that the atmosphere of the world is getting drier.

There is universally a continuous deficiency of rainfall. The ice-cap of the South Pole was found by Captain Scott to be retreating. He states that the Ferrar Glacier was at one time, called the ancient high-tide mark, 3000 to 4000 feet above its present level in places. The inland ice-sheet also stood above its present level, probably to the extent of 400 or 500 feet.

The edge of the great ice-barrier was, only sixty years ago, 20 or 30 miles in advance of its present position.

In the Antarctic, when the glaciation was at its maximum, the glacier valleys were then overflowing, pouring vast masses of ice into the sea. Granite boulders (erratics) and morainic terraces on the slopes of Terror, 800 feet above the present barrier surface, point to great diminution of ice in these regions.

The glaciers of the whole world are also retreating, and are but remnants of their former selves. All this points to the presence of less moisture in the atmosphere. (*See* Glaciers.)

There is also reason to believe that the great desert regions of Australia, South Africa, Asia, America, and the great Sahara are extending from the same cause, as also the Steppes of Russia.

The growing desiccation of large portions of the earth's surface causes great famines, as in India, Russia, etc. Where this was a small and occasional visitation, it is now a serious and frequent occurrence.

From the same cause the Caspian Sea is becoming salter and smaller, as are many other lakes, now receiving a diminished quantity of rainfall in the form of springs, streams, and rivers.

Absorption and Percolation, etc.

When rain falls, according to the quantity, the season in which it falls, and certain atmospheric conditions, it does many things.

Some evaporates; some is absorbed by vegetation. The remainder, after saturating the surface, runs off, forming rivulets and streams, conveying with it the soil over which it passes.

The part rain plays in connection with vegetable life is apparent even to those who pay no heed to nature's work. It may, however, not be irrelevant to call attention to the fact that, but for the water, the food properties in the soil, consisting principally of potash, soda, lime, magnesia, etc., could not be absorbed by vegetable life, as they are in a solid state, and cannot be assimilated by the plants until they have been dissolved by water.

Charles Kingsley says: "It is wonderful—or should have been—in our eyes, that a shower of rain should make the grass grow, and that the grass should become flesh, and the flesh food for the thinking brain of man."

Evaporation is subject to great variation, being influenced by climatic conditions, locality, etc.

In temperate climates, during the summer months, water exposed to the sun loses by evaporation $\frac{1}{6}$ to $\frac{1}{8}$ inch per day, or an average for the year of $\frac{1}{12}$ to $\frac{1}{16}$ inch per day.

In England it is taken as being between 12 and 16 inches per year, and London 16·14 inches.

In dry weather $\frac{1}{10}$ inch has been found to evaporate per day from the large reservoir which supplies Manchester.

In India $\frac{1}{3}$ inch has evaporated in one day. At Nagpur 48 inches evaporated in 272 days of dry weather. A typical instance was given in the *Daily Telegraph*, 9th October 1906:—

"New South Wales boasts of two lakes—Lake George and Lake Bathurst. The former of these is a striking example of the activity of evaporation in the sub-tropical climate. Normally it is a body of water 16 miles long, and 5 broad at its widest part, and presents an area of about 40 square miles; but it has been known for years together to be quite dry. This was the case from 1846 to 1850. Lake George receives the waters of several small streams, and has no outlet, and yet the amount of evaporation in dry seasons exceeds the inflow. On a small scale this repeats the experience of the Caspian and the Dead Sea. The Caspian Sea is as large as France. The waters of the Volga and the Ural River and of the numberless streams from the Caucasus flow into it. There is no outlet, and yet the evaporation is greater than the supply, and the Caspian is becoming shallower and more brackish. In no part of the world, probably, would a body of water persist all the year round if it depended solely on the rainfall upon its surface. In Cape Colony, where the precipitation seldom exceeds 20 inches per annum, the evaporation amounts to 60 inches, where there is water to evaporate."

Vegetation also absorbs a portion of the rainfall.

The available proportion of surface rainfall depends on the nature of the ground. Of that falling on steep surfaces of granite and slate rocks, etc., almost 1·0 is available; on moorland and hills, pasture land, 0·8 to 0·6; on flat, cultivated country, 0·5 to 0·4; that falling on our Chalk formation, 0·0. Under certain conditions it may percolate through the strata, dissolving soluble matter in its journey, and forming springs which break out at lower levels. Or, again, it may penetrate to the deep-seated springs, that have for ages, unseen, poured their valuable contents secretly into the rivers, or into the sea, forming submarine springs. It is estimated that 0·3 to 0·4 of the total amount of rain falling upon the Chalk formation reaches and replenishes the deep-seated springs.

These secret recesses, bored into by man in search of water, form one of the sources of the world's supply.

Should the rain fall on an impervious stratum, it is left to man to turn the work of nature to his uses. He dams up the valleys by powerful masonry, and then stores the excess water that falls in wet seasons, which would otherwise flow to sea and be wasted. In this way provision is made against drought, and a continuous and copious supply all the year round is obtained.

As rain percolates more easily in some places than in others, it forms hollows or pipes in the chalk, which eventually get filled up with clay, gravel, and sand. These may often be seen in the face of chalk pits and railway cuttings.

RAIN

"How beautiful is the rain!
After the dust and heat,
In the broad and fiery street,
In the narrow lane,
How beautiful is the rain!"

LONGFELLOW.

Amount of Rain

In order to measure the quantity of rain that falls, an instrument called the pluveometer, or rain-gauge, is fixed usually in some open situation. This collects the rain-water, which is measured in inches. One inch of rain is equal to—

1	gallon falling over	2 square feet.	
22,427	gallons	,,	1 acre.
14,355,280	,,	,,	1 square mile.

If spread over a period of 365 days, it would yield—

62	gallons	per day	per acre		for one year.
40,000	,,	,,	,,	square mile	,,

With an annual absorption of, say, 10 inches of rainfall, it would yield a daily volume of 400,000 gallons per square mile.

Distribution of Rain

It has been computed that the average annual rainfall of the globe is 33 inches. One-fourth of the land surface receives less than 12 inches per annum; one-fourth has from 12 to 24 inches; one-fourth (including the British Isles) has 24 to 48 inches; and the remaining fourth receives over 48 inches. Of this amount of rain that falls on the land 27 per cent. drains into the Pacific and Indian Oceans; 22 per cent. has no outlet; 51 per cent. is tributary to the Atlantic. The large amount of the latter is due to the Andes and the Rocky Mountains, which drive the whole of the rainfall of South America, and a great part of North America, to the east.

We find in England that the annual rainfall varies from 223 inches at "The Stye," Cumberland (in 1903), to 14 inches at Shoeburyness in 1905.

In Cumberland, as well as in some parts of Scotland, 6 or 7 inches have been known to fall in 24 hours, but this is a rare occurrence. At Glen-na-Smoel Waterworks, Dublin, 5·71 inches fell on 25th August 1905.

The mean rainfall for the British Islands is 36 inches, and for Great Britain 26 inches.

The British Rainfall Statistics for 1905 contain the following interesting figures :—

Extremes of Rainfall in 1905

Greatest	Inches.	Least	Inches.
England			
The Stye (Cumberland)	171·00	Shoeburyness . .	14·57
Styehead Tarn .	146·30	Alford . . .	15·05
Wales			
Snowdon (Glaslyn) .	176·60	Caldecot Level .	21·50
,, (Llydaw) .	147·50	Rhyl . . .	22·24
Scotland			
Glenquoich . .	114·41	Bear Hills . .	19·12
Ben Lomond . .	111·50	Leith . . .	22·18
Ireland			
Gap of Dunloe . .	93·70	Banagher . .	21·52
Brandon Bay . .	79·00	Athlone . . .	22·30

At the following places the mean rainfall, taken over a period of 40 years, works out as follows:—

London 24, Manchester 36, Cardiff 43, Glasgow 39, Cork 40, Galway 50.

When we refer to the statistics of foreign countries, we find some exceedingly high records:—

Cherra Punji (Assam) India . . .	610 inches.
Coimbra, Portugal	224 „
Belize, Honduras	153 „
Guadaloupe Matonba, West Indies .	285 „
S. Luis de Maranhao, Brazil . . .	276 „

We often hear the remark, that the rainfall is so much per cent. above or below the mean annual quantity. The reader will probably ask how the mean annual rainfall is arrived at, and what period is taken. It is found that the average over a period of 40 years gives the minimum of error.

From a large number of records taken all over the world, Sir A. Binnie found the error to be less as the number of years was increased. If the mean of 5 years be taken, there will probably be a deviation from the true mean annual rainfall of 14·93 per cent., above or below; for 10 years, 8·22 per cent.; for 15 years, 4·75 per cent.; for 20 years, 3·24 per cent.; for 25 years, 2·75 per cent.; for 30 years, 2·26 per cent.; and for 35 years, 1·78 per cent.; and for 40 years considerably less.

If the mean annual rainfall of a place be known, it is but a simple matter to arrive at the percentage of increase or decrease. For instance:—

If the mean annual rainfall of a place is 30 inches, which is increased for one year to 40 inches, $40 \div 30 = 1{\cdot}33$; or, the increase being 10 inches, $\frac{10}{30} \times \frac{100}{1} = 33\frac{1}{3}$ per cent. more than the mean.

"The greatest rainfall is in the tropics. The regions of greatest heat are the regions of greatest rainfall. This zone of greatest moisture follows the sun across the equator, as the sun's declination changes, and more rain falls in the north hemisphere than in the south hemisphere" (Chambers).

Tropical Rainfall

Although more rain falls in the tropics than in the temperate zones, the number of rainy days is less, the averages being 80 and 160 respectively.

Of Singapore and Mindoro, one of the Philippine Islands, it may be said with Shakespeare—

> "With hey, ho! the wind and the rain
> Must make content with his fortunes fit,
> For the rain, it raineth every day."

Professor Tyndall has given us a splendid description of tropical rainfall. He says: "The heating of the tropical air by the sun is indirect. The solar beams have scarcely any power to heat the air through which they pass. They heat the land and the ocean, and these communicate their heat to the air in contact with them. The air and vapour start upwards, charged with heat thus communicated, and the heaviest rains occur at those places where the sun is vertically overhead.

"The ascending air is chilled by expansion. This is one source of the coldness of the higher atmospheric regions.

"The aqueous vapour rises from the tropical ocean, with heat to preserve the vapour as vapour: it rises, comes into chilled regions, and is still further chilled by its own expansion. The load of vapour is in part precipitated; clouds are formed; their particles coalesce to rain-drops, which descend daily in gushes, so profuse that the word 'torrential' is used.

"Thus, long before the air from the Equator reaches the Poles, its vapour is in a great part removed from it. Still, a good quantity of the vapour is carried forward, which yields hail, rain, and snow in northern and southern lands."

It has been computed that every year the amount of rain and snow falling on the surface of the globe would be sufficient to fill a lake, 200,000 square miles in extent—about the size of France—a mile deep. In the Khasia Hills, Assam, 600 inches a year have been recorded, and 30 inches have been known to fall on each of five successive days, or 150 inches in five days, which is equal to six years' rainfall in London. This was until recently the largest rainfall ever recorded. Here the average over a period of 24 years is 493·19 inches. At Cherra Punji, in Assam, in 1861 the rainfall was 805 inches, of which amount 366 inches fell in July. Here, on 12th June 1876, 40 inches of rain fell in 24 hours. In Seoni Malwa, in the Central Provinces of India, on 8th July 1905, 19 inches of rain fell in 36 hours, 13 inches of which fell in the last 24 hours, causing a record flood.

I am indebted to Dr Mill for the particulars of the heaviest rainfall recorded in London. This was measured on 23rd June 1878, when 3·28 inches fell between 1.32 P.M. and 3.0 P.M. No rain fell between 2.12 and 2.46 P.M., so that the actual period of rainfall was only 58 minutes.

Other records are—

London . .	3·12 ins. in	2 hours 17 minutes, 1st Aug. 1846.	
Joyeuse (France)	31·17 „	22 „	
Genoa . .	30·00 „	24 „	
Bombay .	24·00 „	one night.	

In the *Geographical Journal* a phenomenal rainfall is reported by Mr Clement Wragge (1893) from observations taken at Crohamhurst, on the western slope of Mont Blanc, a peak on a spur of the D'Aguilar range, South-Eastern Queensland (the whole district is watered by the Stanley River, a tributary of the Brisbane River). The gauge was fixed at an altitude of 1400 feet above sea-level.

24 hours ending 9 A.M., 1st February	. 10·775 inches.
" " " 2nd "	. 20·056 "
" " " 3rd "	. 35·714 "
" " " 4th "	. 10·760 "
Total for 4 days	. 77·305

The result being floods of a disastrous description, creating great devastation, with loss of life, and damage estimated at £2,000,000. The world's record was, however, the phenomenal rainfall at Suva, Fiji, on 8th August 1906, when 41 inches fell in about 13 hours.

It has often been stated that rain-drops in tropical climates have been as large as 1 inch in diameter. Professor Wieser, however, asserts that he never obtained any weighing more than 0·26 gramme, and then only from very low clouds.

Rainless Districts

Rainless districts are few in number. In the Sahara Desert, part of Arabia, the Desert of Gobi, and part of Mexico, it has seldom been known to rain.

The Desert of Gobi is one of the most extensive table-lands of the world, a rainless district of 400,000 square miles.

In certain parts of Chili and Peru no rain has fallen for many years. In the latter case it is a most fortunate thing, most of the houses being built with blocks of "Chili saltpetre" or sodium nitrate, which is soluble in water.

"At Copiapo (Northern Chili)," says Darwin, "there may not be more than one shower in three years. This is generally followed by a rainy year, the floods doing much damage."

In the port of Iquique, on the coast of Peru, but one light shower falls in many years, and the inhabitants obtain water from Pisagua, 40 miles northwards. It is brought in boats, and is sold at the rate of 4s. 6d. for an 18-gallon cask. Darwin (12th July 1835) paid threepence for a wine-bottleful.

Some districts, though not rainless, have but very little rain:—

Madrid, Spain	9 inches per annum.
Socorro, New Mexico . .	8 " "
Cumana, Venezuela . . .	7½ " "
Astrachan, Russia . . .	6 " "

Several districts in Russia and Siberia have as low a record as 5·3, and even 2 inches for the year has been recorded at Port Said.

Impurity of Rain

"Pure water is a perfectly distinct substance. The properties of any portion, however small, of a quantity of pure water are identical with the properties of any other portion.

"But pure water is never found in nature. One may even say that no man has ever seen or handled absolutely pure water. It is an ideal substance, to which some specimens of highly purified water have nearly approached.

"Natural waters are complicated mixtures; but the proportion of impurities, that is, of substances which are not water, in some kinds of lake waters, and in the rain that falls in places far from human habitations, is so small that such waters may be spoken of in ordinary language as pure" (Pattison Muir).

In addition to the water falling as rain, there is the foreign matter, which forms no small proportion of the benefits derived by vegetation from the rainfall.

From experiments and analysis of rain-water in the neighbourhood of Caen (France), Mr J. J. Pierre found that a hectare of land receives annually from the atmosphere, by means of rain—

Chloride of sodium . . .	37·5	kilogrammes.
„ potassium . .	8·2	„
„ magnesium . .	2·5	„
„ calcium . . .	1·8	„
Sulphate of soda . . .	8·4	„
„ potash . . .	8·0	„
„ lime . . .	6·2	„
„ magnesia . .	5·9	„

If water of a great purity be required and rain-water is available, it will be necessary to distil it. Even then the first portion of the products of distillation should be thrown away, for scarcely two-fifths of the whole can be safely used as pure distilled water. Where very accurate results are desired, it is a common practice in the laboratories to re-distil the distilled water, to make certain of its purity.

"Hardness" of Water

When rain-water has filtered through the rocks and soil, reappearing in the form of a spring or river, it is more or less charged with salts from the earth, such as sea-salt, gypsum, and chalk.

When these are present in small proportions the water is termed soft; when it contains larger proportions it is said to be "hard."

The hardness of rain-water varies from 0° to 10°. The latter degree was obtained near the sea-shore, at Land's End, 100 feet above the sea, when the wind was blowing in from the sea. In rough weather the average hardness of rain-water may be taken to be ·62°.

In the purest rain-water, traces of carbonic acid, ammonia, and sea-salt are to be found.

In the Report of the Royal Rivers Pollution Commission of 1874, it was stated that half a pint of rain-water often condenses out of about 3373 cubic feet of air. This is the quantity of air a man breathes in eight days; so that in drinking a tumblerful of such water, which has washed a dirty atmosphere, he swallows an amount of impurity which would only gain access to his lungs by breathing in eight days. Rain-water, where collected, say, 25 miles from a town, is not pure. It contains more organic matter than deep-well water. It gathers impurities from the atmosphere. Fine particles of organic matter from animal and vegetable waste and decay are in dry weather suspended for weeks in the air. By the condensation of the moisture, they are entangled in the small globules of water which form clouds and eventually rain. The carbonic acid dissolved in the rain also attacks the buildings of all large cities, disintegrating the stonework and causing it to crumble away.

Dust Particles in Rain

It has been stated that minute particles of dust in the air are necessary to the formation of rain. It has been ascertained that these particles exist in the lower stratum of air, even over the centre of the oceans, and the number of these particles varies from 7600 per cubic inch of air in the Indian Ocean to 30,000 in the Atlantic. In the

Indian Ocean as low a number as 3000 was found, but that was after rain. In the lower stratum of air over the land, as many as 60,000 per cubic inch have been found.

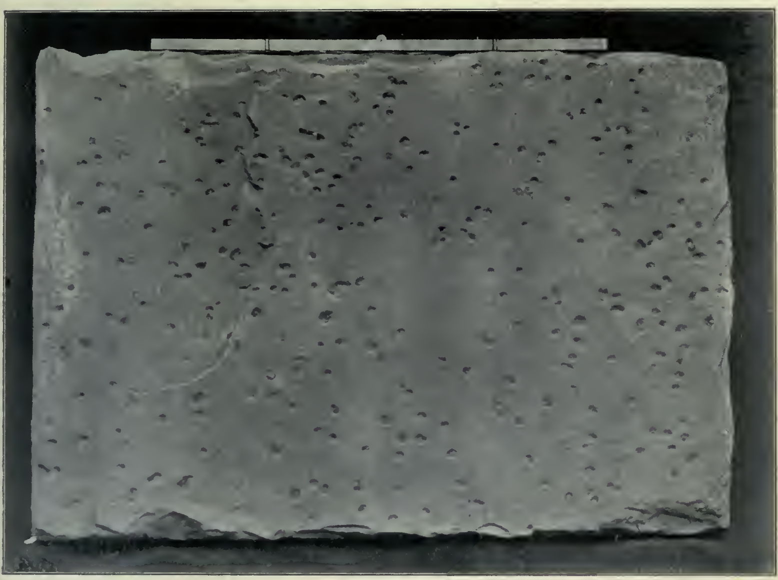
As we rise above the surface the dust particles are found to decrease in number. From observations on the Bieshorn, Friedlander found 14,000 per cubic inch at an altitude of 6700 feet, and only 2300 at 13,600 feet.

As a proof of the time that dust will remain suspended in the air, and of the distance it will travel over the mighty oceans, to assist in forming and bringing to our shores the welcome showers, Darwin states, in *The Voyage of the Beagle*, that dust has fallen on the decks of vessels when far out in the Atlantic—dust proved to be similar to that raised high in the air by the harmattans of Africa, and falling in such quantities "as to dirty everything on board, and to hurt people's eyes a thousand miles from the coast, and at points sixteen hundred miles apart in a north and south direction."

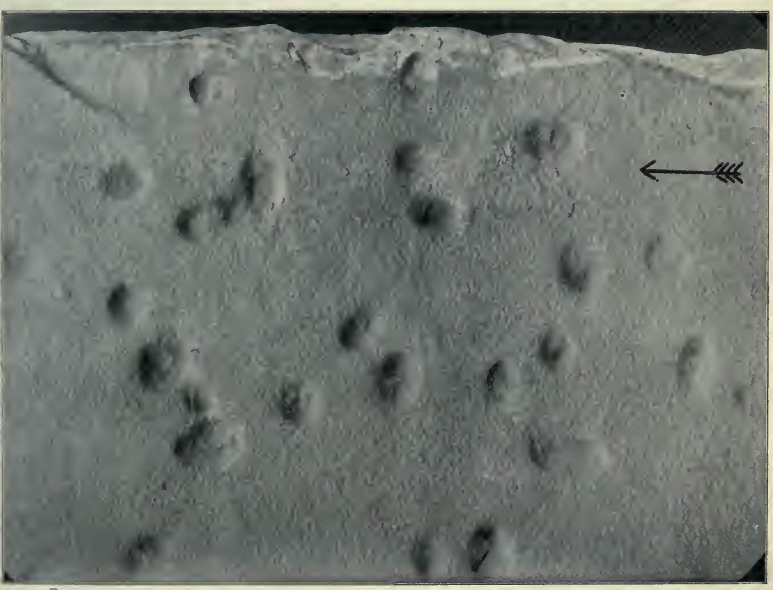
Rain-prints

Prints of prehistoric rain-drops are frequently discovered in the rocks of the Carboniferous Period, during which the coalfields were formed, proving that incessant rains, which promoted the rapid growth of vegetation, were general.

When the tide receded these rain-drops left their impressions on the sun-dried flats of mud. On the return of the tide they were again covered by a fresh layer of sediment, which eventually hardened into rock, and so the impressions, as we now often see them, were preserved.



PREHISTORIC RAIN-PRINTS ON A SLAB OF SANDSTONE.



PORTION OF THE SAME SLAB, HALF NATURAL SIZE.
The arrow denotes the direction of the shower.)

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The slab of sandstone shown in the illustration is a perfect example of the manner in which these memorials of prehistoric rainfall are preserved to us, and is of more than ordinary interest.

With these flagging sandstones, it is a simple matter to remove a layer from the surface. On removing a flake, exactly one quarter inch thick, I found it parted from the one beneath by a shining, pearly coating of mica, bright with an almost metallic lustre; this, however, is frequently found lying along the planes of separation in these stones.

The second layer was also profusely marked with rain-prints, but I was surprised to find that they were not formed by a previous shower, in the sediment left by the previous tide, but were identical with those on the surface layer, and were as clearly impressed.

These facts are noted, as they tell us several things: that rain at this period fell with great violence, enabling it not only to leave its impression on the freshly deposited mud, but to mark distinctly the partly sun-dried mud from a previous tide. That the drops of rain were large is also certain, for some of the casts on this stone are half an inch in diameter; that the wind was blowing at the time is also beyond doubt, for the direction in which the rain-drops fell is clearly apparent; and that the thin flake removed represented the sediment deposited by one tide; all these conclusions are considered by Mr J. Allen Howe, the Curator of the Geological Museum, who kindly examined a portion of the stone, to be most reasonable.

It is not only casts or prints of rain that are preserved in this way, for the rocks have yielded similar casts of sun-cracks, worm-tracks, foot-prints of extinct birds and animals, and other interesting evidences of life in past ages.

In the Bay of Fundy the rise and fall of the tide exceeds 70 feet. This is a greater range than in any other place in the world.

Here extensive mud-flats are left dry between the tides, forming ideal places for the making of rain-prints.

Influence of Trees on Rain

Forests are found to attract rain. Hartwig says: "They cool the atmosphere, their surface offering a warmth-radiating area, so that the vapours readily condense and descend in frequent showers."

Ruined forests mean flooded rivers, periodic droughts, eroded soil, and dried-up springs.

Columbus records the frequent showers experienced along the coasts of Jamaica, Madeira, the Canaries, and the Azores, before their forests were destroyed.

Hugh Miller says: "Man is the only creature, of whom we know anything, who has set himself to carry on and improve the work of the world's original framer—who is a planter of woods, a tiller of fields, a keeper of gardens."

I think we should not lay such flattering unction to our souls, but also state some of man's more patent works of destruction, especially with regard to forests.

It is man's place to enter this field of contest, not with an indiscriminate slaughter of trees, large and small, as is the custom of wood-cutters; but, by an intelligent felling of trees, to make the forests the most effective contribution to human interests.

We have conclusive evidence that these islands of ours were once as bountifully supplied with forests as other lands. The following table, however, will give an idea of the ruthless destruction of forests that has been going on here.

Proportions of forest-land to total area:—

Norway	66 per cent.
Russia.	31 ,,
Sweden	29 ,,
Germany	25 ,,
France	17 ,,
Italy	14 ,,
Belgium	10 ,,
Denmark	6 ,,
Portugal	5 ,,
Great Britain . . .	4 ,,

Mercenary destruction means denuded mountain slopes, the loss of historic forests, and "nature's revenge" in the near future.

Bryant refers to this subject in the following lines:—

"Before these fields were shorn and tilled,
Full to the brim our river flowed,
The melody of waters filled
The fresh and boundless wood.

The reckless and wanton destruction of forests has, says Lord Avebury, ruined some of the richest countries on earth.

Syria and Asia Minor, Palestine and the north of Africa were once far more populous than they are at present; they were once lands "flowing with milk and honey," according to the picturesque language of the Bible.

Why have deserts replaced cities? It is mainly owing to the ruthless destruction of the trees, which has involved that of nations. Even nearer home a similar process may be witnessed—the Hautes- and Basses-Alpes are being gradually reduced to ruin by the destruction of the forests. Cultivation is diminishing, vineyards are being washed away by flooded rivers, the population is dwindling, and unless something is done the country will be reduced to a desert; until, when it has been released from the destructive presence of man, nature reproduces a covering of vegetable soil, restores the vegetation, creates the forests anew, and once again fits these regions for the habitation of man.

Greece and Asia Minor have seen their fertility decrease and vanish with their trees.

At Porto Praya, St Jago, the chief of the Cape de Verd Islands, it seldom rains, but during a short portion of the year heavy torrents fall. "On 16th January 1832 it had not rained," says Darwin, "for an entire year. When discovered, this island was clothed with trees; the destruction of which has caused here, as at St Helena and some of the Canary Islands, almost entire sterility."

The springs that once watered the Tuneberg, a range of hills on the east bank of the Rhone above Strasbourg, have failed since the peasants have hewn down the trees.

Many other instances of a similar result caused by the destruction of forests have been recorded.

The destruction of forest trees in this country might also be considered as disastrous.

We spend many millions annually on imported timber, which we could supply from our own waste lands.

Dr W. Schlich, late Professor of Forestry at Cooper's Hill College, states that in the United Kingdom alone we have more than sufficient surplus land to produce the whole of the timber we require, without touching existing woodland, or putting a single acre out of cultivation.

Surely there is scope here for an energetic Government, and an opening for the useful employment of hundreds of idle hands.

Convict labour might profitably be employed in clothing the barren spots with beautiful trees, rather than in making useless forts, at the cost of millions, to receive an enemy who will never reach our shores, or, should he get thus far, would not be deterred by them.

The people of every city, borough, and village should put forth an effort to make beautiful the places in which they live. Children should also be taught to protect and not to destroy ornamental trees. Drunken hooligans who so frequently destroy trees planted in the streets and roads should be birched.

Unless the wholesale destruction of trees is not soon supplanted by a reasonable and scientific method of cutting, and reafforestation taken up with some energy, there will, it is stated, be a shortage of timber within fifty years. This is serious to contemplate.

Referring to the British Isles, Dr Schlich says: "6,000,000 to 7,000,000 acres of land would produce an amount equal to all the ordinary species of timber imported; and there are 21,000,000 acres of waste, heather, rough pasture, and land out of cultivation, suitable and profitable for afforestation."

Many bodies having control of large tracts of land, such as Water Boards, are planting their catchment areas with trees with advantage and profit; for it is found that the presence of trees adds to the retention of water falling rain as well as by radiation and cooling the adjacent atmosphere, causing condensation and rain; it prevents floods, regulates and purifies the supply, for water from wooded areas is generally purer than that falling on bare land.

Thus we see that trees not only attract rain, but are an all-round source of monetary gain; in addition to the æsthetic improvement of the locality, refreshing our eyes and brains, as well as purifying the air, and covering with verdure the waste and barren land.

The beneficial influence on our general health exercised by the afforestation of neglected acres is beyond dispute. The consumption of carbonic acid gas alone by trees is an apparent gain to all who dwell in their vicinity.

From observations taken at elevated German stations in July, it was found that the surface soil in the forests was 7° F. lower than in the open fields, and rather warmer than the open fields in December.

It has also been found that the mean annual temperature of woodland soil at a depth of 4 feet is 2° to 3° lower than that of open country.

The mighty inland forests are not by their distance from the coasts free from the ravages of man. The timber is floated down the rivers, as in the case of the Manchurian forests on the Amur. The logs from the forests between China and Burma are floated 600 miles down the Yangtse, their journey occupying about six months.

It is, however, satisfactory to note that many forests are now being managed on scientific lines, so that their ultimate destruction will be prevented.

Eighty to a hundred years are required to produce timber fit for the sawmills.

Many of the mighty giants of the forests are of immense age, certainly over 1000 years.

Although grand specimens are found all over this country, it is the opinion of those best qualified to judge, that there is no tree standing to-day which can be proved to be older than 800 years. The rings formed by the annual growth of exogenous trees are the best evidence of their age; but this can only be obtained before the hand of decay has commenced operations.

The king oak in Windsor Forest is old and famous, and the giant oak in Needwood Forest is proved by local documents to be at least 600 years old, and within recent times was far from the last stage of decay. A leviathan is the Cowthorpe oak, near Wetherby, covering nearly half an acre; and another grand old landmark stood at Tilford, near Farnham, and is said to have been mentioned in a charter granted by Henry de Blois, 1256.

James Rodway says: "Trees and rivers are interdependent upon each other. Even in the midst of a prairie, the course of a river is shown by a double line of trees. Is there not some connection between them? Is the river due to the forest, or the forest due to the river? Experience goes to prove that springs are conserved in a well-wooded country, and that they dry up if a great clearance is made. In Guiana it is certain that thunderstorms are more common over the forest than over the sea.

Not only do forests affect the rainfall, they greatly influence the climate of a country.

In the years 1852–62, 70,000 acres of the stately and magnificent forests in Mauritius were denuded, causing drought and floods, with disastrous results; rainfall diminished; rivers dwindled to muddy streams.

Innumerable examples could be found of a similar kind.

Where land is devoid of vegetation, rainfall is almost impossible. The fierce rays of the sun heats the surface; the air in contact then becomes heated too, and will therefore hold more and more moisture, and rain will not fall.

If there be abundant vegetation the vapours readily condense, as above described; for vegetation quickly radiates its heat into space, and becomes colder than the earth. It is one of the laws of nature that whatever tends to lower the temperature of the air below dew-point is a cause of rain.

The influence of trees on the atmosphere is also apparent. A considerable portion of the rain falling upon forest trees is at once taken up by the leaves. The roots also supply the leaves with moisture, which evaporates from them, and so adds to the humidity of the atmosphere.

The evaporation of a wood in one day of summer is said to be equal to 1 inch of rainfall, adding this proportion of vapour to that in the atmosphere brought from the sea by the winds; and this very act of distillation, says one writer, makes every forest a great refrigerator.

Darwin, referring to this, quotes, when at Rio de Janeiro: "As soon as the rain ceased, it was curious to observe the extraordinary evaporation which commenced over the whole extent of the forest. At the height of a hundred feet the hills were buried in a dense white vapour, which rose like columns of smoke from the most thickly wooded parts, and especially from the valleys. I observed this phenomenon on several occasions. I suppose it is owing to the larger surface of foliage previously heated by the sun's rays."

Local rains are often due to large areas of woodland. Forests cause precipitation from clouds that have passed over the plains and still withheld the grateful showers.

"Mountains and rocks," says James Rodway, "are imposing, and cataracts force themselves on our attention by their deafening noise; but in the absence of a setting of green, or clumps of trees, they are lifeless.

"It is the earth, 'with verdure clad,' which appeals to the mind, and which does so much to promote the higher civilisation. The snow-bound and ice-clad earth of the north, and the burning sands of the desert soon become monotonous and dreary, and the wilderness of houses in a great city produces a weariness which only the open fields and woods can relieve."

Before leaving this subject, we might well call to mind one benefit we derive from the destroyed forests of bygone ages. Here the ruthless destroyer was nature, and her destruction was wisdom, not folly, for no man was upon the face of the earth to require the timber. I refer here to the formation of coal. From these wrecked primeval forests we derive our chief supplies of coal, with all its attendant comforts and blessings, such as heat, light, wealth, power, etc.

These stately forests, with their gigantic trees, were destroyed by storms and inundations, only again quickly to spring up in the swampy lands and humid atmosphere, to be again destroyed, and suffer the interment of endless ages, during which chemical changes took place. Within the great laboratory of the earth's crust, "exposed to water, temperature, and great pressure, the gases in the vegetable matter were driven off, thus increasing the carbon, turning it into peat, lignite, bituminous coal, and ultimately anthracite and graphite, which is practically pure carbon." Thus was our coal formed, and by upheaval was again brought above the face of the waters, and made accessible to man, to be consumed for his pleasure and needs as a servant and mechanical force. Its constituents were released by combustion, once again to join the atmosphere from which they originally came, to be again built into the structure of trees to gladden our sight and glorify the earth, and again be utilised for the use of man, and again by decay or fire to be consigned to the earth or the atmosphere, and so continually to assist in the perpetual repetition of nature's wonderful economy.

Referring to this most interesting subject, a correspondent of the *Daily Telegraph* writes: "Ages before man appeared as the chief actor on the world's stage, great forests were in existence, taking their part, whilst living, in the preparation of the earth's surface for the masterpiece of creation, and in death providing materials to be laid away in nature's storehouse for the use of man thousands of years afterwards. It is scarcely possible to overestimate the part filled by trees in the history of the world, or in the life and development of its human inhabitants. Of the beauty of the primeval forests one can but draw an imaginary picture; but, composed as they were of the most fantastic growths, they must have presented a very striking appearance. During the ages which succeeded, the changes were many, and trees of quite another character were evolved, such as firs and palms; then came leaf-bearing trees similar to those of our own day."

It is to be regretted that, owing partly to our want of success in the perfection of the various mechanical contrivances used for the combustion of coal, the heat and power wasted in the process amounts to astounding proportions.

There is certainly a little consolation in the fact that the earliest engine made consumed one bushel of coal in raising 5,000,000 lbs. 1 foot (called foot-lbs.), whereas modern engines would produce at least 100,000,000 for the same amount of fuel.

Great as this improvement is, it is still far from satisfactory; and when we remember that the annual output of the coal mines of Great Britain alone amounts to 250,000,000 tons, and the world's production for the year 1905 was 840,000,000 tons, we shall be able to form some idea of the inroads we are making on the buried forests of ages gone by.

Let us also try to form some idea of the proportion of the above amount that is sheer waste. The results will astound us.

"A first-class boiler will deliver to the engine 75 per cent. of all the energy in the combustible, or, say, 10,875 out of a total of 14,500 heat units; or, allowing about 8 per cent. for ashes, 10,000 heat units for each pound of coal burned. This represents 7,720,000 foot-lbs. of energy, which, if all were utilised by the engine, would give 3·90 h.p. for 1 hour, or at the rate of 0·26 lbs. of coal for each h.p. per hour. But by the greatest refinement in engines yet accomplished, the cost of a horse-power has not been brought below 1½ lbs. of coal per hour, or 17 per cent. of the energy delivered by the boiler; while the average engine uses 3½ lbs. of coal per h.p., and discharges unutilised 93 per cent. of the energy delivered into it."

Unsatisfactory as these results appear, the cause of the greatest waste and extravagance has not yet been touched. It is the domestic fireplace, wasting almost the whole of the heat of the coal. At least 99 per cent. of the heat goes up the chimney; less than 1 per cent. warms the room. When we remember that these fireplaces are to be numbered by the million, we can realise what a large proportion of the available heat is lost.

These enormous proportions of waste of nature's gifts in the production of heat are even more alarming when we consider the waste in the manufacture of light. Professor Sylvanus Thompson calls our attention to the slow progress made by man in artificial lighting. Wood, fish, and animal oils were the earliest substances used. In the eighteenth century vegetable oils came into use. In 1802 coal-gas was used for this purpose. This was followed by electric light. It is, however, the manufactured coal-gas that is such a prolific source of waste. The Professor says: "£10,000,000 to £20,000,000 is spent annually in Great Britain alone in the manufacture of artificial light, and 99 per cent. at least of this colossal sum is thrown away on mere heat." There is also the important factor that not only is the heat unnecessary, but, at the same time, we poison the atmosphere to an alarming extent, for one bat's-wing gas-burner adds to the atmosphere in one hour 536 cubic inches of poisonous carbonic acid. Professor Thompson calls our attention to the fact that the humble glow-worm, and the tropical fire-fly, and other phosphorescent animals, produce a cold light with practically no loss of energy, while to produce one ray of light we have to produce 99 rays of heat. If we but knew the secret of these animals and how to avail ourselves of it, we should get from electricity, gas, and oil at least 400 times the light we now produce from our light-giving sources.

Many natural objects produce light unaccompanied by heat. Sir E. Ray Lankester tells us that, in the case of luminous plants and animals—for instance, glow-worms—the light is due to the oxidation of peculiar fatty matters in their bodies, the oxidation being under the control of their nervous systems; so that they can become luminous or invisible at will.

In all branches of nature's work she has provided for our wants on a lavish scale. Surely it was necessary, so lavishly do we waste them. We therefore not only ruthlessly destroy the forests around us, but we are also making serious inroads, by our ignorance and want of economy in the manner of use, on nature's buried forests of the ages gone by.

Signs of Rain

The reader will now be able to account in many ways for the various indications of approaching rain. Some of the old and well-known sayings in reference to the same do not now appear to be so much a matter of prophecy as of deduction.

I have frequently found the accuracy of the following:—

> "If the hoar-frost come on morning twain,
> The third day surely will have rain."

Without doubt the poem written by the celebrated Dr Jenner (the discoverer of vaccination), as an excuse for not accepting an invitation to join in an excursion, is the finest piece of weather lore we have. It begins with the familiar lines:—

> "The hollow winds begin to blow,
> The clouds look black, the glass is low."

Should the reader be interested in the subject, I would recommend him to read that excellent little book, *The Story of the Weather*, by G. F. Chambers.

The words of Archbishop Benson form an ideal conclusion to this chapter:—

> "Thus in their change let frost and heat
> And winds and dew be given;
> All fostering power, all influence sweet,
> Breathe from the bounteous heaven.
> Attemper fair with gentle air
> The sunshine and the rain,
> That kindly earth with timely birth
> May yield her fruits again."

CHAPTER V

WATER

The Composition of Water

"What has not water done in the past history of the earth? The records of geology are mainly the history of the work of water."—TYNDALL.

WATER is a universally diffused liquid. It was classed among the elements until the close of the last century. It is colourless, tasteless, inodorous, a powerful reflector of light, and a bad conductor of heat and electricity. All substances capable of vibrating may be made to propagate and convey sound. Sound travels through the air at the rate of about 1090 feet per second, but through water at the rate of about 4700 feet.

Joseph Priestley discovered oxygen in 1774, calling it "dephlogisticated air." In 1781 he discovered that when oxygen and hydrogen were exploded in a closed tube, water was produced, and thus proved water to be not an element but a compound of two gases.

The discovery of the composition of water was not brought about by analysis—that is, by resolving the compound into its component parts; but by synthesis—that is, by putting the constituents together and building up the compound.

We may, however, briefly try to make this clearer.

An element consists of an indefinite number of atoms of the same kind. A compound consists of atoms of at least two kinds.

Countless compounds occur in nature which can be reproduced artificially; thousands of compounds can also be produced artificially which do not occur in nature.

All the molecules of an element are the same kind; all the molecules of a compound are also of the same kind. The molecules of the former are composed of similar atoms; those of the latter of dissimilar atoms.

The mixture of oxygen and hydrogen consists of molecules containing the atoms of both oxygen and hydrogen.

The compound (water) formed from the above mixture contains only one kind of molecule, compounded of atoms of both oxygen and hydrogen; while no separate molecule, consisting of the atoms of oxygen or hydrogen, will be found in it.

By weight 88·89 parts of oxygen unite with 11·11 parts of hydrogen to form 100 of water (ratio of 1·8).

The combining weight of hydrogen is 1; the combining weight of oxygen is 16. The symbol H means 1 part by weight of hydrogen; the symbol O means 16 parts by weight of oxygen. The composition of water, then, is expressed by the formula H_2O, which means that it is composed of hydrogen and oxygen; that 18 parts by weight of the compound are composed of 2 parts by weight of hydrogen and 16 of oxygen.

Air is a mixture of gaseous elements, mixed but not combined, each element retaining its own characteristic property.

Water consists of two gaseous elements, but it displays the properties of neither. It is not a blend or mixture of the two: it is totally different, it is a compound.

These two gases, hydrogen and oxygen, may readily be measured and mixed together in a tube, in the correct proportions. They form, however, only a transparent mixture of two gases, not water; neither does the mixture possess any of the properties of water; and yet the tube contains in the proper proportions all that is necessary for the production of water.

Pass an electric spark through the tube; the gases will disappear, and in their place will be found a drop or two of water, which water, if required, can again be decomposed into the mixture of two gases as before. Here we see the difference between a mixture and a compound.

The affinity of oxygen for hydrogen as measured by the heat developed by their combination is very great, 68,376 units of heat being evolved in the combination of 16 grammes of oxygen with 2·005 grammes of hydrogen, the product being liquid water 18° C.

Thus we see water is composed of two bodies, which in their free state are known only in the physical condition of gases.

No other chemical change excepting that stated can be made in water.

If frozen into solid ice, it retains its chemical constitution, although it may have altered its physical form. If converted by heat into steam, it is evaporated into invisible vapour. The ice, the steam, and invisible gas will all consist of oxygen and hydrogen in proportions exactly similar to that of water. All these forms are dependent upon temperature only for their maintenance. Reduce the temperature and the gas reverts at once to water; increase the temperature and the ice returns to its original form—water.

Water in all its forms is also absolutely unlike either of the gases of which it is composed, being neither a supporter of combustion, like oxygen, nor combustible, like hydrogen. Oxygen is a gas, the most widely distributed of all the elements, eight-ninths by weight of water, one-fourth of air. About one-half of silica, chalk, and alumina consist of oxygen. It exists largely in nearly everything. It is estimated that within 60 miles of the earth's surface it forms 50 per cent. of the elements that compose the crust. Without it in our blood we could not live. It enters into the constitution of nearly every rock and mineral; disintegrates our body after death, as well as by respiration enabling us to live. Every plant, tree, animal, bird, fish, depends for life on an ample supply of it.

Like its partner in the composition of water, it is invisible, tasteless, and inodorous. It is heavier than air, having a specific gravity of 1·1056, referred to air as 1·00. It is soluble in water to the extent of 3 volumes in 100 at ordinary temperature. It was first liquefied in 1877 by intense cold and pressure, and it has also been solidified.

The oxygen both in the atmosphere and in water acts on various substances in the rocks, principally compounds of iron, altering them by conversion into other compounds, a simple instance being the familiar rust termed oxidation, which is seen to scale ironwork exposed to the weather, when unprotected by paint.

Pure hydrogen is a colourless, tasteless, inodorous gas, very inflammable, burning with slightly luminous, but intensely hot flame.

The most intense heat that can be produced is caused by burning hydrogen in oxygen gas. A pound of hydrogen will produce by combustion 9 lbs. of water, and in so doing produces 62,500 heat units, which is equal to raising the temperature of 417 lbs. of water from 60° F. to 212° F. Two volumes of hydrogen with six of air form an explosive mixture.

Hydrogen is the lightest kind of matter known, having a specific gravity of ·0693, atmospheric air being 1, and is therefore 14½ times lighter than air. It can be liquefied by exposure to 650 atmospheres' pressure and −140° C., but remains liquefied at 320 atmospheres' pressure, the temperature remaining the same. It is only slightly soluble in water, and no liquid will dissolve it in great quantity.

Molecules of Water

In the beginning of this chapter reference was made to a molecule of water. Let us see what this really means.

Lord Kelvin has shown that if a drop of water were magnified to the size of the earth, its molecules would be of a size intermediate between that of a cricket-ball and of a marble. Now each molecule contains three atoms, two being of hydrogen and one of oxygen. The molecular system probably presents some sort of analogy with that of a triple star, the three atoms replacing the stars revolving about one another in some sort of dance which cannot be exactly described. I doubt whether it is possible to say how large a part of the space occupied by the whole molecule is occupied by the atoms; but perhaps the atoms bear to the molecule some such relationship as the molecule to the drop of water.

A molecule is the smallest particle of any body that is capable of separate existence. The Rev. J. M. Wilson tells us: "Water consists of separate molecules, each of which is about $\frac{1}{500,000,000}$ of an inch in diameter."

The number of molecules in one drop of water would amount to a million million million millions.

It is these molecules that dart from the surface of the water and make vapour, penetrating among the molecules of the air.

"They fly with a velocity exceeding that of a cannon-shot, which is twenty miles a minute, for the distances, almost inconceivably small, that separate molecules, and have their direction altered by collisions thousands of millions of times in a second.

"It is these infinitesimal molecules whose motions are quickened by heat, so that they take more room, or expand, and at a lower temperature contract. At a still lower temperature they again expand, rearranging themselves in exquisite crystalline order as ice.

"Those that evaporate carry with them stores of heat. They are unalterable, permanent, incapable of growth, decay, or destruction. There is nothing more wonderful, nothing that fills the mind of anyone who can grasp the above description with more awe, admiration, and reverence, than the constitution of the properties of a drop of water and its molecules."

"No one imagines," says the same writer, "that water is an evolved product, or that it has acquired by development its present properties. Such as it is, it always was. How marvellously these original, unchanged, and unchangeable properties of water contributed to making the earth the suitable place it is for the development of life and of man!"

Specific Gravity of Water

Frequent reference is made to specific gravity, more especially when dealing with ice and freezing. It forms the key to some of the peculiarities of water.

The specific gravity of a body is obtained by weighing that body while immersed in water. Subtract this

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weight from the ordinary weight of the body to find the weight of the water displaced—that is, of a volume of water equal to that of the body—and the ordinary weight of the body, divided by this, will be its specific gravity.

To find the specific gravity of a substance heavier than water, and not acted on by water—

Weigh the substance in the atmosphere and then in water. A = weight in air, a = weight in water; then S.G. $= \frac{A}{A - a}$. We will suppose the two respective weights to be 54·3 and 47·8 grammes; specific gravity

$$\frac{54{\cdot}3}{54{\cdot}3 - 47{\cdot}8} = \frac{54{\cdot}3}{6{\cdot}5} = 8{\cdot}3.$$

If the body is lighter than water, a sinker is attached to the body to make it sink. A different formula is then necessary.

The easier way, however, is by using an instrument called the hydrometer, especially constructed for this purpose.

The weight of a cubic foot of water at a temperature of 60° F. is 1000 ounces avoirdupois. This is taken as a standard to which the specific gravity of all liquids and solids is referred.

A number of competent men, by various means at various times, have made careful experiments with the object of finding out the mean density of our earth, as compared with that of water, the results varying from 4·950, 5·44, 5·48, 5·66, to 6·565. For various reasons little reliance could be placed on the first and the last, and 5·66 is the result of the most reliable and accurate research.

It is therefore found that the mean density of the earth is 5·6 times that of water.

The specific gravities of the following substances should be of interest:—

Water, rain		1·000
,,	distilled, 39°	·998
,,	,, 60°	·999
,,	,, 212°	·957
,,	sea	1·026
,,	Mediterranean	1·029
,,	Dead Sea	1·240
Ice at 32°		·920
Atmospheric air		·001205

Note.—Distilled water is 815 times heavier than atmospheric air.

The change of volume and density of water with change of temperature is so small as to be generally overlooked, but it varies as follows:—

			Density.	Weight of cubic foot.
At 0° Cent.	or	32·0° F.	·999884	62·417 lbs.
,, 1°	,,	33·8°	·999941	62·420 ,,
,, 2°	,,	35·6°	·999982	62·423 ,,
,, 3°	,,	37·4°	1·000004	62·424 ,,
,, 4°	,,	39·2°	1·000013	62·425 ,,
,, 5°	,,	41·0°	1·000003	62·423 ,,
,, 6°	,,	42·8°	·999983	62·423 ,,
,, 45°	,,	113·0°	·999038	61·823 ,,
,, 100°	,,	212·0°	·95866	59·844 ,,

As an object lesson in specific gravity we have the air-bladder or sound, the sac or bladder-like structure found in some fishes, which by distension or contraction alters the specific gravity of the fish, enabling it to rise or sink at will, and so to adjust itself to the varying depth and pressure of the water in which it lives. It also serves for changing the centre of gravity of the fish.

The gas in the air-bladder of sea fishes is usually oxygen; that in fresh-water fishes is mostly nitrogen.

Evaporation

We have already seen that natural evaporation is the turning of water or any other substance into vapour at the surface only, and is carried out at all temperatures, even below freezing point.

Ebullition, or boiling, on the other hand, is the turning of water into steam throughout the mass of liquid, or the heating of a fluid up to that point at which it is converted into vapour, the bubbles of vapour rising to the surface and breaking there, causing commotion or ebullition.

The surface of water sustains the weight of the atmosphere. Before it can be converted into steam within the mass, it must have a force sufficient to lift 14·67 lbs. per square inch of the surface of the vessel in which it is contained (at certain pressure and level).

Water boils at 212° F. only when the barometer stands at 30 inches. If this pressure be increased, the boiling point will be raised, and if the pressure be lowered, the water will boil at a correspondingly lower temperature.

If boiling be attempted on a mountain, it will be found that, for about every 600 feet of ascent, water will boil at 1° F. lower temperature.

Whenever liquid becomes a vapour, it can only do so by absorbing a large amount of heat.

By exhausting the air from a vessel containing water, the liquid is made to evaporate rapidly. To effect its evaporation, it abstracts heat from all the bodies in the neighbourhood. By this means great cold can be produced, and water may be made to freeze by its own evaporation.

Take a shallow dish full of water, support it over a vessel containing a little pure sulphuric acid, and place both under the receiver of an air-pump; upon exhausting the air, the water evaporates, the acid absorbs the vapour as soon as it is formed, and thus the rate of evaporation is increased; the water, surrendering all its own heat to produce vapour, begins to freeze.

If a cup of warm water be put under the receiver of an air-pump and the air exhausted, it will commence to boil rapidly, illustrating the fact that if the pressure be diminished, ebullition will ensue at a lower temperature.

When water is heated until the thermometer rises to 212° F., ebullition commences. The heat still passes into the vessel, but the thermometer does not rise. As in the case of ice, it becomes latent in turning the water into steam.

To evaporate 1 cubic foot of water requires the consumption of 7½ lbs. of ordinary coal, or about 1 lb. of coal to 1 gallon of water. If the fuel be dry wood, the quantity would require to be about 2¼ lbs. instead of 1 lb. of coal.

In evaporating and cooling of water intense cold is produced. Every pound of water evaporated has expended in the process a loss of 966·6 heat units.

Steam

Steam is the vaporous substance into which water is converted under certain conditions of pressure and heat. In its perfect state it is transparent, colourless, and invisible; when visible in the form of cloudy appearance, it is condensed and is then water.

Water gives off vapour at all temperatures; but it is generally understood that steam is the fluid given off by water when heated to boiling point, when little globules of vapour are formed, which rise to the surface, escaping as vapour or steam.

The use of steam as a mechanical power was first mentioned about 130 B.C., but the idea had no practical results.

The mechanical equivalent of the amount of heat contained in steam is of interest. It is found that 1 lb. of water heated from 32° F. to 212° F. (an increase of 180°) requires as much heat as would raise 180 lbs. 1°; hence . . . . 180°

1 lb. of water at 212°, converted into steam at atmospheric pressure, absorbs as much heat in its conversion as would raise 966·6 lbs. of water 1°; hence . . . . 966·6°

The units of heat contained in 1 lb. of steam = 1146·6°

This of itself does not convey to the mind of the uninitiated any idea of the power of steam. To do so we must proceed a step further. We have found the units of heat, and, as we saw in the first chapter, each thermal unit of heat contains a power of exerting 772 foot-lbs. Therefore, the mechanical equivalent, or the maximum theoretical duty of this quantity of heat as contained in 1 lb. of steam, is 772 lbs. × 1146·6 units of heat = 885,175·2 lbs. raised 1 foot high.

Steam at 212° occupies a space 1642 times as large as the water from which it was generated; or it may be more easily remembered that 1 cubic inch of water, when evaporated under ordinary atmospheric pressure (temp. 212° F.), is converted into 1 cubic foot of steam (approximately), and that 26·64 cubic feet of steam at atmospheric pressure weigh 1 lb.

It is this fact that makes an explosion by bursting of a boiler such a serious affair. Boilers could be burst by cold water pressure without danger, but by steam a different set of circumstances arises. A short explanation of this will not only be of interest, but will also help us to grasp some of the other facts mentioned in this chapter.

The temperature of steam and water cannot be increased unless the pressure be increased. If the safety-valves be weighted to the pressure of, say, 80 lbs., the temperature necessary to generate steam at this point will be 311·80° F. If we increase the pressure to 100 lbs., the temperature necessary to create steam would be 327·58° F.; at 400 lbs. pressure the temperature would be 445·15° F.

Take a more general pressure, say 100 lbs., for our example. Here, with a temperature of, say, 327° F., the steam would occupy a space over 271 times larger than water. If the boiler is unable to control this it bursts; the pressure of 100 lbs. is at once relieved; the steam explodes with a report, occupying the space it naturally fills at ordinary atmospheric pressure, of which the equivalent figure is 271 to 1642, or 6 times its capacity, while the water, being 115·58° F. above boiling point, immediately explodes into vapour also, expanding to its natural volume of 1642 times larger. Hence the awful devastation that follows in the wake of an explosion of a boiler, steel plates being rent like so much paper. Not a vestige of water is left; it has disappeared invisibly into the atmosphere in the form of vapour. Compare these figures with an explosion of gunpowder. The bulk of the gases by the combustion of this substance when expanded to ordinary temperature of the atmosphere, is only about 240 times as large as the powder, or about 8 times less space than steam demands at 212° F. But Professor Abel says that at the moment of the explosion the temperature (800° F.) would expand the volume 10 times, so the figures for comparison would really be, gunpowder 2400, steam 1642.

We see here the care with which man must handle nature's simple gifts in making use of them for his own purposes. Who would imagine that such mighty powers lurked in the clear, sparkling water, and the dreadful results of not making careful calculations in order to control them sufficiently and safely?

The simple manner in which accidents may occur is illustrated in the explosion of a traction engine at Maidstone, Kent.

The men in charge left their engine to obtain some food, and on returning found, to their surprise, that the steam-pressure gauge apparently indicated a low pressure of steam. In reality it recorded a very high pressure, for the hand had by some mischance passed the stop-pin on the face of the gauge; it had passed the highest figure and had begun a second revolution of the dial. The men made up their fires and increased the pressure, preparing for a start, when they were hurled into eternity!

Let us deal with a small quantity of water, say 1 cubic inch, and see what power it contains.

One cubic inch of water at atmospheric pressure is converted by evaporation into 1700 cubic inches of steam, and will produce force enough to raise 2120·14 lbs. (about a ton) 1 foot. One pound of good coal will evaporate 240 cubic inches of water, and will provide a force of 508,000 foot-lbs. (equal to 15 horse-power).

Latent Heat of Steam

Latent heat is that amount of heat which exists in any body without producing any effect upon another, or upon the thermometer. It is also termed insensible heat, as distinct from sensible heat. It is given out, or becomes sensible, during the conversion of vapour into liquid, and of liquids into solids. On the other hand, a portion of sensible heat disappears, or becomes latent, when a body changes its form from the solid to the liquid, or from the liquid to the gaseous state.

If the reader refers to the details of the mechanical equivalent of heat, he will see that the converting of water at 212° into steam at 212° absorbs 966·6 units of heat, there being no increase in the temperature; therefore, the latent heat of steam is 966·6.

Latent Heat of Water

To illustrate the manner in which to determine exactly the quantity of heat which becomes latent when ice is converted into water, or water to steam (*see* Latent Heat of Steam)—

Provide a constant source of heat. Place a vessel containing 1 lb. of water over it, and note the extent to which its temperature rises in a given time. We will assume that it rises 10° in one minute.

Remove this vessel, and substitute one containing 1 lb. of ice at a temperature below 32°. The temperature will rise to 32°, and will remain at that point a trifle over 14 minutes, at the end of which time the last particle of ice will be melted. In this time the amount of heat absorbed is sufficient to raise 1 lb. of water a little over 140° ($14{\cdot}2 \times 10° = 142$), yet the water is still only 32°. All the heat has been used in turning the solid into a liquid, and as it did not affect the thermometer, it is called latent heat.

Let the vessel still remain exposed to the heat. In 18 minutes it will have attained the boiling point, for $18 \times 10°$ plus $32 = 212°$.

Let the vessel still remain until the water has entirely boiled away. This will occupy about 95 minutes, or nearly $5\frac{1}{2}$ times as long as it took to rise from 32° to 212°; and yet the temperature of the steam has at no time exceeded 212°. All this amount of heat, viz. $5\frac{1}{2} \times 180 = 960°$ (more accurately, as previously stated, 966·6°), has been rendered latent.

If the steam given off in this experiment be conducted by a tube into a vessel containing 5½ lbs. of water at 32°, after some time this water will boil. It will now be found that there is 6½ lbs. of boiling water in the vessel, and that 1 lb. of steam has been condensed, and the latent heat of that was sufficient to raise 5½ lbs. of water 180°. It is this large amount of latent heat in steam that renders it so useful as a heating agent. Heat cannot be destroyed, but it is rendered sensible or given out again when the steam becomes condensed.

Were it not for the latent heat of steam, the moment water attained the boiling point would be a dangerous one indeed. It would immediately be converted into steam, with an explosive force equal to that of gunpowder; for a cubic inch of water, when converted into steam, occupies nearly a cubic foot of space.

As a simpler example of a solid becoming a liquid, rendering latent a certain quantity of heat—

If equal parts of water at 32° F. and 174° F. be taken and mixed together, the temperature of the mixture will be the mean of the two, or 103° F.

Take equal weights of ice at 32° F., and water at 174° F., mix as before, and the temperature will be found to be only 32°, not 103°; all the ice would be melted, and the 142° of heat has then been consumed in melting the ice.

To convert a cubic yard of ice at 32° F. to water at 32° F. would absorb the whole of the heat emitted by the combustion of 1 cwt. of coke.

Specific Heat of Water

Various substances require different amounts of heat in order to raise the same weight to an equal temperature. This is called the specific heat.

Water is taken as the standard. The thermal capacity of a unit mass of cold water is unity, and the number which denotes the thermal capacity of a body expresses the mass of water which has the same thermal capacity as that body. The thermal capacity of unit mass of a substance is called its specific heat, and is identical with the ratio of the thermal capacity of any mass of that substance to that of an equal mass of water.

So the specific and latent heat of bodies is ascertained by finding the amount of ice the body melts in cooling, or from the increase in its temperature it produces in the water around it.

If water and mercury are both subjected to the same amount of heat, the mercury will be found to have a much higher temperature than the water. Water, having absorbed the heat, gives very little out.

Mercury can only contain one-thirtieth of the heat taken in by the water. It gives off a much larger quantity, and therefore has a much higher temperature. Therefore it takes 30 times as much heat to raise the temperature of 1 lb. of water 1°, as to raise the temperature of 1 lb. of mercury by the same amount.

The following table gives the specific heats of a few common substances :—

Water	1·0000
Alcohol	·6603
Ice	·5040
Aluminium	·2143
Iron	·1138
Copper	·0952
Mercury	·0333
Gold	·0324
Platinum	·0324
Lead	·0314

The specific heat of water is greater than that of any other substance; therefore, the sea always tends to preserve a uniform temperature. For this reason islands have a much more even temperature than continents. They do not experience the extremes of heat and cold; for the sea absorbs a great deal of heat when the temperature is high, giving it out again as the temperature falls.

Maximum Density of Water

Warm water is lighter than cold. Water attains its maximum density at 39·2° F. As the temperature approaches the point of solidification (32° F.), the increase of volume is slow and gradual; at 32° F. the water begins to turn into solid crystals of ice. (*See* p. 113.)

Let us make this point clearer, viz. that water expands before freezing, while it is still liquid. If hot water be taken, and cooled gradually, it will contract slightly and continuously until it reaches 39·2° F.; no further contraction occurs, it is now at its heaviest temperature. If the process of cooling be continued, the water will be found to expand slightly for the next few degrees, until freezing point is reached, when its expansion, with solidification, is both sudden and intense.

Congelation of Water

Solid iron floats on molten iron, as ice floats on water.

Were it not for the fact that water increases in volume after passing below 39°, all lakes, as the cold water from the surface gives place to the warmer from below, would in time reach 32°, and the water would be formed into a solid mass of ice, killing all fishes and other living inhabitants; but by the wonderful provision of nature, as water approaches 32° it increases in volume, throwing a protecting mantle of ice over the water.

We have seen that water boils at 212° F.; mercury, however, requires 660° F.

With alcohol it is very different. This boils at 173° F. at atmospheric pressure, and if placed under the receiver of an air-pump, it will boil at ordinary temperature. Mercury freezes at $-39°$ F., but the congelation of alcohol, which has only lately been achieved, takes place at a temperature of $-203°$ F., for which reason this is the liquid selected for recording very low temperatures.

Cause of Expansion

Contraction is caused by the molecules of water approaching each other as the water cools; but at 39° new forces come into play, and the molecules rearrange themselves, demanding more room in the process of solidification.

Water does not always freeze at the same temperature. If the temperature be gradually reduced, and the water be kept perfectly still, 3° or 4° below 32° F. may be reached before ice begins to form; but the slightest movement will turn it to ice, or if the smallest particle of ice be in the water, this experiment cannot be carried out, for ice will then form at 32°. Ice, however, invariably melts at a fixed temperature.

Compression of Water

Air may be compressed almost indefinitely, and on pressure being relieved it regains its former bulk; but water is practically incompressible. It has been found that a pressure of 15 lbs. per square inch will compress water only 51·3 millionths (or ·00005) of its bulk.

Under a pressure of 1 atmosphere (15 lbs. per square inch), the following reduction in volume takes place. In

Alcohol	·00216	per cent.
Ether	·006158	,,
Mercury	·000265	,,
Water	·004663	,,

Temperature and Pressure

The freezing point of water is lowered by pressure. A cylinder of water under pressure remains liquid at below 32°; but if the pressure is removed it turns at once to ice. If water be prevented from expanding it cannot freeze.

The boiling point of water is raised by pressure. "Water, even in open vessels, may be lowered many degrees below its freezing point and still remain liquid; it may also be raised to a temperature far above boiling point and still resist boiling.

This is due to the mutual cohesion of the water particles, which resist the change of the liquid either into the solid or the vaporous condition.

If you throw a particle of ice into overchilled water, cohesion is ruptured and congelation immediately sets in.

If into superheated water you introduce a bubble of air or steam, cohesion is likewise ruptured and ebullition immediately commences (Faraday).

Matter in Suspension

All water, whether fresh and pure, or salt and full of impurities, is derived from the rainfall.

Rain-water is the purest water obtainable, and is really distilled water, distilled by nature; but it gathers impurities from the atmosphere on its journey to the earth: oxygen and nitrogen and carbonic acid gas.

When falling through the air over or near towns, it dissolves sulphurous acid gas and ammonia.

"Both sulphate and carbonate of lime, apart from their occurrence as independent minerals, are almost universally diffused throughout the world's crust (as well as in the waters of the ocean). The sulphate is appreciably soluble in pure water; while the carbonate, though practically insoluble in pure, is quite decidedly soluble in carbonic acid water."

After rain has fallen on the earth, in passing through soil, sand, and rock it gathers up soluble inorganic matter, together with organic matter.

By continued filtration through the ground the former (sulphate and carbonate of lime) is increased, the latter diminished.

If filtration is sufficiently perfect the organic matter is altogether eliminated, the oxygen combining with the injurious nitrogenous compounds, and the resultant acids, with the alkalies of the soil, forming harmless nitrates.

Hardness of Water

The difference between hard water and soft water consists in the relative quantities of bicarbonate of lime in it.

Water of less than 5° of hardness is considered "very soft," 5° to 10° "fairly soft," 10° to 15° "neither hard nor soft," 15° to 20° "moderately hard," 20° to 30° "hard," over 30° "very hard."

There are two kinds of hardness, permanent and temporary. The former is due to the presence of sulphate of calcium; the latter is due to bicarbonate of calcium (lime).

When water is boiled, the bicarbonate is decomposed, yielding the insoluble carbonate as a deposit.

The water of the Thames Head well, near Cirencester, is said to contain 27·44 parts of solid matter in suspension per 100,000. This consists principally of carbonate of lime, the hardness being 23°, of which 18° is temporary and 5° permanent.

Ordinary good chalk water would have a hardness, averaging about 20° temporary (before boiling), and about 3° to 4° after boiling. As a rule it is exceedingly pure, and from a domestic point of view all that can be desired.

Some waters possess a hardness up to 200°.

One sample from a boring 165 feet deep at Longeaton, in Derbyshire, which passes through red marl, permeated by bands of gypsum, was described as being "a nearly saturated solution of sulphate of lime." It had a total hardness of 116°, and a permanent hardness of 115°, and was absolutely unfit for use.

Hardness and its Influence on Health

The hardness of chalk water has given rise to much discussion; various opinions have been given as to its deleterious effect on the health of the population.

The following table from the sixth Report of the Rivers Pollution Commission is very clear upon the point:—

No. of cities.	Population.	Degree of hardness.	Rate of mortality.
26	73,000	under 5°	29·1
25	81,000	5° to 10°	28·3
60	44,000	over 10°	24·3
London	3,250,000	16° to 32°	24·6

Other returns show similar results, and the opinion of the Commission was that "both soft and hard waters are equally wholesome, and we give no preference to soft water."

I am of opinion that hard water is beneficial to the human system to a far greater extent than we are generally aware, especially to children and young people, the lime in the water helping to build up their frames.

Children cannot drink too much of this water; for it has been noted that in hardwater districts the absence of rickets is apparent, and the inhabitants generally have better teeth than those living in soft-water districts.

If this is so, the whole frame must also derive an equal benefit, though not so apparent, even though in a few isolated cases hard water may perhaps prove injurious to persons of mature age.

Wanklyn, in his practical treatise on water analysis, says: "The Metropolitan water contains 4 or 5 times as much solid matter as the Manchester and Glasgow waters.

"The healthiness of London is higher than either, and I am warranted in saying and maintaining that a high solid residue in drinking water can have no very markedly injurious effect on public health.

"London proves it. Here the major part of the solid residue consists of carbonate of lime. Subtract this, and the rest of the solid residue will not be much higher than the water of Manchester, and other soft waters.

"If in a few isolated cases hard water is injurious, the difficulty is easily overcome, and the hardness removed by boiling."

The following remarks in the *Lancet* will be of interest to many:—

"It is a popular, but probably wrong, impression that hard drinking waters are prejudicial to the health, and moreover are injurious to delicate skins when used regularly for ablutionary purposes. Gout, kidney disease, and dyspepsia, by an interesting line of reasoning, have been supposed to be due to, or aggravated by, the drinking of excessively hard water. Some mysterious connection between the chalk of the water and the formation of "stone" in the kidney, or of "chalk" in the joints, in gout, is a favourite speculation with many; but in the history of the world's water supplies there is no trustworthy evidence that the drinking of hard water influences for the worse these diseases. The idea is, in fact, chimerical."

It may be added that a Royal Commission some years ago reported that where the chief sanitary conditions are observed with tolerable uniformity, the rate of mortality is practically uninfluenced by the softness or hardness of the water supplied to different towns.

In an article dealing with this subject, Dr A. T. Schofield remarks: "The best water is fresh spring water. This, however, is a luxury that is rarer than good wine, and the bulk of the population have no idea what such a water is like."

Precipitation of Lime in Water by Boiling

The simplest way of softening water is by boiling. The greater the heat, the greater the amount precipitated, as will be seen from the table given below.

In this process the bicarbonates of lime and magnesia are decomposed into free carbonic acid, which escapes, and insoluble carbonate of lime and magnesia, which are precipitated. The hardness thus removed was the temporary hardness; that remaining, consisting principally of the sulphates of lime and magnesia, is termed the permanent hardness.

Temperature	217° F.	50·0	per cent. deposited.
"	227°	60·5	"
"	236°	69·0	"
"	250°	81·7	"
"	261°	90·3	"
"	290°	100·0	"

One degree of hardness implies that each gallon of water contains 1 grain of bicarbonate or sulphate of lime, and that 1 lb. of soap for each degree of hardness will be required to soften every 833 gallons of water; or, according to Clark's scale, ¼ oz. of soap will remove 1° from 10 gallons of water.

This appears to be a very serious item; but when one considers the few gallons of water that are used with soap, in proportion to the other uses of water, its seriousness to a great extent vanishes.

In the simple process of washing our faces, we do not soften the whole basinful of water, but only the small quantity on our hands, or the article we are using for the purpose.

We should therefore think seriously before we condemn water for its hardness, and convert the hard, bright, sparkling, natural water into soft, insipid, "treated" water.

No doubt, as far as the domestic boiler and kettle are concerned, we have some cause for complaint. For when these precipitated matters form a scale or deposit in any article in which water is boiled, there is a loss of heat. This scale, being a bad conductor of heat, possesses 2·7 per cent. less of heat-conducting power, as compared with the shell of the boiler. If the scale formed be ⅛ inch in thickness, we shall have to burn 15 per cent. more coal to produce the same results.

In the case of large boilers for raising steam, the difficulty can be overcome in several ways; but it is not within the scope of our story to go into the subject in detail. One method only will be described shortly.

Clark's Method of Softening

In this method of softening waters which contain carbonate of lime (retained in solution by excess of carbonic acid), lime is added until the excess of carbonic acid is neutralised. When this has taken place, the lime added, as well as that previously in solution, is precipitated in the form of carbonate, only a minute quantity remaining in solution.

This process will reduce the Thames and New River water to 3½°, or lower than if it had been boiled for one hour, but will rarely bring any water below 2½° of hardness.

This process, in addition to reducing the hardness from, say, 21·2° to 4·4° (as at Caterham), removes a large proportion of organic matter, and any matter giving a colour to the water. Where these latter considerations arise, of course, softening has more in its favour.

Water Analysis by Professor Dewar

HARD WATER FROM THE CHALK

	Results in grains per gallon.
Appearance	Clear
Odour	None
Reaction	Slightly alkaline
Oxygen required	0·000
NH (ammonia)	0·000
Nitrogen	0·406
Nitrogen as combined nitric acid	1·827
Colour of residue	White
Total solids	27·20
Total chlorine	1·512
Equivalent to common salt	2·478
Hardness before boiling	20·12
" after "	3·30
Organic carbon (parts, per 100,000)	0·010
Organic nitrogen (parts, per 100,000)	0·004

Remarks.—This water is exceedingly pure, and free from organic impurity.

SOFT WATER FROM THE LOWER GREENSAND

	Results in grains per gallon.
Appearance	Clear
Colour	Very pale blue
Reaction	Slightly alkaline
Colour of residue	White
Total solid matter	22·800
Chlorine	1·800
Equal to chloride of sodium	2·950
Nitrogen as nitrites	0·000
Nitrogen as ammonia	0·010
Oxygen required to oxidise organic matter	0·004
Degree of hardness	0·780
„ „ after boiling	0·780
Organic carbon (0·098 parts per 100,000)	0·068
Organic nitrogen (0·003 parts per 100,000)	0·002
Carbonate of sodium	16·600
Sulphuric anhydride (SO_3)	1·160

This water, from the 664-feet artesian boring at Luton, Chatham, is of great organic purity, remarkably free from hardness, and carbonate of soda is present in unusual quantities.

Sea-water

No attempt at an exhaustive treatise on water would be complete without some reference to the nature of the water of the ocean—the home of the waters. The first question that will probably arise in some minds is, "Why is it salt?"

Nearly all the water from springs and rivers eventually reaches the sea, carrying with it all the dissolved substances gathered on its journey, principally carbonate of lime and common salt. The former, however, is being continually appropriated by the marine animals. For the latter there is but little use ; thus we find that in ordinary sea-water salt is present in very large quantities.

These saline ingredients are generally found in the proportion of 30 to 40 per thousand, and their presence accounts for the density of sea-water, which averages 1·026 ; but it varies even in the same ocean. It is greatest in the North Atlantic Ocean; and in the passage of the trade wind, where the evaporation is rapid, 1·02781 has been registered.

Among broken ice of the Arctic the density sinks to 1·02418.

The mineral that gives sea-water its special character is sodium chloride, the proportion varying according to whether the seas are open or closed; to the distance from the coasts, where rivers pour their fresh waters into it; to the amount of evaporation in the different regions; to the distance from the melting iceberg of the Polar regions; and to the depth of the water. It has also been found that generally the greater the saltness the greater the transparency. For instance, where the water is very salt it will be dark blue; where less salt, lighter blue. Where the sea is near a river, and the saltness is greatly reduced by dilution with fresh water, the colour is as a rule of a greenish yellow.

A ship will carry more cargo in salt water than in fresh when equally immersed. If a ship loaded in fresh water proceeds to sea, it will be found that the mark made on the side of the vessel in fresh water will be some distance above the surface of salt water.

The fact that we can swim more easily in salt water than fresh is due to the greater density of the sea-water, which gives it greater buoyancy. (*See* the Dead Sea, p. 305.)

The following comparisons between fresh and salt water are of interest :—

	Fresh water.	Salt water.
Greatest density . .	39·2° F.	Freezing point (variable).
1 cubic foot at 39·2° F. weighs . . .	62·348 lbs.	64 lbs.
1 gallon weighs . .	10 lbs.	10·3 lbs.
1 ton weight equals .	35·943 ft. cube	35 ft. cube.
1 ton contains . .	224 galls.	217 galls.
Freezes at . . .	32° F.	26° to 31° F. according to saltness.

It is often found necessary to obtain water for domestic purposes from the sea. This is done by distillation and aeration. Aeration as well as distillation is necessary; for the process of evaporation and re-condensation gives us fresh water, but with a "flat," most repulsive taste, and a disagreeable odour.

Special apparatus for condensing water is constructed, by which the steam is aerated on its passing from the evaporator to the refrigerator.

The apparatus used for this purpose in the large ocean greyhounds and many men-of-war will yield about 1 gallon of potable water from the sea for every pound of coal consumed.

Analysis of Water from the English Channel

Water	963·74372
Sodium chloride	28·05948
Potassium chloride. . . .	·76552
Magnesium chloride . . .	3·66658
Magnesium bromide . . .	·02929
Magnesium sulphate . . .	2·29578
Calcium sulphate	1·40662
Calcium carbonate	·03301
Iodine	Trace
Ammonia	Trace
Oxide of iron, Silver }	In some seas
	1000·00000

We have seen that water exists in almost everything, to a far greater extent than we might have imagined.

A human body weighing 150 lbs. contains about 113 lbs. of water, and requires daily for its sustenance, either as a liquid, or combined with food, 5½ lbs. of water. This equals more than half a gallon, and seems an enormous amount to be consumed by an ordinary (non-thirsty) individual. We shall better understand how we take in this necessary amount without being aware of it if we consider the amount of fluid that exists in various articles of our diet.

Proportion of Water in Articles of Food

Bacon, pork, ham	22	per cent.
Eggs	65	„
Butter	11 to 16	„
Richest milk	87	„
Cucumber	97	„
Salmon	75	„
Beef	73	„
Cabbage	89	„
Potatoes	75	„
Cheese	25 to 50	„
Strawberries	90	„
Apples and grapes	80	„

The Aquarium

All water contains air, but the air in water has double the quantity of oxygen in it that is present in atmospheric air, and for this reason the fishes have only to pass through their gills (which fulfil the same functions as our lungs) half the quantity of water they otherwise would have to.

If fish were put into water that had been boiled, and the air expelled, they would come to the surface and breathe our air, and would eventually die unless the water were aerated, and thus supplied with the proportion of oxygen they require.

Aquatic plants give off oxygen to the water, and the fishes breathe it, giving out carbonic acid, on which the plants thrive; so beautifully does nature arrange the minutest detail of her work.

To manage an aquarium successfully the first consideration must be the balancing of animal and vegetable life. This is not by any means an easy task; and resource is generally had to changing the water, or artificially aerating it. When the fishes become exhausted owing to the absence of sufficient oxygen in the water, they swim at the surface, with their mouths taking the air from the atmosphere.

No single hobby gives such a maximum of pleasure for such a minimum of labour as an aquarium, and if the tank be properly constructed, there is no fear of a leak. It is a study of the most interesting kind; but though little work and attention is necessary, it must have that little.

Many readers are discouraged in starting an aquarium by the usual statement in books on the subject that the best water for the purpose is that from a river; next, from a clear pond; next, *clean* rain-water; last of all, hard water from well or tap.

Now all the first three are more or less impossible to obtain, from one reason or another; but it is possible to keep Prussian carp, dace, stone loach, tench, minnows, golden carp (gold-fish), and the beautiful golden orfe in water from the tap; so we need not set out hopelessly, or abandon the idea, owing to our distance from a clear river or clean pond.

Two golden orfe completed twelve years' confinement in my aquarium two years since; but as they developed cannibalistic propensities in the thirteenth year by devouring the minnows, they have been turned into a pond, which they much appreciate.

Many students, including the writer, with but little spare time, fail also in attempting to run the aquarium on really scientific lines—not changing the water, but by balancing the conditions between animal and vegetable life.

Only one here and there can succeed in this, and that only when ample attention can be paid to it, and situation, water, light, and many other conditions are exceptionally favourable; but the pleasure may be secured with absolutely no trouble whatever by arranging a supply from the domestic pipes direct to the tank. It is not a question of the quantity of water, but the quality and convenience of supply.

The cost is small, for the consumption of water would not exceed 1 gallon per day all the year round for a large tank, as in the winter no fresh water is required for a week at a time, and then but little need be added.

If the supply be arranged to deliver downwards under pressure, with the end of the pipe a moderate height above the water, the jet need not be thicker than an ordinary needle. It will then carry down with it into the tank the atmospheric air, and if only turned on for, say, half an hour per day, will keep the occupants healthy. When the jet is forcing the air down, the fishes, especially the minnows, will gambol and sport in the silver stream of air-bubbles and water, darting up against the stream to the surface. It is indeed a pretty sight.

Even when the water is supplied through a jet, by all means introduce the water plants, snails, etc.; but even should these not thrive, the fishes will not suffer.

Given the above conditions, by the help of a good book, such as Bateman's *Fresh-Water Aquaria* (Upcott Gill), as a guide to feeding, shade, etc., there should be no failure.

Of all water-plants, the Italian water-weed, *Vallisneria spiralis*, is the favourite for many reasons, one being its peculiar method of reproduction, and another its circulation of sap, which can be seen by the aid of a microscope. It is also a free producer of oxygen. Its air cells contain air only, the juices of the plant being contained in separate vessels.

Great pleasure may also be obtained during the summer by making a partition with a sheet of glass for observing the stages of development of the frog or the toad, from the spawn, the tadpole, the growth of the hind legs, followed by forelegs, and the absorption of the tail, finally, the pretty little creature ready to jump out on the floor, which he will do on the very first opportunity.

There is also the interesting triton, better known as the water newt, which under suitable conditions will take to tank life readily. It is very interesting to watch them come to the surface to breathe, in doing which they make a little popping noise, and to see the female lay her eggs and wrap each in the fold of a leaf. Great pleasure is also possible when these creatures shed their coats. The old skin can, if care be used, be floated on to a piece of card-board by the aid of a small brush; it will be found complete even to its tiny toes.

This creature, in common with many other animals, can reproduce its lost limbs. I trust the reader will accept my word for this fact, and will not proceed to the cruel sport of testing the statement.

There is the stickle-back, who will build a nest, if conditions favour, like a muff. The female will lay her eggs in it, guarded by the male, who will attack any fish that may venture too near. He persuades many females to enter the nest and deposit their eggs, until a sufficient number be laid.

Nearly all fishes can be tamed and taught to feed from the finger of their keeper, on whose approach they will eagerly come to the near corner to be fed.

Instead of a partition in the aquarium, a separate globe may be used for the purpose of observation, but space will not admit of further treatment of this subject; but there are endless varieties of beetles, water-flies, bugs, scorpions, snails, limpets, and worms, all equally interesting, and worth a place where their development and peculiarities may be studied.

"With plenty of light you will see," to quote Mr Gosse, "thousands of tiny globules form on every plant, and even all over the stones where the infant vegetation is beginning to grow, and these globules presently rise in rapid succession to the surface all over the vessel, and this process goes on continuously as long as the rays of the sun are uninterrupted. Now these globules consist of pure oxygen, given out by the plants under the stimulus of light."

Referring to the aquarium, Charles Kingsley says: "These animals, their habits, their miraculous transformation, might give many an hour's quiet amusement to an invalid imprisoned in a sick-room, and debarred from reading, unless, by some such means, any page of that great green book (*of nature*) outside, whose pen is the finger of God."

CHAPTER VI

FORMS OF WATER

Dew

> "The benediction of these covering heavens
> Falls on their heads like dew."
>
> SHAKESPEARE.

DEW is the water of the atmosphere deposited in minute globules upon the earth. It does not fall, in the ordinary sense of the term; but after the sun has set, and the supply of heat is cut off, vegetation that has been warmed by its rays and has absorbed them, radiates its heat back into space and becomes rapidly cooled, until it becomes lower in temperature than the surrounding air. The result is that the moisture from the lower stratum of air is condensed and forms dew. The water vapour which is being continually breathed out by plants also helps in the formation, for on a still night it is supposed that the amount of water deposited is more than could have condensed out of the air coming into contact with the leaves of the plants, and that the plant itself assists in the deposition of moisture on its leaves. Dew is deposited, not on plants alone, but on all objects that have become cooled by radiation. Plants radiate their heat more freely than other bodies, and so receive a greater proportion of moisture.

The annual amount of dew falling in Great Britain is estimated as averaging a depth of 5 inches all over the surface, and is always more abundant in maritime countries than in the centre of large continents.

The surface of the earth is never cold, heat being radiated from it continuously. For this reason dew is never found on the earth.

Dew is not formed in cloudy or windy weather. The clouds prevent the escape of heat into space by radiation. Clouds, like grass and foliage, are good radiators, sending back an amount of heat equal to that received, and so the balance of the temperature of the earth and atmosphere is maintained and no dew is formed, there being no condensation. The wind, by continually changing the air in contact with the ground, prevents the temperature from falling sufficiently low for the formation of dew.

Dew falls freely in some parts. Where it seldom rains it falls heavily, and is nature's only means of preserving vegetation in these thirsty regions of the globe, thus providing every leaf with its allowance of moisture, night after night, enabling it to grow and flourish.

Thus in the tropics during the intense heat of day the amount of heat absorbed is very considerable. The vapour also exists in great quantities owing to the excessive evaporation. This, followed by the clear skies, makes the conditions complete, and as a result we get dew deposited very freely.

"In the South American forests," says Humboldt, "notwithstanding the sky is perfectly clear overhead, rain frequently falls in heavy showers, caused by the copious formation of dew by the radiating powers of the tops of the trees, in contact with the vapour-laden atmosphere of the tropics."

In cold, damp climates little dew is deposited, as the frequent presence of clouds prevents it. Fortunately, here again nature has beautifully arranged for moisture to be deposited where it is most needed; for, as soon as the sun shines, or the atmosphere becomes warmed, the dew disappears, and is again absorbed by the atmosphere.

> "Such did the manna's sacred dew distil,
> White and entire, although congeal'd and chill;
> Congeal'd on earth, but does dissolving run
> Into the glories of the Almighty Sun."
>
> ANDREW MARVELL.

We often hear the pearly dew referred to as an emblem of purity. This is far from right; for dew, being principally condensed out of the lower stratum of air, naturally contains a far greater amount of impurities than rain, which is formed in the higher regions.

The instrument used for ascertaining the quantity of dew which falls is called a drosometer (Greek *drosos*, dew), consisting of a balance, one end of which receives the dew, the other end carrying weights which are covered to protect them from the dew.

Hartwig says: "The very name dew is refreshing, and calls forth a host of pleasing ideas. How beautiful are its diamonds, glittering, in all colours of the rainbow, on verdant meads, or on the blushing petals of the roses!"

Before leaving this interesting subject, it will be well to mention one other useful purpose performed by the condensation of the vapour in the atmosphere, and deposited on the surface of pools, which are called dew ponds, which, even in the driest weather, almost always contain water. The origin of this supply is explained by Professor Henry Robinson in an article on water supply, in which he says: "Under certain conditions evaporation ceases, and water is condensed on the surface of the reservoirs. On Salisbury Plain, and other elevated districts on the Chalk formation, small ponds called "dew ponds" are constructed on the tops of the hills, where little or no surface water can run into them; yet a small supply of water is obtained, owing to the very heavy dew arising from the condensation of the vapour which is evaporated from the surface of the chalk."

Dew ponds are thought by many people to be natural reservoirs; but this is at any rate not always the case, for the following description of their construction was given me by an old "mist-pond" maker hailing from Wiltshire, where these ponds are more or less common.

For a pond 60 or 70 feet in diameter, the depth in the centre would be 7 to 8 feet. After the excavation is complete, the surface is puddled, that is, made watertight, a layer of clay being spread over the surface, and well beaten down, or "puddled," to form an impervious bottom. A layer of lime is then put over the clay; this is covered with wheat straw, which is well sprinkled with water. The whole is then covered with chalk gravel.

My old friend would not agree with the theory that the evaporation from the chalk assisted in replenishing the ponds, which is no doubt correct; but he could hardly be expected to have grasped this point. He, however, admitted that both dew and rain deposited on the surface of the water *helped to keep* up the supply; but it was principally by the condensation on the vegetation trickling into the pond that the supply was maintained. My informant said that a dew pond could be made in any convenient situation, and on any geological formation, but that they were more successful on the chalk—why, he could not tell—and that altitude had but little to do with the spot selected. He preferred to make them on a dead-level surface, as the objection to rain-water running into the pond was that it carried dirt.

I pressed him as to why they are said never to dry up, which he maintained is a fact, and added: "There is always a certain amount of dew."

On the matter of the amount of yield of these ponds, I could only gather, "All depends upon the season"—a wise and safe reply! He was, however, keen to impress upon me their entire independence of rainfall.

They are, it appears, ready for use, and yield almost immediately on completion; and many farmers, at least in Wiltshire, rely solely on these ponds for water for all farm purposes.

"We have no water to delight
Our broad and brookless vales,
Only the dew-pond on the height,
Unfed, that never fails,
Whereby no tattered herbage tells
Which way the season flies,
Only the close-bit thyme that smells
Like Dawn in Paradise."

KIPLING.

On referring to White's *Selborne*, I find that in a letter dated 7th February 1776, this interesting subject is treated at some length: "To a thinking mind, few phenomena are more strange than the state of little ponds on the summits of chalk hills, many of which are never dry in the most trying droughts of summer. One in particular, on our sheep-down 300 feet above my house, which, though never above 3 feet deep in the middle, and not more than 30 feet in diameter, yet never is known to fail, though it affords drink for 300 or 400 sheep, and at least twenty head of large cattle. Ponds in the vales dry up, but those on the very tops of the hills are but little affected." He sums up the reason as follows: "The moister the earth is, the more dew falls on it at night; and more than a double quantity of dew falls on the surface of water than on moist earth. Hence water, by its coolness, is enabled to assimilate to itself a large quantity of moisture nightly, by condensation, and the air, when loaded with fogs and vapours, and even with copious dews, can alone advance a considerable and never-failing resource."

Surely there is ample scope for the energies of the professional "dew-pond" maker on our north and south downs, where there is the perpetual difficulty of finding a supply of water for thirsty flocks and herds.

Hoar-frost

When the temperature sinks below the freezing point, after dew has fallen, the tiny globules of water take the solid form; the particles freeze, and hoar-frost is formed; and it is one of the prettiest sights one can see in winter, the hoar-frost forming every conceivable pattern on the bare branches, varying with the kind of tree, shrub, etc., on which it may be deposited.

"The mystery of crystallisation," says Ruskin, "by which, obeying laws no less arbitrary than those by which the bee builds her cell, water produced by the sweet miracles of cloud and spring freezes into hexagonal stars of the hoar-frost."

One can derive great pleasure from watching the manner in which this most interesting form of ice will decorate and beautify even barbed-wire fences, wire-netting, or iron railings, and does not ignore the unsightly telegraph wires, which now unfortunately make our main roads hideous; even the delicate spider-web is turned into an exquisite sparkling net.

Sleet

Sleet is composed of snowflakes partially melted in their fall by passing through warm air.

Mrs Aubrey Le Blond.

HOAR-FROST ON A TREE.

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Of this least interesting form of all atmospheric condensation, Robert Burns says:—

> "The wintry west extends his blast,
> And hail and rain does blow,
> Or the stormy north sends driving forth
> The blinding sleet and snow."

Hail

Hail is rain which has passed through a cold stratum of air, and has been converted into ice. It is a curious fact that hailstorms are most common in tropical regions, and during the heat of summer, and they usually occur during the hottest part of the day.

Darwin states that when at the foot of the Sierra Tapalguen, he had ocular proof of the falling of large hailstones. Hail as large as small apples fell with great violence, killing a large number of deer and birds. He also mentions that in 1831, in India, flat hailstones fell, one being 10 inches in circumference, and concludes by referring to the fact that their dinner consisted of hail-stricken meat.

Hailstones have often fallen of enormous sizes. In 1697 Robert Taylor, in Hertfordshire, found them 4½ inches in diameter. Hailstones of this size are fortunately rare. There is no reason, however, to doubt the accuracy of the statement, for, if it were not true, it would scarcely have survived for 200 years. Hailstones up to 3 and 4 inches in diameter have frequently been noted.

In referring to the curious shape and stratified appearance at times assumed by hailstones, Professor Tyndall concludes that it is due to the velocity with which they fall, and that they must have encountered condensed hot air in front of them, and rarefied cool air behind them.

The destruction of bloom and bud in orchard and vineyards by this visitant causes it to be greatly dreaded by the fruit-grower.

On 2nd August 1906 very heavy losses were sustained in portions of the counties of Huntingdon, Bedford, and Cambridge by a terrible hailstorm which in many cases completely ruined the crops. Hailstones, which were jagged pieces of ice, were in many cases 5 inches in circumference. They fell with a force sufficient to kill a flock of starlings roosting on a tree. Rabbits were killed in the fields, and many coveys of partridges. The damage to the crops was estimated by practical valuers, who had carefully inspected the storm area, at £20,000. The wheat, barley, and oats were so threshed as to have the appearance of having passed through the machine. At Stagsden the storm was very fierce, the hailstones being larger than walnuts. Windows were broken and the corn destroyed, while beans were threshed and cut. In the village of Thurleigh many windows were broken, and damage done to property, while beans and oats were stripped.

A correspondent of the *Daily Telegraph*, writing from Verviers, stated that damage to the extent of many thousands of pounds was caused to property, fruit, and crops by the phenomenal hailstorm. Orchards and nurseries were completely ruined. The farmers were panic-stricken on realising the damage that had been done, and feared ruin. Nothing similar had ever been known. The hail, in falling, was met by whirlwinds which massed it into thick blocks, one of which weighed over 4 lbs.

This recent visitation will serve to illustrate the severity of a hailstorm.

Fog or Mist

Fog or mist is caused by a cloud formed near the ground, or the surface of water; or in river valleys where the air

Author.

A NETWORK OF PEARLS.
(Fog precipitated on a spider's web.)

Mrs Aubrey Le Blond.

MOUNTAIN MISTS.

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is nearly saturated with vapour rising from the water or moist land, the cloud itself being caused by the condensation of the vapour in contact with the cold surface of the earth, or a cold current of air.

Even this least interesting form of atmospheric precipitates makes an attempt, as if to redeem its lost reputation, of decorating all that comes in its way. It is attracted by the delicate spider's web, on which it forms minute pearly drops outlining every strand. Every twig and bud will glisten with the transparent beads, which increase in size until of necessity they fall to the ground, and their places are taken by other tiny growing beads.

Ordinary white mist that we see in the country is the unadulterated mist pure and simple, and is not nearly so objectionable as its London relative.

The latter is practically the same as the former, but in addition contains in suspension the smoke and impurities of the city.

If a stream be warmer than the air, more vapour is given off than can be dissolved in the air. This also causes fogs, similar to those that prevail along the course of the Gulf Stream. The Behring Strait is seldom free from fog.

No words of mine are necessary to describe the injurious effects of city fogs upon the respiratory organs; but the chief injury arises from the matter in suspension, and not from the mist itself.

Recent experiments prove that with fog, as with rain, invisible dust particles in the atmosphere are necessary for its formation. It will be well if we give some little time to this matter of the dust particles in the atmosphere, where they play such an important part.

From whence does the supply of these minute particles come? Dr Mill tells us that 20,000,000 meteorites reach our earth daily. These are broken up by friction with the air, thus supplying cosmic dust. He tells us that a puff of smoke from a cigarette contributes about 4000 million separate granules of dust. We have also the numerous chimneys assisting in the work. All the elements of disintegration also provide their quota.

These dust particles are found even in the higher atmosphere around the mountain tops, though in greatly reduced numbers.

It is to these minute particles of dust and vapour that even more credit is now given, for their scattering of the sun's rays gives the sky its clear blue appearance, the finest particles giving the strongest blue to the light reflected from it.

The tints of sunrise and sunset, rain, vapour, twilight, dawn, fog, mist, cloud, all rely on these invisible dust motes for their formation and effect; for water vapour never condenses except upon a solid substance, and the dust particles provide the necessary nucleus. It is stated that in air quite free from dust, water vapour has been cooled far below the dew-point without condensation taking place. Upon admitting a puff of ordinary dust-laden air, each dust mote becomes the centre of a tiny globule of water, and condensation proceeds in the usual manner.

Thus we see that fog or mist differs only from clouds in the place of origin; and, as Professor Huxley tells us, "fog or mist is a cloud resting on the earth; and a cloud is a fog floating high in the air. In like manner icebergs are often attended by fogs, simply because the mass of ice cools the surrounding air, and thus precipitates its moisture."

Lightning and Storms

> "From peak to peak the rattling crags among
> Leaps the live thunder, not from one lone cloud;
> But every mountain now hath found a tongue,
> And Jura answers, through her misty shroud,
> Back to the joyous Alps, who call to her aloud.
>
> BYRON.

Lightning is a flash of light, resulting from a sudden discharge of atmospheric electricity. How this comes to pass, Dr Hugh Robert Mill explains :—

"When the electric potential of a cloud becomes much higher than that of another cloud, or of the earth, a disruptive discharge takes place between them, through the air. The electrical energy is mainly converted into heat by the resistance of the air, the particles of which become instantly white-hot; but the passage of the electric current is so rapid that only a brilliant flash is visible. The intensely heated air expands suddenly, and then as suddenly contracts, setting up a succession of air waves all along the line of the flash, reaching the ear as a prolonged growl or roar, or as a sharp, rattling explosion, according to the distance from the observer and to the direction of the flash.

"The sound is prolonged by the echoes from the earth's surface and hills, or from the clouds."

The water in the atmosphere, no doubt, has a great influence on lightning and storms. It is found that clouds are always charged with positive electricity, but during heavy rains negative electricity has been observed.

It is supposed that the electricity is first developed or generated on the molecules of water as they condense from vapour, and combine to form clouds; as there are billions of billions of molecules in one drop of rain, we can more easily account for the accumulation of electricity in the atmosphere.

Thus water existing as vapour in the atmosphere and in the ascending currents plays an important part in the formation of thunderstorms; for it is stated that where the climate is dry and rainless, like that of Jerusalem in summer, thunder is unknown.

Before a great thunderstorm, the lower air is usually at an abnormal temperature and fully saturated with water vapour.

Drops of rain are often individually electrified to a very high potential, as is proved by the frequent occurrence of "luminous rain," where the ground is feebly lit by a multitude of tiny sparks given out by the drops as they come near it. Flakes of snow are also at times strongly electrified.

We have already seen how an ordinary fall of rain purifies the air. The rain and thunderstorm combined not only purify it by washing out the impurities, but freshen it, storing it with ozone.

The electricity present in the air is at its maximum twice a day—in the morning and again a little after sunset. In the evaporation of water electricity is evolved, and the friction caused by the particles of watery vapour driven by the wind also adds to its accumulation. The speed of lightning is about 290,000 miles per second, or half as fast again as the velocity of light.

Lightning is of four different kinds, viz. forked, sheet, summer, and ball or globular. The first three are common; the latter fortunately rare, as it is very dangerous.

Sheet lightning is unaccompanied by thunder, and is the reflection from the vapour and clouds of ordinary lightning occurring at a considerable distance below the horizon.

The ball or globular form moves more slowly than the others, and when it comes in contact with any object

Mrs Aubrey Le Blond.

ON THE MATTERHORN—THE WAY BLOCKED BY MIST.

Mrs Aubrey Le Blond.

ABOVE THE FOG AND MIST, 12,000 FEET ABOVE SEA.

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it explodes with a loud report, sometimes doing much damage.

The distance of the storm may be gauged accurately. Sound travels at the rate of 1120 feet in a second, in air of ordinary temperature; so when we hear the thunder five seconds after the flash of lightning, we know it is about one mile distant.

Here, again, water forms a factor for consideration. Sound is more audible and will travel further in damp than in dry air; a sound that could not be heard in dry weather could be heard distinctly in damp air.

Thunder can be heard at a distance of 30 miles; an explosion at 100. The firing at Waterloo was heard at Dover. The eruption at Krakatoa was heard at Rodriguez, in the Indian Ocean, 3000 miles away, the sound taking four hours to reach this point. The air waves propagated by the disturbance travelled round the whole globe seven times with the same velocity as the sound waves, taking thirty-six hours to complete each circuit.

Before leaving this subject, I cannot refrain from referring to the dread that some people have of thunderstorms. The loss of life from lightning is, indeed, small compared with that caused by storms of wind and the havoc they play around our coasts, though they are not dreaded nearly so much, at least by those on land, as thunderstorms. I have known many instances where even adults were prostrated with fear during a storm.

This fear is really the outcome of ignorance, combined with superstition handed down from generations.

The poet Cowper may have had this in mind when he wrote:—

> "Ye fearful saints, fresh courage take,
> The clouds ye so much dread
> Are big with mercy, and shall break
> With blessings on your head."

We also find, in Longfellow's *Golden Legend*—

"I hear the thunder
Mutter its curses in the air;
The devil's own and only prayer."

If those who fear would only seek to know more of the wonders of the heavens, instead of calling to mind the superstitions of dark ages, there would be less fear. I remember only too well being told when a child that thunder was the voice of God speaking in anger; it was also supposed to be the forerunner of the last awful day. Then followed the shutting or opening of windows, covering of looking-glasses, removal of fire-irons, etc., to the basement. I have even seen adults, who should have known better, sit with their heads buried in pillows, with eyes covered and ears stopped. Such conduct is in itself enough to frighten any sensitive child.

Lightning certainly causes death; so does the innocent orange peel. In fact, loss of life from lightning is so small, that the possibility of danger may be altogether overlooked, and the heavenly display enjoyed without fear.

The study of nature's wonders, which is becoming general in our more enlightened times, enables us to regard with reverent enjoyment spectacles which in bygone days were sources only of superstitious terror.

There is no doubt that many people have a genuine fear of a thunderstorm without knowing why. I can only assure them they will be well repaid by bravely trying to admire this most sublime of nature's wonderful displays.

Waterspouts

We all have a vague idea what a "waterspout" is; but few of us have seen one. The dark spiral or tapering column of cloud reaching down from the heavens, usually over the

Mrs Aubrey Le Blond.

THE ALPS FROM BELALP, AFTER A STORM.

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sea, and more rarely on land, is caused by a whirlwind which is itself caused by two currents of air being impelled obliquely against one another and producing a whirling motion. These two currents of air are usually of different temperatures, causing the condensation of a considerable amount of vapour, and producing heavy black clouds.

When a waterspout occurs over a large body of water, its motion forms a conical column of vapour reaching nearly down to the surface of the water, which is much agitated, and it appears as if the sea is being sucked up. This has been proved not to be the case, as the water falling from the waterspout on the deck of a vessel is fresh.

Sometimes it travels over the land, and falls to the ground with considerable force, making excavations in the surface. The chief danger to shipping is from the violence of the gusts of wind, though, should the waterspout strike the vessel, which very seldom occurs, the effect is very disastrous.

Rainbows

"Meantime, refracted from yon eastern cloud,
Bestriding earth, the grand ethereal bow
Shoots up immense; and every hue unfolds
In fair proportion, running from the red
To where the violet fades into the sky.
Here, awful Newton, the dissolving clouds
Form, fronting on the sun, thy showery prism."

JAMES THOMSON.

Rainbows are the result of certain modifications which light undergoes by reflection, refraction, etc., from drops of rain and vapour, forming it into a bow or arc of a circle, in which all the prismatic colours are shown, the radius of the red bow being nearly 42°.

A rainbow can only occur when rain is falling from clouds opposite the sun while it is shining. The elevation of the bow depends upon the altitude of the sun. The rays strike the falling drops of rain and are refracted as they issue into the air.

If the sun be on the horizon, it will form a complete semicircle; if the sun be at an altitude of 42°, the bow will be so depressed as to be hardly visible; with the sun at a greater altitude, the bow will be invisible, being beneath the horizon; therefore, if the observer be on a mountain top, it is possible to see a complete circle.

A perfect rainbow has two concentric arches, the inner (primary) and the outer (secondary), each formed of the colours of the solar spectrum, but arranged in the reverse order, the radius of the violet in the secondary bow being almost exactly 54°.

When a broken bow is seen, it is caused by the absence of falling rain at the missing portion of the bow.

The manner in which the rays of light strike the spherical surfaces of the individual drops of rain, or spray of waterfall, etc., and issue from them, forming this most interesting phenomenon, is beyond the scope of our story.

On more than one occasion the writer has succeeded in making small portions of a bow in the simple process of watering a tennis court with the garden hose. The display was certainly feeble, but nevertheless interesting.

Halos, etc.

"The moon thro' banks of clouds unseen,
The glimmering streaks of light between."

Halos, coronæ, aureolas, parhelia, and other phenomena of this kind, are the names given to the coloured circles sometimes seen round the sun or moon.

These optical phenomena are all more or less due to the same cause as the rainbow, that is, the interference of the rays of light by minute globules of vapour, rain, or minute crystals of snow, as in a cirrus cloud. When rays of light pass through these a halo is formed.

When the light of either sun or moon passes through fleecy clouds or globules of vapour, a corona is formed, varying in accordance with the size of the globules. When the constituent circles of a halo intersect, and an image of the sun or moon appears, this is called a mock-sun or a mock-moon, or parhelion and paraselene respectively. These images are often tinted with prismatic colours, as described by Professor Tyndall after an ascent of Monte Rosa. "I looked upwards," he says, "and saw a most gorgeous exhibition of interference colours. A light veil of clouds had drawn itself between me and the sun, and this was flooded with the most brilliant dyes. Orange, red, green, blue—all the hues produced by diffraction were exhibited in the utmost splendour."

Anthelia are luminous rings, seen generally in Alpine and Arctic regions, opposite the rising or setting sun; they are also due to the diffraction of light.

Aurora Borealis

The aurora as seen in the Polar regions is one of the most interesting and beautiful sights it is possible for us to imagine. It is considered by some to be of luminous meteoric origin, caused by clouds of meteoric dust coming into contact with our atmosphere; but the more general opinion is that it is caused solely by electrical discharges in highly rarefied air, or in stellar space, and is not due to any of the forms of water. But as some doubt exists as to its real origin, I take this as an excuse for devoting a few lines to the subject. The same phenomenon is seen in equal, if not greater, splendour in the South Polar regions, where, however, it is called Aurora Australis.

It is supposed to be caused by positive and negative electricity emanating from the sun, which, coming into the earth's magnetic field in the upper air, is attracted to the Poles, discharging with a light similar to that emitted by an X-ray tube.

The rays of the aurora have been known to reach the earth. Sir W. R. Grove saw the rays between himself and the houses, and other observers have had similar experiences; but all altitudes up to 1000 miles have been given by various observers.

If electricity be passed through rarefied air it exhibits a diffused luminous stream of light characteristic of the aurora, and magnetic storms are usually apparent in connection with the display, accompanied by a noise like the rustling of silk.

Although it is only in the regions more nearly approaching the Poles that this phenomenon is usually seen, yet it is occasionally visible even in the south of England. In November 1905 the "northern lights" were seen as far south as Kent.

There had been a fairly low temperature all day, with hail at places (London), and snow was also reported in many parts of the country.

About 6 P.M. the sky to the north appeared to be covered with huge banks of vivid pink clouds, with shafts or streamers of paler light running up and down every few seconds. The colour of the sky deepened to a flame red, then slowly faded away. In many parts it was thought, by those who had never before seen the aurora, to be the reflection of a large fire.

About 8.30 it reappeared, the sky presenting a glorious spectacle, irregular clouds of a rich pink colour being clearly visible even in the bright moonlight, which was illuminating white fleecy clouds that filled the sky.

This is supposed to have been the most vivid display ever seen in England, and those who saw it should indeed be congratulated, for it was a rare sight.

What this display is like in the northern climes we can only wonder. I have nowhere seen a better description than that given in one of my old school-books:—

"Darkness broods over the Polar world; no object can be seen moving over the wide expanse of frozen sea.

"Suddenly from east to west appears a beautiful arch of living gold. The lights dart to and fro, their colours rivalling those of the rainbow. Beyond the arch a stream of golden rays shoots up far above the rest, and the stars are obscured as 'the merrie dancers' sweep along in waves of light.

"There is something surpassingly beautiful in the appearance of the true 'auroral curtain' fringed with coloured streamers: it waves to and fro as if shaken by some unseen hand.

"Then from end to end there passes a succession of undulations, and the curtain seems to wave in a series of graceful curves.

"Suddenly, as it were by magic, there succeeds a perfect stillness, as if the unseen power which had been displaying the varied beauties of the auroral curtain were resting for a moment. But even while the motion of the curtain is stilled, we see the ultimate waxing and waning of its mysterious light, and the noble span of the auroral arch, from which the waving curtain seems to hang, gives a grandeur to the spectacle which no words can adequately describe."

Stalactites and Stalagmites

These interesting products of the work of water claim a place in our study; for the knowledge gained in an endeavour to follow the manner of their formation will help us to understand many other curious works that water, in a similar manner, performs, but producing different, though not less interesting results.

We have seen that pure or distilled water, like rain, readily absorbs, in various proportions, every gas with which it comes into contact. The most prominent of all is carbonic acid, without which there would be no stalactites. Water at 60° will absorb its own volume of this gas.

Under normal conditions of temperature and pressure, 100 volumes of water dissolve 1·48 volumes of nitrogen, 2·99 volumes of oxygen, and 100·2 of carbonic acid, besides ammonia.

This explains the manner in which the rain, originally pure, becomes laden with such impurities as will enable it to attack the rocks and to pick up matter in solution; carry it and deposit it as stalactites, and many other interesting forms, a few only of which we shall be able to describe. It is solely by the dissolving and removal of solid matter, by the aid of water, that underground channels, caves, etc., are formed in the solid rocks.

Stalactite Caves

In the boiling of water there is an escape of the free and loosely combined acid, and the carbonate of lime is deposited, forming a "crust" on the inside of the kettle; and when the water is sufficiently concentrated by evaporation, the sulphate is likewise partly deposited. The decomposition of the "bicarbonate," in fact, takes place, though slowly, even at ordinary temperatures, where the water in which it is held in solution is exposed to the atmosphere. It is in this manner that the stalactites are formed.

Stalactites consist of a semi-crystalline deposit, usually of a conical or cylindrical form, found in caves of the limestone rocks. They are formed by water percolating through the rock becoming charged with carbonate of lime, which is held in solution by free carbonic acid gas, which the water gathers from the air and soil. When the water reaches the roof of the cavern, from which it drips, the gas escapes and so deposits the carbonate of lime in the form of icicle-like pendants from the roof.

If the deposit be formed on the floor of the cavern the shape is reversed, and pinnacles of this calcareous rock are formed. These are called stalagmites. They sometimes rise into columns, meeting and blending with the stalactites above.

The rate of the accumulation of the stalactite and stalagmite in caves varies. In the Ingleborough Cavern a stalactite measured in 1839, and again in 1873, was found to have grown at the rate of ·2946 inch per annum. The rate of growth varies with the amount of percolation and the presence of varying currents of air.

These may be seen in the caves of the Rock of Gibraltar, the grottos of Demoiselles, Arcy, and the Mammoth Cave of Kentucky: this cave has been penetrated to a distance of 14 miles. There is also at Buxton, in Derbyshire, a stalactite cavern of considerable size, called Poole's Hole. Kent's Hole, Torquay, has also a cave of this description. A short description of the Adelsberg Cavern will be of interest.

The grottos of Adelsberg are situated about 1 mile from the market town of that name, in the province of Carniola, Austria.

The cavern was known in the Middle Ages, but remained undiscovered in modern times until 1816. The grottos are of enormous extent, and fully 2½ hours are occupied in traversing them. The most extended of the ramifications cover a distance of over 2 miles, and consist of a succession of stalagmite and stalactite chambers.

The temperature of this cavern is 48° F. The river Poik flows into it some considerable distance, disappearing into a subterranean passage, reappearing again lower down under the name of Unz, only again to travel through another stalactite grotto.

The largest grotto is the Franz Josef Elizabeth, which is 665 feet long, 640 feet wide, and 100 feet high.

One of the grottos in this renowned cavern is called the Cathedral, 72 feet high and 158 feet broad. From this a staircase of 85 steps leads into the grotto called the Ballroom, 150 feet long, 90 feet wide, 45 feet high, which is illuminated every Whit-Monday, on which day the annual ball is held.

There are many other remarkable grottos in this cave, in which are statues, curtains, calvarys or crosses, columns, and innumerable figures, all of natural stalactites and stalagmites.

There are grand illuminations of the interior of this cavern on certain days. Those who have been fortunate enough to visit the grottos on these occasions, pronounce the sight most impressive, and one not easily to be forgotten.

In Manville Fenn's *Life of G. A. Henty*, we read that immediately below the entrance to the Adelsberg Cavern a stream plunges into the earth, reappearing 10 miles distant to the north. A piece of cork thrown into the water does not emerge for twelve hours; and it is stated that this points to the fact that the underground ramification of the stream must extend at least double that distance.

In the same volume it is stated that in Carniola "rivers of navigable size and depth issue from its mountains—rivers which far surpass the subterranean streams of

Central France—and these, after running for a few miles, enter a cavern and lose themselves as mysteriously as they appeared."

Nature's work in this direction is nowhere displayed so marvellously or in such gigantic proportions as in the Mammoth Cave in Kentucky, U.S.A., which was discovered by a hunter named Hutchings, in 1809. Its entrance is in a forest ravine 600 feet above the sea. The Main Cave is 40 to 300 feet wide, 35 to 125 feet high, 4 miles long.

The whole cavern and its innumerable winding passages cover an area having a diameter of 10 miles, containing about 150 miles of accessible avenues, cataracts of falling water 250 feet high, lofty domes 300 feet high, pits 190 feet deep. There is a wealth of crystal flowers, ferns, canopies of fleecy clouds, and cascades of great volume. Some of the underground streams are impassable for seven months of the year; and one of them, like the Poik, disappears into the bowels of the earth. The Mammoth Cave also contains extensive lakes. One called the Styx is 40 feet wide and 400 feet long. The temperature is 54° F., and the whole scene is really beyond description.

The Luray Cavern, Virginia, U.S.A., is also of enormous extent, containing innumerable grottos, corridors, halls, avenues, etc.; draped stalactite columns up to 50 feet high, some 30 feet in diameter, some snowy white and others pink, blue, and amber in colour. It contains no stream, but has hundreds of little lakes varying up to 50 feet in diameter and from 6 inches to 15 feet deep.

It is indeed a wonderful work of nature—cathedrals, chasms, vales, balconies, bridges, cascades 40 feet high by 30 feet wide, with cataracts of milk-white, alabaster-like cascades, every ripple of polished carbonate of lime deposited by the water.

Its area covers 100 acres, but there are several tiers of galleries, the vertical depth between the highest and lowest of which is 200 feet. The temperature of the cave is uniformly 54° F., similar to that of the Mammoth Cave, Kentucky. It is visited by 12,000 people per annum.

The river Garonne is a notable example of a disappearing river. It rises in Spain on the slopes of the Pyrenees, and is fed by snow and ice waters of the Pic Nethou. It is, however, swallowed up by a sink-hole known as Trou de Taureau, reappearing 2½ miles lower as a gushing spring at the hill of Castellon.

There is a wonderful cave in Somaliland, situate about 30 miles south of Guinea. Here the river Web has carved for itself a superb underground palace, as it dashes through a mountain of quartz.

"It seemed," says Dr A. D. Smith, "as if nature had confined herself to human ideas of the grand and the beautiful in this work, so regular and ornate were her designs. Passing columns and arches and altars of apparently the whitest marble, the clear water disappeared into the dark recesses of a pillared temple. I can give you," he says, "no idea of how ornate the columns were, with their beautiful capitals and splendid bases, or of the magnitude of the subterranean chambers."

Coming nearer home, we have in Belgium, 70 miles south of Brussels, the vast limestone caves of Wamme, Rochefort, Han, and Eprave; also the subterranean river Lomme, which disappears in the Rochefort Grotto and reappears in the cave of Eprave. The caves of Rochefort take some two hours to traverse: the principal chamber is the Salle du Sabbat, nearly 300 feet high, draped with stalactites.

The caverns of Han are of considerable extent, consisting of galleries at various levels, leading to many large chambers,

CAVERNS OF HAN, SALLE D'EMBARQUEMENT.

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some decorated with stalactites: the largest, the Salle du Dome, has no stalactites. It is 500 feet long, 450 feet wide, and is about 180 feet above the river Lesse, which traverses it. The visitors can also descend to the cavern Salle d'Embarquement, on the Lesse, where they enter a boat and are rowed out of the cave. The illustration of this interesting chamber and subterranean river was kindly given by Director Monsieur E. de Pierpont.

In the caves near Enniskillen (Ireland), of which the marble arch is the most important, three rivers disappear suddenly into three holes, and by erosion and corrosion these underground rivers have enlarged the fissures in the rocks, forming them into magnificent galleries of considerable area and length.

Near Gort, 1½ miles east of Kiltarton (Ireland), is a river which disappears into the earth and goes no one knows where.

Peak Cavern (Derbyshire) is also a subterranean river course.

The Manifold, in Staffordshire, also disappears into the earth, through which it flows a distance of 3 miles.

Bagshaw Cave, at Bradwell, discovered in 1806 by miners who were in search of lead, is also traversed by a river which may be from 1 mile to 2 miles long. It is the torrent of Bagshaw Cave that feeds the source of the river Bradwell.

In Yorkshire (Ingleborough) we have the cave of Gaping Ghyll, which engulfs the large stream of Fell Beck, which has a perpendicular fall of 300 feet into an abyss. At a depth of 210 feet a large pipe, varying in diameter from 13 to 29 feet, opens in the vault of an immense subterranean hall 480 feet long, 70 to 110 feet wide, and 80 to 100 feet high. Here the waters have excavated a reservoir of 100,000 cubic yards' capacity, as well as about half a mile of galleries. This stream comes out three-quarters of a mile further on, through the grotto of Ingleborough.

A hole still deeper than Gaping Ghyll is Rowten Pot in Kingsdale, described by and first descended by Cuttriss in July 1897 (*Geographical Journal*, xiv.). "About 100 feet from the surface a natural bridge spans the gulley; while at 235 feet, after two waterfalls have been passed, the bottom of the main chasm is reached. Lower down other waterfalls occur; while the lowest point of all, 365 feet below the surface, and more than 20 feet below the bottom of the valley itself, is reached by winding passages. The whole undertaking occupied over 14 hours."

These cavities, which are found all over the earth, and are not at all uncommon, are no doubt formed by the action of water continually removing soluble matter.

It is to this action that many chemically formed rocks owe their origin, including travertine, gypsum, siliceous tufa as deposited by the hot springs, selenite, rock salt, and many others.

Salt

The formation of salt is essentially the work of water, by which it has been deposited.

Chloride of sodium (common salt) exists in great quantities, dissolved in sea-water, in salt springs, and in the solid deposits of past ages. This last is known as rock salt. When rock salt is flooded the resulting solution is termed brine. When common salt is obtained from sea-water by evaporation it is called bay salt.

Under the headings of sea and lakes we shall see how fresh waters become salt, a process which is going on day by day through the continual evaporation of the water, leaving the saline particles behind.

The enormous deposit of marine salt, to which we shall refer presently, belongs to the Keuper or Saliferous Period, so named from the salt deposits it contains, which can only be attributed to the enormous quantities of sea-water, which, by the convulsions of nature, became separated from the oceans, then evaporated, again flooded, and yet again separated and evaporated. Hence the various layers of salt between alternate layers of clay as we now find them.

What food for thought is here! All the work of water, absorbing the saline properties from the soil on which it has fallen as rain, carrying them into the lakes and sea by the streams and rivers, where, by the silting up of their outlets, lagoons are formed ; then the water is evaporated, leaving behind the salt, which by convulsion and upheaval is buried and preserved for our use.

Chloride of sodium (common salt) is fortunately one of the most widely distributed, as well as one of the most useful and absolutely necessary, of nature's gifts ; and it is a matter of much comfort to know that this mineral exists in such enormous quantities that it can never be exhausted.

"Had not," says Dr Buckland, "the beneficent providence of the Creator laid up these stores of salt within the bowels of the earth, the distance of inland countries from the sea would have rendered this article of prime and daily necessity unattainable to a large proportion of mankind; but under the existing dispensation, the presence of mineral salt, in strata which are dispersed generally over the interior of our continents and larger islands, is a source of health and daily enjoyment to the inhabitants of almost every region."

Even supposing that the whole of the mines, brine pits, and springs become exhausted, we can fall back on the sea, whose supply is as boundless as its restless self ; and there is as little fear of its exhaustion as there is of the failure of the sun's heat.

The salts contained in sea-water, which causes its bitter, unpleasant taste, form about 3½ per cent. of its weight, and consist principally of common table salt, as will be seen from the following analysis of the mineral constituents of sea-water:—

	Per cent.
Chloride of sodium (common salt) .	75·786
„ magnesium . . .	9·159
„ potassium . . .	3·657
Sulphate of lime (gypsum) . . .	4·617
„ magnesium (Epsom salts) .	5·597
Bromide of sodium	1·184
	100·000

The residue from evaporated sea-water, after the common salt has been taken from it, is used in the preparation of Epsom salts (sulphate of magnesium), Glauber's salt (sulphate of soda), etc.

Sodium is the metal of which soda is the oxide. It is more abundant on our globe than any other metal, and constitutes two-fifths of all sea salt.

Salt-gathering forms one of the oldest of our industries. For over 1000 years it has been the staple industry of Droitwich, and it is little wonder that subsidences in the overlying rocks occur, with streets of tottering houses, commonly seen in the neighbourhood of these salt-works, so enormous has been the quantity of the brine pumped up, and salt obtained.

Where it is found as rock salt, it is purified by dissolving it in water and then evaporating the solution in shallow pans by artificial heat, leaving the salt crystals. Saturated solutions do not boil at 100° C.

Water, when saturated with salt, boils at . .	109° C.
„ „ nitre, „ . .	115·6° C.
„ „ potassic carbonate, boils at	140° C.

The temperature at which a saline solution boils will determine the proportion of salt present.

Generally it may be taken that all salt to be used in connection with human food is obtained from brine, and rock salt is the kind generally used for various agricultural and manufacturing purposes.

The top of the rock salt at Northwich is only 130 feet below the surface, and the deposit varies in thickness to about 200 feet at Winsford.

The beds in Cheshire and the neighbourhood cover an area of 20 miles long by 15 miles wide, and the deposit is estimated at 150 feet thick.

At Hartlepool the salt beds are from 800 to 1600 feet below the surface. The chances of this salt ever being required for use are very remote.

Northwich, in Cheshire, provides us with about 1¼ million tons of salt per annum. Here, after passing through about 130 feet of soil and rock, we come to a bed of rock salt 75 feet thick, at the base of which there is another bed 30 feet thick; and beneath this there lies a third bed 90 feet thick. Here there has been excavated an enormous chamber, 17 acres in extent and 25 feet high, the roof being supported by pillars of salt about 10 feet square, at intervals of about 25 yards.

The principal supply, however, is obtained from brine springs. About 10,000,000 tons of brine are pumped annually, from which are obtained over 2,000,000 tons of salt.

One gallon of Cheshire brine fully saturated yields 2½ lbs. of salt; while sea-water rarely contains more than ¼ lb. This salt is also much purer than salt from the sea.

In Saxon times a place where salt was dug was called a "wich"; hence Droitwich, Nantwich, Northwich, Middle-wich. This fact alone reminds us of the antiquity of the industry.

The revenue of the salt mines was one of the chief sources of income to Worcester Cathedral in 816 A.D., when Kenulph, king of the Mercians, gave ten houses at Wich, with the salt furnaces; and in 906 A.D. five more were given to this same church.

In the evaporation of brine, if fine table salt is being obtained, a temperature of 226° F. (the boiling point of brine) is required. For the manufacture of coarser-grained salt, called "fish salt," the brine is only heated to 110° F., the evaporation being slower. The salt is then deposited in larger crystals.

In the year 1900, 547,395 tons of salt, valued at £457,340, were exported from Great Britain; and of the amount consumed at home it is estimated that at least 200,000 tons are used for manufacturing purposes and manure; in the former case for glazing pottery, hardening soap, and the manufacture of glass.

Salt is also the source of soda and chlorine, and is largely used for fertilising the soil and for the manufacture of artificial ice.

In England it is found in great abundance in Cheshire, Yorkshire, and Worcestershire.

In the Sahara Desert there is an oasis called Bilma, where it is said that there are large deposits of salt.

On the south-west coast of the Dead Sea is a range of hills of rock salt 7 miles long, 300 feet high, called Khashm Usdom, "The Ridge of Sodom."

Large quantities are found in New York, Pennsylvania, and Würtemberg.

The salt mines of Wielicza, in Galicia, Austria, are but a little depth below the surface.

These are the most celebrated mines in the world, and have been worked continuously for 600 years. The mass of salt is calculated to be 500 miles long, 20 miles broad, and 1200 feet thick. The galleries and chambers in this mine extend to 30 miles, yielding 55,000 tons per annum.

In Cardona (Barcelona) there is a hill of rock salt 500 feet high, the appearance of which in the sunlight is of dazzling brightness.

Near Kalabagh (India), on the Indus, are hills and cliffs of solid rock salt which are extensively quarried.

Schönebeck, on the Elbe, is also an important salt-mining centre.

In Michigan, U.S.A., salt of great purity occurs; the basin containing the same covers an area of 8000 square miles.

Salt is produced in large quantities in Ohio, U.S.A. The brine of the Tuscarawas valley yields 1·lb. of bromine to 1 barrel of salt. Half the bromine of the world is produced in Ohio.

In Nevada, U.S.A., we have the salt lakes Walker, Carson, and Pyramid. Here the mineral abounds, and is of great purity.

In Reichenhall (Bavaria) are most important salt-works, the mineral being obtained from brine springs. Similar salt springs abound in Jura, east of France, bordering on Switzerland.

In Gironde (France) salt is obtained from lagoons. In the south of France we have also Aigues Mortes (dead waters), a small town near the mouth of the Rhone, where a considerable amount is obtained from lagoons.

In Anegada, the most northern group of the British West Indian Islands, salt is obtained from numerous salt ponds.

These few instances will give us some idea of the universal distribution of salt, and the enormous quantities in which it is found.

CHAPTER VII

SNOW

Snowflakes

"Out of the bosom of the air,
  Out of the cloud-folds of her garment shaken,
Over the woodlands brown and bare,
  Over the harvest-fields forsaken,
Silent, and soft, and slow,
Descends the snow."

LONGFELLOW.

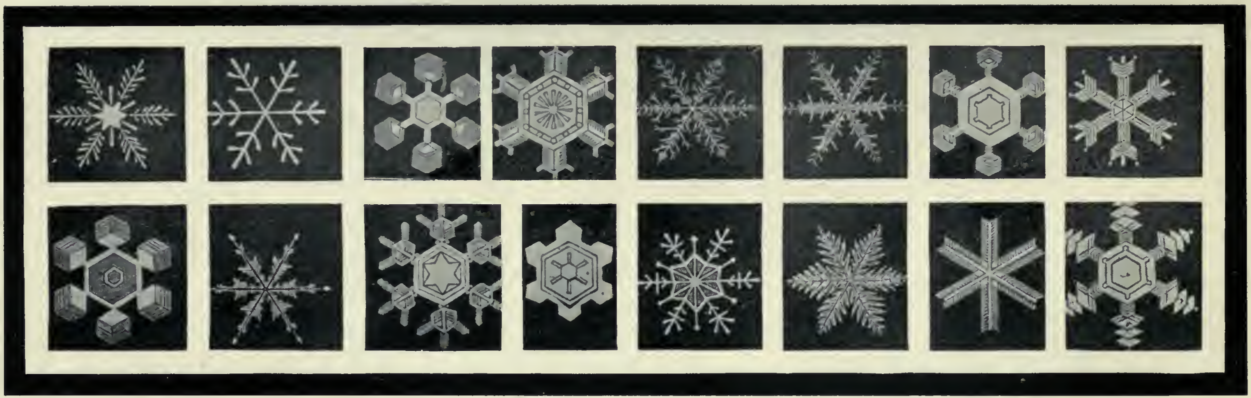
We have, in the preceding chapters, given some attention to the several forms in which the moisture in the atmosphere is precipitated, both in its liquid and solid forms. We have, however, singled out that most beautiful form, snow, for special consideration.

How Snow is Formed

Snowflakes are assemblages of minute crystals of ice formed from the aqueous vapour in the atmosphere. As we ascend from the earth the atmosphere becomes colder, until freezing point is reached.

The aqueous vapour in the air can no longer be retained as such, but is condensed and clouds are formed, which ultimately become ice, in the form of snowflakes.

Snowflakes vary in size from one-fourteenth of an inch to 1 inch in diameter. The smaller ones are found when the temperature is very low, but the larger not until it is near 32° F.



SNOW CRYSTALS.

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We frequently hear mention of *Protoccus nivalis* (red snow). Darwin mentions having seen it in his passage of the Cordillera. The footsteps of the mules, he states, were stained pale red, as if their hoofs had been slightly bloody, the snow being coloured only where it had thawed very rapidly, or had been accidentally crushed. A little rubbed on paper gave it a faint rose tinge. He at first thought it was dust blown from the surrounding mountains of red porphyry. This was not so, for the colour is due to the presence of a genus of algæ which appears on the surface of snow. Extensive tracts, both in the Arctic and Alpine regions, are in a short time frequently tinged deep crimson by this minute plant, which consists of groups of microscopic spheres, in colourless cases, each $\frac{1}{1000}$ part of an inch in diameter.

Snow Crystals

"From the clouds to earth nature was busy marshalling her atoms, and putting to shame by the beauty of her structures the comparative barbarities of art."—TYNDALL.

When produced in calm, cold air, these icy particles form beautiful stellar shapes, each star having six rays. There is no deviation from this hexagonal shape. The clear spicules of ice always cross at an angle of 60°, usually forming six rays arranged symmetrically about a centre. The flakes have great diversities of density and display innumerable varieties of the most beautiful forms.

As will be seen in the illustration, though they vary in figure, the six rays are common to all; it will also give an idea of the beautiful forms these stellar figures take.

During a fall of snow there will be a strong similarity in the forms of the crystals, varying with the different storms; and we can but admire the inimitable delicacy and beauty of nature's handiwork in their formation.

"Let us imagine," says Professor Tyndall, "the eye gifted with a microscopic power sufficient to enable it to see the molecules which composed these starry crystals; to observe the solid nucleus formed and floating in the air; to see it drawing towards it its allied atoms, and these arranging themselves as if they moved to music, and ended by rendering that music concrete."

He also refers to these beautiful stellar forms in his account of an ascent of Monte Rosa in 1858: "Some snow fell upon my hat; it was, in fact, a shower of frozen flowers. All of them were six-leaved. Some of the leaves threw out lateral ribs like ferns; some were rounded, others arrowy and serrated; some were close, others reticulated; but there was no deviation from the six-leaved type. It was wonderful to think of, as well as beautiful to behold.

"And thus prodigal nature rained down beauty, and had done so here for ages unseen by man."

Professor Tyndall draws attention to the fact that snow crystals differ from ice-flowers; the former being "crystallised," the latter the result of breaking down or "decrystallisation" of the ice.

Transparency of Snow

"As white as snow" is a common expression; but snow is colourless; its apparent whiteness is produced by the reflection and refraction of light from the minute surfaces of the crystals.

When a snowflake is examined under a microscope, it will be found to consist of perfectly clear, transparent ice.

There is no prettier sight in nature than that of a fall of snow. Every branch and twig, every obstacle it meets in falling, is enveloped in its feathery flakes: even the trees bow their heads under the weight of their snowy burden.

Mrs Aubrey Le Blond.

CRYSTALLIZED SNOW.

Mrs Aubrey Le Blond.

A STUDY OF SNOW IN DETAIL, TAKEN AT ST MORITZ.

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Even in snow animal life exists, for the small worm Enchytræus lives in it at the temperature of freezing water. It is curious, too, that in northern regions nature, in addition to providing all birds and animals with suitable covering to protect them against severe climatic conditions, also, with the advent of the snow, changes their colour to white as an additional protection from their enemies. Some, of course, wear their white cloaks all the year round, as do the Alaskan wild sheep, Polar bear, etc.; but the mountain hare, willow grouse, ptarmigan, ermine, Arctic fox, and many others, change to white only during the winter.

This interesting phenomenon can be seen in our Zoological Gardens. An observer referring to this writes, (28th December 1906):—

"What do the animals in Regent's Park Gardens think of an English winter, with its interesting surprises and absolute uncertainty of mood? To most of them it is probably a sore subject. It interferes with the seasonal changes of colour in many of them.

"The poor little Arctic foxes, for instance, when we had a cold snap last November, hurriedly began to drop their fine blue summer suits and get into the white livery they ought to wear at the year's end. Then it turned warm when December came, and the change in their fur stopped responsively, and so went on by fits and starts in a most inconvenient and unbecoming manner. The weasels, too, who turn white down to the tips of their tails in winter, like some of their betters, never know what to wear in the between-times of English seasons; and only a few of the most strong-minded of those who dress according to the equinoxes are courageous enough to get into cold weather trim when the proper time comes, whatever may happen to the thermometer."

A curious instance of change in colour has occurred in one of my own fowls. The bird is one from a brood of a first cross between a fine strain of Indian game and Houdans. The chicks were all uniformly black, but during the first year one of them became speckled black and white all over, without changing feathers. Next year she changed to pure white all over, during the summer; and now she has once more become spotted black and white in nearly equal proportions. All the others of the same brood have remained consistently black.

Snow as a Conductor

Snow is a bad conductor of heat, and is therefore a suitable substance for use when we wish to resist external changes of temperature. When snow throws its mantle over the land it protects vegetation from the cold blasts of winter and so preserves it. The Esquimaux of Greenland defy the icy blasts of the Arctic regions by retiring to huts built of snow and ice.

It is probably not within common knowledge that at the approach of winter the female Polar bear retires to some sunny recess among the rocks, but not merely to sleep through the cold months. The snow covers her completely many feet deep, leaving no trace of her whereabouts; but the warmth of her body keeps clear a small space in which she may move freely, and in this space her young are born and remain with their mother, protected by a mantle of snow, until the spring comes and releases them.

A fresh fall of snow from 10 to 12 inches deep, when melted and measured in a rain-gauge, has been found by the writer to yield a quantity of water equal to a fall of 1 inch of rain. This confirms the results given by others who have made similar tests.

The water derived from old snow, however, is considerably more. Sometimes 4 inches of old snow will yield 1 inch of water.

It is found that snow of average density offers four times greater resistance to external changes of temperature than does ice of equal thickness, and that independently of its peculiar property of retaining radiant heat. This affords a measure of the protective power of a snow-covering to the surface on which it rests.

The comparison of the thickness of the snow-covering with the amount of precipitation gives as a mean result 10 inches snow = 1 inch rain. The temperature observations show that while the minimum temperature on the surface of the earth, under a thin layer of snow, is considerably lower than that of the air, on account of radiation, the snow is in general warmer than the air; and that while a thin coating of snow reduces the temperature of the soil at the surface, a covering of 12 to 16 inches thick affords great protection.

It has been ascertained by experiment that during the whole winter the temperature 4 inches below the surface of the snow-covered soil never fell to the freezing point, while on ground kept clear of snow it was below freezing from 31st January to 1st April at a depth of 19½ inches.

The specific gravity of newly fallen snow ranges from 0·038 at low temperature to 0·161 under humid conditions; and on a hard crust being formed by melting it, it rises to 0·489.

Impurity of Snow

The benefits we derive from a fall of snow are far greater than we casually imagine. It has been called "health-giving snow," and such it is. Its purifying effect upon the air as it falls is said to be greater than if the same quantity had fallen in the form of rain.

"Probably," says the *Lancet*, "when the snowflakes are absolutely dry, they would fall to earth practically unsullied by atmospheric impurities. It is rarely, however, that snow is quite dry, and thus it presents a more or less moist surface to both the soluble and suspended impurities of the air, and so carries them to the earth. The action as regards impurities may be compared with the clarifying effect of a fine, insoluble powder, which, when thrown into impure water, gradually subsides, carrying with it a large amount of the impurities. The process in natural waters is known as purification by sedimentation. Snow, of course, is colder than rain, and hence would have a greater dissolving capacity for gases, since these are more soluble in cold than in warm menstrua. Tradition has it that after a fall of snow men feel stronger, owing to the exhilarating effects of the snow-swept air. Science, at all events, cannot quarrel with this conclusion, inasmuch as it is easily demonstrable that the air is purer and sweeter after a fall of snow."

Exercise in the snow is remarkably bracing, as is seen in the glow of health invariably shown on the faces of those who sleigh, ski, toboggan, or skate, or whose pastime is the simple one of snowballing. Apart, however, from the removal of impurities by snow, there is some reason for believing that the vital qualities of air are intensified by some obscure action of the snow on the oxygen of the air, forming perhaps ozone, or even oxygenated water, as peroxide of hydrogen is sometimes called. Snow-swept air, at all events, especially if it be dry, readily responds to the ozone test paper, and the peculiar "metallic" smell of the air after a heavy snowfall is doubtless due to ozone or a closely related substance. That the heavy fall of snow

12,000 FEET ABOVE THE SEA.

OFF TOWARDS THE MATTERHORN.

Mrs Aubrey Le Blond.

A CORNICED RIDGE ON AN ENGADINE PEAK.

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which took place in the early hours of the day after Christmas Day 1906, removed a great mass of impurity from the air in London, is plainly indicated in the results of an analysis which was made of the snow taken from the roof of the *Lancet* offices. The results of the analysis of the clear snow-water were as follows:—

	Grains per gallon. London.	Kent.
Free ammonia	0·067	0·030
Organic ammonia . . .	0·039	Nil.
Nitrates and nitrites . . .	Nil.	Nil.
Chlorine	0·840	0·630
Common salt	1·400	1·030
Sulphuric acid	1·730	Nil.
Total solid matters . . .	5·60	1·68
Tarry compounds . . .	1·40	Traces

Hundreds of tons of these impurities—tar, ammonia, and sulphur—must therefore have been brought to earth in London by that snowstorm. The second analysis refers to snow which fell at the same time, but on the lawn of a country garden in Kent, some twelve miles south of the Metropolis (*Daily Telegraph*, 5th Jan. 1907).

Snow-Line

"Mont Blanc is the monarch of mountains,
They crowned him long ago,
On a throne of rocks, in a robe of clouds,
With a diadem of snow."

BYRON (*Manfred*).

Snow-line is the limit of perpetual snow, or the line above which mountains are perpetually covered by snow. Here the snow may evaporate or the sun's rays may melt some of it, but the cloak of snow never disappears. The mountain Kilimanjaro, in Africa, is 19,400 feet high; and though it is but three degrees from the Equator, it keeps its white crown of snow continually, in spite of the tropical sun.

If we travel towards the Pole, the snow-line gradually lowers, until in the chilly Polar regions it is at the sea-level; and here we find the perpetual snow- and ice-fields.

In England the freezing point is in summer 1½ miles from the ground, but in winter the level at which snow is formed often comes down to the surface of the earth.

Many mountains only thrust their heads a little way into the cold regions, and get but a small accumulation of snow in the winter, which generally disappears during the summer: such mountains are therefore said to be below the snow-line.

The distance down a mountain that the snow reaches varies with the seasons.

On the Swiss mountains the snow-line is 8500 feet above sea-level; in the Caucasus 14,000 feet; the Himalayas 16,000 feet to 19,000 feet; at Spitzbergen only 1500 feet.

On the Himalayas the snow-line is from three to four thousand feet higher on the north side than on the south, notwithstanding that this side is nearer the Equator; but the winds that blow upon the south side have passed over the Indian Ocean and are heavily charged with moisture, which is deposited on the southern slopes in the form of snow, while the snow-line on the north side is raised by the hot, dry winds which blow across the plains of Thibet.

As we have seen, the snow-line is subject to slight variation from local circumstances; outside these considerations it depends primarily upon the latitude. Though it may vary from year to year, if an average of many seasons be taken it is tolerably uniform, and varies from the heights given down to nothing; for, as we travel towards

Mrs Aubrey Le Blond.

SNOW-FIELDS, FROM PIZ PALÜ, ENGADINE.

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the Poles, the snow-line gradually lowers until it reaches sea-level.

Mountain snow would accumulate to an enormous thickness were it not for the annual melting and the quantity which disappears in the form of glaciers and avalanches, and, last but not least, by continual evaporation; for snow evaporates even above the snow-line, with the temperature continually below freezing point.

"One very long, dry summer," writes Darwin, "all the snow disappeared from Aconcagua (Central Chili), although it attains the prodigious height of 23,000 feet." And he concludes that it evaporated rather than thawed.

Snowfields

There are permanent fields of snow found on the tops of mountain ranges above the snow-line.

"These vast piles of snow," says Darwin, "which never melt, and seem destined to last as long as the world holds together, present a noble and even sublime spectacle."

The snowfields of Norway are numerous; one, Instedalsbrae, is 580 square miles in area, and reaches an altitude of 5000 feet, sending off numerous glaciers.

The temperature here in the land of mountain snow is different from the cold experienced in the Arctic regions; in the former regions the intense solar radiation by day raises the surface when dry to a temperature of 80° F., alternating with nights of severe frost.

Half-way up the Alps the mean temperature has been found to average 32° F., a height which in snowy regions is never reached.

Even where the temperature is lowest, the solar radiation by rocks and snow is very great, frequently over 120° F. being recorded.

Professor Tyndall describes his experience on Monte Rosa as follows: "There was not a breath of air stirring, and, though we stood ankle-deep in snow, the heat surpassed anything of the kind I had ever felt: it was the dead, suffocating warmth of the interior of an oven which encompassed us on all sides."

On the Himalayas, at an altitude of 15,000 feet, the variation of the temperature in twelve hours (noon to midnight) shows an enormous range. A solar temperature of 157° (32° below boiling point at this altitude) was registered, and at midnight the thermometer fell to 24°.

Among the Nun Kun Peaks, at an altitude of 21,300 feet, about 2.30 P.M., the sun reading of a black-bulb thermometer was 192° F. There was a misty atmosphere, and the heat was only rendered bearable by wrapping wet towels round the head. At 4.30 the shade reading was 60° F. When the sun set at seven o'clock, the temperature fell at once to freezing point, and at nine was nearly zero.

In the Arctic Circle the snowfields are of enormous area and hundreds of feet in depth; they are continually receiving fresh accumulations of snow, which would go on indefinitely but for the reasons stated.

Here we find a low, equable temperature is maintained, rarely rising more than a few degrees above the freezing point. The snow melts to some slight extent during the heat of the summer day, and evaporates to a still greater extent: the snow that remains is granular, owing to the water trickling into its mass and freezing round the crystals.

This alternate freezing and thawing year after year causes the snow to become stratified, the different layers being divided by dirt lines, each of which indicates the previous year's snow, on which the wind has deposited dust, leaves, insects, etc.

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CROSSING A SNOW BRIDGE OVER A CREVASSE (SELLA PASS).

(Showing the stratification due to successive snowfalls, with great definition.)

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This granular mass is the névé or firn; it is not ice, but the beginning of the ice-river or glacier.

Avalanches

Avalanches are large masses of snow or ice detached by heat, etc., from the mountains. They usually occur after a heavy fall of snow in still weather, which enables the snow to collect on the steep sides of the mountain, where, under more boisterous conditions, it would not remain sufficiently long to accumulate; it then overbalances by its own weight, or, loosened by the warm sun, without warning, slides down, bearing with it rocks, trees, etc., overwhelming everything in its path. Valley streams then carry the debris down to the lakes, or on to the sea. In this way the mountain summits mingle with the sediment eroded from the valleys.

It is found that if the rocks lie at an angle of 60°, very little snow can accumulate, and this is soon removed by the wind.

It is because of the perpetual danger from avalanches that many of the beautiful valleys in the mountain regions remain unpeopled.

In 1820, 64 persons were killed in the Engadine (at Fettan), and 400 cattle and 23 persons at Brieg in the same year.

This is only typical of what is continually happening in these snowy regions, and I would refer the reader to the *Adventures on the Roof of the World*, by Mrs Aubrey le Blond, for a graphic description of the sufferings of a family who were buried for a month under an avalanche.

Periodically great devastation is caused by the mighty snow-slips: villages are entirely buried, and forests destroyed.

The sliding avalanches, caused by the melting of the snow nearest the ground detaching the mass from the bed on which it rests, move slowly at first, eventually carrying all before them. These usually occur in the spring of the year: they differ from the loose snow avalanches which are common in the winter, and are the least dangerous.

Avalanches of ice and frozen snow, detached from glaciers by the summer heat, are more serious, and are also of common occurrence.

The velocity of these frozen masses is enormous, and one has been known to descend with such momentum that it ascended 400 feet on the opposite side of the valley.

It is no uncommon thing for an avalanche of snow and ice to dam up rivers, the water eventually finding its way underneath, and the avalanche forming a bridge of ice which sometimes remains many months before completely disappearing.

In some instances the damage done to life and property by the wind set up by the rush of the avalanche exceeds that done by the actual mass of snow; and by this means alone, buildings, trees, cattle, and human beings have been destroyed. One would scarcely believe that the displacement of the atmosphere from this cause could form such violent artificial tornadoes, with such serious results.

It is said that the vibration of a single voice is at times sufficient to start a catastrophe of this kind, and that in some parts the guides insist on perfect silence. It seems indeed terrible that a single exclamation may possibly cause the death of a whole party of tourists.

Avalanches consisting partly of snow, ice, and stones, including huge boulders, are at times hurled down the mountains with great fury, sending clouds of ice-dust high into the air, covering the ground with rough angular stones, fragments of the towering peaks displaced by frost.

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THE REMAINS OF AN AVALANCHE.

Mrs Aubrey Le Blond.

A TRAIN STUCK FAST IN AN AVALANCHE ON ROCHER DE NAYE.

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Floods

Floods are often caused by the sudden melting of the snow on the mountains, owing to a rise in the temperature, when the water rushes down, as in the case of the Ganges, where in the spring the water from the Himalayas overflows and floods the surrounding plains, at times to a great depth.

Some of our rivers overflow their banks and flood the surrounding country for miles, from the same cause, or from an unusually heavy and continuous rainfall. The Thames, for instance, has been in a state of flood several times within the last few years.

Floods are also caused by the bursting of natural reservoirs. The great flood of the Dranse de Bagnes in 1818 was due to the outburst of the lake, which had been dammed back by the glacier Gretroz.

A great portion of Egypt is flooded each autumn by the river Nile; but in this instance it is not a catastrophe, for the greater the flood the greater the prosperity.

The Danube overflowed in 1877, rendering 12,000 persons homeless. The floods of the Loire did damage to the amount of £8,000,000 in the year 1856.

Innumerable instances of similar catastrophes could be given, but bearing in mind only those caused by the melting of the snow, with which this chapter is principally concerned, it is surely something little short of marvellous, that the pretty feathery snowflake, by its accumulation, should be capable of forming such sublime sights, and causing, unfortunately, such devastating havoc and loss of life.

CHAPTER VIII

ICE

From sunward rocks the icicle's faint drop,
By lonely riverside, is heard, at times,
To break the silence deep ; for now the stream
Is mute, or faintly gurgles far below
Its frozen ceiling ; silent stands the mill,
The wheel immovable and shod with ice.

JAMES GRAHAME.

THE properties of ice are most interesting, and will repay us for the time spent in their study.

Freezing, congelation, or solidification, is the transformation of a liquid into a solid or non-elastic fluid (so termed as possessing but little elasticity under the influence of cold), a fluid being a body whose particles, on the slightest pressure, move and change their relative positions, without separation ; therefore ice is the crystalline form assumed by water when exposed to a sufficiently low temperature. In again melting into water, it occupies just 91·675 per cent. of its volume in the solid state, it having expanded in the process of freezing, the density of ice compared with that of water at 0° C. being ·92.

Each liquid always solidifies at a constant temperature under the same conditions, which is called its freezing point, and the solids melt again at the same temperature.

Formation of Ice

Fresh water continues to contract with the cold until a temperature of 39·2° is attained (its maximum density),

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AN AVALANCHE BLOCKING A STREAM.

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A TUNNEL 300 FEET LONG CUT THROUGH AN AVALANCHE.

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when the reverse action commences, and continues until 32° is reached. This has already been referred to, but will bear repetition here.

Water shares this peculiarity with few other substances, as iron, bismuth, and antimony, each of which requires more room in the solid condition than in the liquid, for solid iron floats on molten iron as ice floats on water.

Silver thaw, sometimes called "glazed frost" or "icy night," is an interesting form of ice; it is neither hail, hoar-frost, nor snow, but rain, each drop of which solidifies as it touches any solid body, forming small flattened pastilles of ice. It usually occurs after a severe frost at the beginning of a thaw, and is formed by a damp, warm air passing over grounds of low temperature, depositing its moisture in the solid form on any object on which it may fall. This occurred in London on 22nd January 1867, when many serious accidents occurred owing to the glassy, slippery state of the ground. It also occurred in a more severe form in France (Loiret), 21st to 22nd January 1897, when it accumulated to such an extent on the branches of the trees as to snap them off at the base, split them from top to bottom, or bear them over and uproot them.

Ice also exists in the form of minute needles or spiculæ in the higher atmosphere: the enormous height at which some clouds float, and the temperature encountered, make it impossible that they can consist of water, and it is through the refracted light of these banks of minute ice particles, when we look at either luminary, we see the formation of haloes and other similar phenomena which are only possible when the light has passed through prisms of ice.

Artificial freezing is attained by the liquefaction of solids or the evaporation of liquids. These processes absorb heat, and, by abstracting it from the surrounding substances, freeze the latter.

There are also many freezing mixtures: for instance, 2 parts pounded ice or fresh snow and 1 part common salt will cause the thermometer to fall to $-4°$ F.; 3 parts snow with 4 parts of crystallised chloride of calcium produce $-54°$ F. With a mixture of liquid nitrous oxide and carbon disulphide a temperature of $-220°$ F. is reached.

Ice-Flowers

Ice, like snow, forms six-rayed stars.

If a piece of ice be placed in the path of a sunbeam, the passage of the light through the ice will be marked by a number of glittering points, each of which, when examined under a lens, will be found to consist of perfectly formed six-rayed stars, called ice-flowers; they consist of little cavities filled with water, formed by the melting of a single ice crystal.

Huxley tells us that these beautiful forms, which commonly resemble blossoms, with six petals or floral leaves, are not solid crystals, like the crystals of snow, but are simply hollow spaces of regular shape filled with water; they may indeed be called "negative" or "inverse crystals."

Tyndall refers to this as being "the reversal of the process of crystallisation. The searching solar beam is delicate enough to take the molecules down without deranging the order of their architecture."

Unfortunately, few of us have seen these pretty stars or flowers.

Who can but admire the familiar ice-ferns and flowers we see formed by the frozen moisture on our windows in the winter?

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AN AVALANCHE GULLY IN ARCTIC NORWAY.

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AN ICE-CAVE IN THE MORTERATSCH GLACIER.

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Although they are of countless designs, it is found that the angle between the little shoots and branches is the same as that between the rays of the star in the snow-flake, or the petals of the ice-flower, viz. 60°.

I wish that my readers would, when the occasion presents itself, watch the process of the formation of these ice-pictures; and if no opportunity be found naturally, they may be produced artificially in a small room—the bath-room for convenience. By means of hot water saturate the air with moisture, until it streams down the window; then shut off the source of heat and keep the door closed; for the dry air will carry away the moisture, and prevent the display. The room will quickly cool, and if the temperature out of doors be low enough, the crystals will soon form, and can be seen, commencing at the edges of the pane, as crystal after crystal forms and joins with others, visibly extending their fantastic figures until the whole pane is covered.

These feathery pictures are admirably described by Hannah F. Gould in lines entitled *The Frost*:—

"He went to the windows of those who slept,
And over each pane like a fairy crept,
Wherever he breathed, wherever he stept,
By the light of the morn were seen
Most beautiful things; there were flowers and trees;
There were bevies of birds, and swarms of bees;
There were cities; with temples and towns; and these
All pictured in silver sheen."

Referring to the formation of ice, Tyndall writes: "The deeper glacier pools are shaded in part by their icy banks, and through the shadowed water needles of ice are already darting; all day long the molecules had been kept asunder by the antagonistic heat: their enemy is now withdrawn, and they lock themselves together in crystalline embrace,"

I give this extract with a definite reason. If the reader would like to see these serrated blades of transparent ice, of every conceivable form, he has but to put a glass vessel in the way of a sharp, freezing current of air, and they will quickly form.

I once saw, in my aquarium, lace-like spears of ice spreading in fan-like form across the aquarium in all directions; and through them the fishes threaded their way, as if wondering what change had come over their home.

This was probably caused by a freezing current of air striking the glass at various points, and it would eventually have congealed the whole mass and burst the tank, had the temperature not been raised.

Expansion and Pressure

We have previously stated that, by reason of expansion, a piece of ice weighs less than an equal bulk of water. A certain bulk of water will weigh 1000 lbs., and a piece of ice of similar bulk will only weigh 916 lbs.; hence it floats with about only one-tenth of its volume above water. It is a fact that ice always melts at 32° F., and is but slightly influenced by pressure, to the extent only of 0·00757° C., for each additional atmosphere.

If water be put under pressure, it takes a greater amount of cold to solidify it; should the pressure be removed, it will immediately congeal, and expand in the process.

The pressure required to prevent water from freezing at 30° is 138 tons to the square inch, and so on in proportion to the temperature.

Therefore, our water-pipes, that give so much trouble to the householder in winter, and are such a source of work and profit to the plumber at the same time, have no alternative but to burst their sides with the expansion caused

Mrs Aubrey Le Blond.

No. 1. ICE-FLOWERS IN THE ALPS.

(Showing the black ice of a frozen pool near St Moritz, with the ice-flowers beginning to form.)

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by freezing. Even if made strong enough to resist 138 tons to the square inch, they would only be able to resist 2° of frost; 3° of frost would still cause them to burst.

Heat given out by Freezing

There does not appear to be much logic about this, and to the uninitiated it appears at least curious or doubtful; but it is a fact.

The very freezing of water gives out heat. Any body, in solidifying from the liquid state, gives up a quantity of heat without exhibiting a decrease of temperature, and the amount of heat given out by a pound of water as it freezes, would suffice to raise it to 140° F. If the reader was able to follow the explanation of "latent heat" previously referred to, he will have no trouble in understanding how these conditions arise.

Therefore, to put it shortly, the quantity of heat absorbed or liberated in melting ice or freezing water is sufficient to raise the temperature of seventy-nine times its weight from 0° C. to 1° C.

It is this singular property of water which greatly mitigates the cold of the Arctic and sub-Arctic regions. The cold is expended in freezing the water, not in lowering the temperature still further.

The absorbing or liberating (as the case may be) of heat or energy by freezing or melting, by condensation or evaporation, goes on continuously; whether it be in evaporation from the bosom of the tropical seas, the mighty snowfields, or the never-idle glaciers, or from the domestic kettle.

The old saying, "It will be warmer after the shower," is founded on experience; for the heat absorbed in the evaporation and formation of the vapour in the atmosphere, reducing the temperature of the latter, is given out when the vapour is condensed into rain, causing a rise of temperature.

Before leaving this subject, it will be of interest to many to know a little of the action of heat on ice.

We have in previous chapters seen the effect of heat upon water and ice from 32° F. upwards. The reader will probably wonder what effect it has on ice at 0° F.

"Suppose radiant heat," says Dr Mill, "be supplied to 1 lb. of ice at 0° F. Each unit of heat raises the temperature of the mass by 2° (hence the capacity for heat of ice is only half that of water), and by the time 16 units of heat have been absorbed, the mass of ice has expanded considerably and its particles are vibrating with increased energy, so that the temperature is 32°."

Freezing of Lakes

We have but to remember the increase in volume of water when freezing, and we shall see how miraculously nature does her work; and then imagine, if we can, what would happen to the world and to us, if the contraction with cooling of water continued throughout the scale of the thermometer from 39·2° F. downwards: there would simply be no life on the earth. Let us take the freezing of a lake, and see what happens.

The surface of a lake cools down as winter approaches, the water at the surface, being heavier, sinks, and the warmer water from the bottom rises to take its place.

This circulation goes on as long as the surface continues to cool, but when the whole of the water in the lake has reached a temperature of 40° F., the surface-water, if further cooled, becomes lighter and remains on the top, and, should the cold be severe enough to reduce the water

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No. 2. THE SAME SPOT TWENTY-FOUR HOURS LATER.

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to 32°, a thin layer of ice will be formed over comparatively warm water.

This preserves the animal life in the water and forms a barrier of protection to the water underneath, from the cold; were it not for this peculiarity, the lakes, etc., would be converted into a mass of solid ice.

"If ice had been heavier than water, the sea-bottom in higher latitudes would have been covered with solid crystal, till finally the whole sea, to far within the temperate zone, would have formed one solid mass of ice. The sun would have been as powerless to melt this prodigious body as it is to dissolve the glaciers of the Alps, and the cold radiating from its surface would have rendered all the neighbouring lands uninhabitable" (Hartwig).

Freezing Point of Sea-Water

Sea-water is heavier than fresh water, owing to the salt it contains, and requires a temperature of about −2° C. to freeze it.

The Greenland ocean does not freeze until a temperature of 26° F. to 31° F., according to its saltness, is reached, or about 3½° lower than fresh water.

When concentrated till its specific gravity reaches 1·1045, sea-water requires a temperature to freeze it of 18⅓° lower than fresh water. Even then the crystallising force rejects four-fifths of the salt, and freezes the water alone, with the result that the ice of sea-water, when melted, produces fresh water. But this fresh water tastes bitter and unpleasant, for it still contains some salt which was entangled mechanically in the spaces between the ice-crystals.

If a mixture of sulphuric acid and water be frozen, a similar result is obtained, for the ice is pure and free from acidity.

Ground, Bottom, or Anchor Ice

In addition to the ice formed on the surface of water, it forms also at the bottom of rivers and seas where conditions are suitable, and remains there for some time. This curious phenomenon, the formation of ice at the bottom of the sea, is apparently in direct opposition to all theory in reference to the increase in bulk of ice from that of water, or the relation between the densities of water in its solid and liquid states.

Bottom-freezing occurs in the Cattegat, the Baltic, in the Polar seas, in shallow water near land, and off the coast of Labrador, etc., where ice forms at considerable depths; it has been found that seals caught in the lines at those depths are at times frozen solid.

Darwin states that "in the shallow sea on the Arctic coast of America the bottom freezes, and does not thaw in the spring so soon as the surface of the land."

The surface of the sea, previously clear, has been within half an hour or so covered with bottom ice, so as to be impassable by boats.

The ice forms in plates, coming to the surface edgeways, with such force as to raise the upper edges several inches out of the water.

Its formation is accounted for in the following manner: although no lower temperature can be carried down by the water than that to which it has been subjected at the surface, the water that does not freeze at, say, $-2{\cdot}5°$ C. when lying upon the surface, changes into ice when it comes in contact with the irregular bottom, probably through the more ready dissipation of the heat set free in the act of congelation, and is retained for a time by the cohesion between it and the stones of the river bed; when at last it is forcibly released from this contact,

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No. 3. THE ICE-FLOWERS AT CLOSE QUARTERS.

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it rises to the surface, bringing with it stones, rocks, chains, etc.

Ice-Fields

Vast fields of ice of enormous extent and thickness are formed in Polar latitudes every winter, but are broken up in the summer by heat and the force of the waves; drifting, by the aid of wind and ocean currents, they become piled into dangerous heaps, forming a menace to the navigation of ships in Polar seas.

The ice-fields of Iceland are of large area. The principal, "Vatnajokull," covers 4000 square miles.

The average thickness of sea ice is about 8 feet. Some writers affirm that, if undisturbed by heat and waves, it will attain a thickness of 18 feet.

It is stated that a sheet of ice 1½ inch thick will support a man, 4 inches thick will support cavalry, 5 inches thick will support 84-lb. cannon, 10 inches thick a multitude, and 18 inches thick will support a train. During the war between Russia and Japan, this method of transit over Lake Baikal was resorted to; this large fresh-water lake is in Eastern Siberia, and is about 360 miles long, with a maximum breadth of 50 miles and maximum depth of 400 feet.

Where sheets or fields of ice from 30 to 100 feet thick are met with, they have been formed by the sheets being forced one over another.

The ice-fields of Greenland are beyond our comprehension: how high the plateau rises we cannot say. Greenland is 1400 miles long and 900 miles broad. No man has yet penetrated more than 130 miles from the coast on the west side, where the ice is nearer the sea. It is related that explorers, after travelling 130 miles, saw a solid wall of ice 6000 feet high, and rising towards the east. This has been doubted, and is probably exaggerated, but from other observations there seems to be no doubt that it attains at least a thickness of 3000 feet. Here in June and July the sun is constantly above the horizon: this short summer is followed by a long and dreary winter.

The interior, which is lofty, and has the appearance of being one vast glacier, is uninhabitable; the tongues of ice, 2000 to 3000 feet in thickness and over 50 miles in width, steal down the valleys and push far out to sea, breaking up and forming the dreaded icebergs.

Polar Expeditions

Considering the important part these regions of snow and ice take, more particularly the effect produced on the sea and the atmosphere of the world generally by the cold counter-currents issuing from them, which influences the climate, a few brief particulars of some of the Polar expeditions may be of interest.

Expeditions of discovery into these regions, both north and south, have long had a fascination for man.

In 1517 Sebastian Cabot searched for a north-west passage round America to India. In 1850 M'Clure attempted a similar task, discovering a passage from the Atlantic to the Pacific, which he named the Prince of Wales Strait. Becoming imprisoned in the ice at Melville Sound, his further progress was prevented, and here he was rescued by M'Clintock.

The voyage through this North-West Passage has only lately been accomplished by that redoubtable sailor Captain Amundsen, who sailed from Christiania in the small ship called the *Gjoa* on 16th June 1903. His voyage of adventure occupied three years, during which period, to use his own words, "the earliest dream of his childhood

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No. 4. DETAIL OF PETALS OF THE ICE-FLOWERS.

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No. 5. THE ICE-FLOWERS MEET WITH AN UNTIMELY END.

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was realised." In his small craft he had accomplished the North-West Passage, a task fraught with many tragic memories of previous aspirants for the honour; for which Captain Amundsen received the gold medal of the Royal Geographical Society.

Since Cabot's time frequent attempts have been made to lessen the distance between the known and unknown in both the Arctic and Antarctic regions.

Of those attempting to reach the North Pole, space will but admit of the mention of such names as Frobisher, Davis, Bylot, and Baffin; then, after a lapse of effort for about two centuries, came Ross and Parry in 1818, followed by the fateful Franklin expedition, which set out for the northern region in May 1845.

Numerous expeditions went in search of the missing explorer, and at length, in 1853, Rae, and in 1855 Anderson, discovered relics of the *Erebus* and *Terror*; M'Clintock, however (1857–9), established the fact that the Sir John Franklin expedition ceased to exist in 1847.

The writer recalls with pleasure the frequent stirring descriptions of M'Clintock's expedition that were given him by one of the party, with whom he was most intimate; the old sailor, with his snow-white hair, took a never-tiring delight in relating his experiences, and would proudly show the relics brought home, some being from the actual lost expedition; and the pride with which he would produce the watch presented by Lady Franklin, made no little impression on the writer. The good old man, alas! left these shores for a calmer port some years ago.

Since the above we have the names of Nares (1875), Greely (1881–4), who reached the then farthest north, viz. 83° 24′. In 1888 Nansen beat all previous records, approaching within 260 miles of the North Pole. This has, however, been eclipsed by Peary, who reached 87° N. lat.

on 21st April 1906, or only about 200 miles from the Pole. Here, however, unlike the South Polar explorers, he could replenish his larder with musk oxen, reindeer, seal, walrus, hares, and fish from Lake Hazen. Notwithstanding these luxuries, the privations and sufferings of the explorers were great, and the risk of life can only be appreciated by reading the published accounts of the expedition.

Not less interesting are the accounts of those who have endeavoured to pierce the Arctic region, in trying to discover the North-East Passage, along the northern coasts of Europe and Asia to the Pacific; this attempt, like all these expeditions, resulted in much suffering and loss of life, for it will be remembered that Henry Hudson, discoverer (in 1610) of the bay or strait bearing his name, was put by his mutinous crew into an open boat with his son John, and several of the most infirm of the sailors, and cast adrift in these awful regions, never to be heard of again: an action that needs no remark!

Frequent attempts were made during three centuries to discover this North-East Passage, and it was at length accomplished (1878–9) by a Swedish explorer, Nordenskjöld.

The first to discover land in the Antarctic Circle was the Dutch navigator Dirk Cherrits, who was unwittingly driven southward to lat. 64°.

Cook was the first explorer to pass the 70th parallel, in 1772, reaching 71° 10′ on 30th January 1774.

All attempts at the exploration of the South Pole have, up to the present time, been frustrated by an insurmountable barrier of ice.

Sail southward, and you will come to an ice wall 50 to 400 feet high; as far as the eye can reach, there is nothing but snow and ice.

Captain R. F. Scott describes it as "forming a frowning obstacle 400 miles at least in length; it is a solid wall of ice, which nothing can penetrate or dislodge; here and there the sea has eaten into its sides deep and treacherous caves."

This region of desolation is without animal or vegetable life, its cliffs of solid ice reaching to the sea.

Ross was the first to penetrate the ice-pack, in 1841–2; reaching 78·10°, he sailed eastward along this marvellous wall of ice (which was described as being 1000 feet thick) for a distance of 450 miles, and found it without a break.

He was the first man to gaze on this mighty "ice-wall," which he rightly christened "The Great Ice Barrier," for it is truly a barrier; he saw only the face of the huge "Ice Cap" which covers the whole of the South Polar regions.

In 1899, Mr Borchgrevink reached 78·50° and located the South Magnetic Pole. Many other expeditions have also entered these regions.

Captain Scott, however, has the honour of penetrating farthest into these regions; by the means afforded by one of the rivers of ice, the "Ferrar Glacier," he was able to ascend to the surface of the Ice Cap. Here his party was greeted by bitter, cutting, blinding winds, and after suffering great privation, on 30th November 1903 they stood where never yet man had been, in the heart of the ice wilderness of "Victoria Land," lat. 82° 17′, about 600 miles from the South Pole.

Glaciers of the valley or Alpine type are found in the Antarctic on the most stupendous scale. One mentioned by Ross, as being on the east coast of Victoria Land, fills a valley bordered by mountains 6000 to 10,000 feet high, sending a tongue of ice far out into the sea.

The reports as to the Southern Ice Cap are very conflicting.

Mr Croll estimated the accumulation of the ice and snow at the South Pole as being 10 to 20 miles thick, but recent investigation into the properties of ice, the relation of its melting or freezing point to the temperature and pressure, shows that this is impossible.

If the Ice Cap rests on rocks of a temperature half a degree below the freezing point, then the greatest thickness of the ice formed on the continent would not be likely to exceed 1600 or 1800 feet: this is just a little more than the greatest thickness of the Great Ice Barrier, when it is floated off into the ocean as ice islands or bergs.

This great glacier or Ice Cap of the Antarctic is described by Murray in the *Geographical Journal* as being pushed out all over the low lands into the ocean, forming there the true Ice Barrier, a solid perpendicular wall of ice, probably from 1200 feet to 1500 feet in thickness, rising from 150 to 200 feet above, and sinking 1100 to 1400 feet below the level of the sea. When the forefronts of this great creeping glacier are pushed into the depths of 300 or 400 fathoms, large stretches are broken off and float away, giving birth to enormous icebergs.

It is stated that this ice cap has a movement of about 100 feet a month.

In these regions (Antarctic) Captain Scott, at a distance of 142 miles inland, had reached an altitude of 9000 feet, travelling miles over clear blue glacier ice.

Captain Scott, in an address delivered before the Royal Geographical Society, stated that the great Southern Ice Cap of to-day is but a remnant of what existed at a former period of glaciation, and concluded that a great glacial epoch was the result of a comparatively mild climate; he also expressed a belief that this mighty ice barrier is really afloat, but this is open to doubt.

That this great ice barrier is receding, in common with the European and American glaciers, is accepted by scientific men. These facts, as well as the regular recurrence of famines in Russia and other most fertile districts, point to the same cause—the presence of less moisture in the atmosphere.

Icebergs

As we have already seen, icebergs are the offspring of the Polar glaciers, which are forced continually downwards into the sea, and detach themselves in enormous masses.

Some of these rise hundreds of feet out of the water. It must also be remembered that the specific gravity of ice compared with sea-water is about as ·920 is to 1·026, varying with the density of the ice and the saltness of the sea, and it is variously estimated that the weight of the ice submerged is from eight to fourteen times that of the portion appearing above the surface.

Another authority gives the different densities of ice and sea-water as ·92 and 1·03 respectively, so we may conclude that only $\frac{11}{103}$ or about one-ninth of the iceberg appears above water.

Another authority states that a floating iceberg will have 89·6 per cent. of its volume immersed, if it has the same temperature and consistency throughout.

The upper layers of these ice-islands are much less dense than the deep blue lower layers, therefore the probable height above water is about one-seventh of the total thickness of the berg.

Sir John Murray estimates the submerged part of the Antarctic berg as seven-eighths of the whole mass; but, for the reason that the mass throughout must contain large quantities of air, Captain Scott considers the proportion to be 5 to 1.

Vice-Admiral Marakoff, commander of the Russian ice-breaker *Yermak*, when in the Arctic regions made experiments with twenty-six samples of ice, and found that the specific gravity of the floating portion of the ice varies from 6·5 per cent. to 16·4 per cent., while the average of the whole is 12 per cent. The strength of ice was also tested, glacier ice requiring 180 lbs. to break it, floe ice only 63 lbs.; other ice averaged 110 lbs.

Where the ice forming icebergs is clear, compact, and solid, it has a bluish-green or deep blue tint.

"The deep blue colour is due to the fact that the air has been expelled by the constant melting and regelation which takes place throughout the whole mass as it moves over land."

"A cannon ball fired into the azure blue ice does not penetrate, but large masses of ice fall away. When fired into the upper areolar white layers of the table berg, it penetrates without producing any visible effect."

Fragments of the latter were subjected to pressure and impact, and could easily be deformed; fragments of the former behaved quite differently.

"Waves dash against the bergs, cutting caves and caverns of the most heavenly blue. These cavities contain fresh water, from the melting of the ice."

"As the bergs drift, they tilt and turn; the submerged prongs and spits are thrown high into the air, producing pinnacled bergs higher than the original table bergs."

Admiral Marakoff, when in the Arctic region, took the temperature of the centre of a 14-foot ice-floe broken by the *Yermak* and found it to be 28·2° F., or only 0·5° F. below freezing point of sea-water. "I am not sure," he says, "whether it shows that such thick blocks do not lose entirely during the summer their excess of cold received in winter."

His various experiments for melting point of ice from different depths of the floe proved it to be very near the freezing point of fresh water.

Sea ice was subjected to the influence of a current of salt water at 29·8° F., and the ice melted in that temperature very easily. "It is rather remarkable," he states, "that ice melts in water the temperature of which is more than 2° below its melting temperature."

The specific gravity of liquefied ice was then tested, proving it to contain very little salt indeed.

Surface ice gives the purest result; but the bottom of the floe gives a little more salt, salinity varying from 0·01 to 0·69, the latter from the spongy part of the floe.

The reader will probably ask what is the size of the largest iceberg which has ever been seen.

Floating mountains of ice of all shapes and sizes up to 20 or 30 miles in length and about 12 miles in breadth have been reported pretty often, while at least one berg has been met with which towered no less than 1500 feet out of the water—that is to say, the total height of that block of ice was about 5000 feet! But 30 miles is not the record for length. On 17th January 1893 the *Loch Torridon* fell in with a gigantic island of ice which measured in one direction the almost incredible length of 50 miles; and when she had sailed to the end of this side of the berg, no end to the ice in the other direction was visible, even from aloft.

In Baffin Bay Sir John Ross saw icebergs aground, standing 1500 feet out of the water.

Reliable authorities have seen icebergs aground in 500 feet of water, standing 250 feet out of the same; giving the not unusual height of 750 feet for the greater icebergs.

An iceberg seen by Ross and Barry was 2½ miles long by 153 feet high, and supposing it was a cone reared on an elliptical base, there would have been 150,000,000 tons of ice above water; the entire mass would equal 1,500,000,000 tons.

The largest iceberg seen by Captain Scott in the Antarctic was apparently aground off King Edward Island, 5 or 6 miles long, and it seemed to run back an equal distance. Many high ones were seen, one 240 feet.

The glaciers (Jakobshavn, Humboldt, etc.) of the Greenland ice-field supply most of the Atlantic icebergs, and the Antarctic ice-sheet those of the Southern Ocean.

Greenland has been called the mother of icebergs; the immense mass covers an area of 512,000 square miles; the whole of the interior is capped by an enormous glacier, always moving towards the coast, breaking off in icebergs which rise from 60 to 300 feet out of the sea.

Recent observations of one of the principal discharging glaciers of Greenland prove it to be 920 feet thick, 18,000 feet wide, having a summer advance rate of 47 feet a day.

So enormous are some of the Arctic icebergs, and the amount of heat required for their liquefaction is so great, that they sometimes travel 2000 miles before disappearing.

The means by which they travel such a distance is the Polar Stream, which carries them southward from the Arctic zone towards the Equator.

Referring to the icy monsters, Longfellow writes:—

> "Southward, for ever southward,
> They drift through dark and day,
> And like a dream in the Gulf Stream
> Sinking, vanish all away."

The climatic effect of an iceberg is sometimes very marked, frequently the lowering of the temperature warns the mariner of its presence before it becomes visible.

Notwithstanding frequent reference by many writers to this lowering of the temperature in the vicinity of icebergs, careful research and frequent experiment appear to have exploded the idea that their presence is always indicated in this manner, for Captain Magill tells us, in the *Geographical Journal*, 1901, that if a ship is to the leeward of an ice-field of vast extent, at a distance of a mile or two, the temperature of the sea surface, and the air especially, may be colder, but in the case of bergs no perceptible difference will be noticed until too late to avoid a collision. He states that he passed forty-five in four or five hours, distant 1 to 7 miles, with no change of temperature; he also took the temperature of sea and air every ten minutes from first sight to within one-quarter mile of a large berg, and found no change whatever.

Ice-Floes

Ice when formed on the surface of the sea is called field ice; when broken and piled up by wind and waves it forms floe ice or solid masses of ice many miles in area. Unlike the ice of icebergs, it is porous, incompact, and imperfectly transparent.

When open sea freezes the first thin covering is called "bay ice." Floe ice is a sheet of ice the limits of which are visible; ice-field a sheet of ice of such extent that its limits cannot be seen.

Pack-Ice

This consists of fragments of an ice-field or floe forced together by wind or currents.

The greatest thickness attainable by sea ice in Polar seas is 7 feet. Old ice will become thicker in the second year and attain 10 feet. Where floes 80 to 100 feet thick are found, they reach this thickness only by the accumulation of snow on the ice year after year.

Captain M'Clintock's ship *Fox* was frozen into an ice-pack from August 1867 till the following April, and during these 242 days the ship was carried southwards 1385 miles.

Many similar experiences are recorded, and many fine vessels have been crushed by pack ice and their crews have had to subsist for months on those floating islands of ice until rescued by some passing vessel.

The following anecdote, from a most interesting little book on ice by W. A. Brend, is an example of the hardships referred to.

"In 1871 the *Polaris*, an American vessel exploring to the north-west of Greenland, became frozen into the ice-pack (lat. 79°) near the entrance to Smith's Sound. On the 15th October a storm arose and the pressure of the ice threatened to crush the ship. Provisions were placed upon the ice and nineteen persons retreated there for safety.

"During the night a channel opened between the floe and the ship and the two parties drifted apart.

"Among the little party who thus commenced a drift destined to last seven months were two Eskimos with their wives and children, including a baby only four weeks old.

"Snow-huts were built on the ice-raft, and a fire was sometimes made by using seal blubber as fuel.

"Great pieces of the floe broke off from time to time, consequently diminishing the size, the portion of the ice bearing the encampment fortunately remaining intact."

The trials of this party, the weary months of anxiety with the awful fear that after all they might be hurled into eternity in a moment, the difficulties and want of food, the awful exposure to cold, etc., need but a little careful thought to realise. However, on 30th April they were rescued by the steamer *Tigress*, in latitude 53°·35 N. They had been 197 days on the ice, and had travelled in this manner 1700 miles; and, in spite of hardship and privation, not a single life had been lost.

Similar experiences, with less happy endings, are unfortunately well known; it is little wonder that descriptions of these Polar expeditions have such a fascinating attraction for all readers.

Sea Ice

Nansen has given us, as the outcome of his investigations in the Polar regions, particulars of thickness attained by the ice of the Polar seas by means of direct freezing. The greatest thickness found without being piled up was 13 feet 10 inches:

"As soon as ice is formed it grows very rapidly, but as the thickness increases the growth becomes slower and slower, as the loss of heat by radiation during the long winter night has then more difficulty in penetrating down to the underside of the ice. The ice which was formed in October and November of the first autumn (1893) had in April 1894 attained a thickness of 7½ feet, but it continued to increase steadily during the summer. On 9th June it had reached a thickness of 8 feet 3 inches, notwithstanding there was already a severe thaw on the surface caused by the rays of the sun. On 20th June the thickness was still the same; the thaw on the surface was considerable, and there were large fresh-water pools in every direction. The rest of June the ice continued about the same, until on 10th July it suddenly received a new layer underneath, so that it measured a thickness of 9 feet, despite the decrease by thawing of an inch or two a day on the surface.

"This formation of new ice on the underside was owing to the layer of fresh water which, by reason of the surface thaw on the ice, now floated above the cold salt water, the temperature of which was considerably below the freezing point of fresh water, and which cooled the latter off so effectually that at the line between the fresh water and the salt water, at a depth of about 8 feet, a layer of fresh-water ice was formed.

"This lasted through the summer, but then the united thickness of the old plus the new layer began to decrease slowly until in September the thickness was about 6½ feet. The growth began again in October. On 10th November the thickness had become 6 feet 7 inches; on 11th December, 7 feet, and continued to grow slowly through the winter; on 6th February the thickness was 8 feet 4 inches. During the spring the ice went on growing; on 11th May 1895 it had become 9 feet 10 inches, and it was the same on 30th May.

"It will thus be seen that the ice does not attain any very considerable thickness by direct freezing, and this ice had made the journey from the north of the New Siberian Islands to the sea north of Franz Josef Land, that is to say, across no inconsiderable part of the Polar basin."

Icicles

Icicles vary in length from the tiny crystal spears we see hanging from every ledge, sill, or window, to those 30 feet in length, found hanging over the sides of a crevasse, where they usually form on the southern edges.

We will now try to find out how they are formed. The rays of the sun melt the ice, but do not warm the air, and the ice is melted though the air may be many degrees below freezing; as the water runs from the sunshine into the shadow, it congeals and forms the nucleus of an icicle; this process continued builds up those beautiful spears of transparent ice:

> "Winter giveth the fields and the trees, so old
> Their beards of icicles and snow."
> LONGFELLOW (from Dante's *Purgatoria*).

Ice which accumulates under pressure (as in the case of glaciers) differs from ordinary ice, which has a white appearance, due to innumerable air bubbles in the mass. In glaciers crystalline ice is formed; the enormous pressure squeezes out the minute air bubbles and leaves the ice transparent and clear. I have seen the time by an ordinary watch distinctly through a block of this ice about 2 feet square, and a newspaper can be read easily through the same.

Ice formed in Caves

Ice-caves so termed are seen where the formation of subterranean ice occurs in caves. They are to be found in various parts of Europe, Asia, and America, notably in the Jura, Switzerland, the Italian Alps, the Eastern Alps, in Tyrol, Russia, one in Iceland, one on the Peak of Teneriffe, several in Siberia, one in Japan, and many other places too numerous to mention.

This formation of ice in caves is supposed by one writer (Mr E. S. Balch) to be "due to the cold air of winter, which re-forms anew each year the ice which has been destroyed by heat the preceding summer."

Another authority accounts for this interesting phenomenon of the forming of ice in caves by the theory that, because of their depth below the surface of the earth, their height above the sea-level, or their exposure to suitable winds, or two or more of these conditions in combination, they are unaffected by ordinary climatic changes, so that the mean annual temperature is sufficiently low to ensure the permanency of the ice.

An interesting reference is made to ice-caves in the *Geographical Journal*, 1902, by Mr H. H. Kimball, who states that there are freezing caverns recorded in 300 places in the entire world, sixty-five of these being in the United States. In one of the Port Henry Mines, N.Y., which contains ice all the year round, a temperature of −38° F. has been recorded.

If water oozes into a cavern and then evaporates, the air temperature of the cave is lowered, and ice forms.

In Iceland there is a cave of considerable dimensions called Surtghellir, containing the most gorgeous ice stalagmites of all sizes and shapes, from the densest white to a pale transparent blue. Here, as in the stalactite caves, the icicles from above join the ice stalagmites from below, forming glittering colonnades and screens, etc., in endless variety. (The temperature of the cave is 33° F.)

The ice supply of the island of Teneriffe is obtained from such a cave, which is 100 feet long, 30 feet broad, 10 to 15 feet high, situated on the Peak 10,000 feet above the sea-level.

Extremes of Temperature (Arctic)

In the Arctic regions 73° to 84° F. below zero have been recorded, but the coldest temperatures are not at the Poles, for the circulation of the water tends to bring the heat from the Equator.

The lowest temperature recorded by Captain Sverdrup (of the Nansen expedition), taken north of Franz Josef Land, was −62° F.; the highest, +37½° F.

Peary in these severe climes in 1898 experienced a

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A SUMMER RIVER OF ICE.

(Some distance up the glacier the snow-line can be distinctly seen.)

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temperature of $-65°$ F. or 97 degrees of frost, the mean temperature being stated as $-53·18°$ F.

A few Antarctic temperatures will tend to make us give some little thought to the hardships experienced by explorers in the South Polar regions.

The *Belgica* records the minimum temperature for the month of September as being $-45·4°$ F. This was in 71° south latitude.

Captain Scott, at Cape Armitage on 16th May 1903, recorded $-67·7°$, or nearly 100° of frost.

The coldest regions are N.E. Siberia and N.E. America. In Verkhoiansk in January the mean temperature is 55° F. below zero, and only reaches 5° above zero all through the year.

It is stated that here 81° below zero has been recorded, and that the soil is frozen to a depth of 400 feet.

In Siberia, at Irkutsk (50° to 52° N. lat.), mercury freezes as early as November.

Labrador is described as the "most uninviting region on the face of the earth, whose coast is blasted by frost and beaten by waves: language fails to describe the awful desolation of the Labrador peninsula."

Sir Archibald Geikie says: "England, clothed in perennial verdure, and Scotland, where grass grows for eleven months of the year, are in the same latitude as the frozen and horrible coast of Labrador, the difference being almost entirely due to the Gulf Stream."

The winter temperature of the Polar Sea is higher than that of Siberia, proving that the sea tends to equalise the temperature even in these rarely visited northern extremities, for in the former $-62°$ F. has been recorded by Nansen as the minimum, whereas at Verkhoiansk, in Siberia, the minimum temperature is $-90°$ F.

The capability of the human body to withstand extremes of temperature differs according to temperament and constitution. Some would rather suffer heat than intense cold; some find the 78° F. below zero of Siberia quite bearable, even pleasant on a calm day; whereas, with a temperature 60° higher, if the air be damp and wind high, death might result.

Many feel a damp, foggy November day in London more severely than the first-named temperature.

The men hewing ice on the Norwegian lakes may be seen working in their shirt-sleeves. When arriving in England with the blocks, they are muffled up, wearing great-coats; proving that it is not so much a matter of degrees of cold as dryness and stillness of the atmosphere.

The same argument applies to heat: a moist heat of, say, 80° to 90° F. is simply overpowering, whereas a dry heat of over 100° F. will not cause such inconvenience.

The general impression is that great cold is more easily borne than great heat.

CHAPTER IX

GLACIERS

"The glassy ocean of the mountain ice."

BYRON.

INTERESTING as the forms of ice already mentioned may have been, it is the glacier that will impress us most. These rivers of ice move slowly; yet, as Hartwig says, "it might be supposed that the waters which congeal on the sides of the mountains covered with perennial snow, or fill Alpine valleys in the form of glaciers, were eternally fixed on earth—but there also we are deceived by delusive appearances of immobility. Every year the glacier slowly but restlessly makes a step forward into the valley, and while its lower end dissolves, new supplies of snow constantly feed it from above."

Let us see what we can learn of these ice masses, which, formed by the congelation and compression of the mountain snow, creep so stealthily down the mountain slopes until they either evaporate or melt into rivers, or force themselves into the lakes or seas.

They are, of course, common in the Polar regions, but are not confined to these latitudes.

In the Himalayas we find rivers, up to 60 miles in length, of ice coming from an altitude of 29,000 feet.

Mount Kenya and Mount Kilimanjaro in Africa, on the Equator, send forth their rivers of ice, as also do the mountains in South America.

Many glaciers terminate only after having thrust themselves down the valleys into the fields, orchards, and forests, where their ends are being continually melted by the sun's rays.

Formation of Glaciers

We have seen that above the snow-line more snow falls than the summer sun can melt; and it would go on accumulating indefinitely, were it not carried away regularly by means of glaciers.

That which is melted by the sun sinks down into the mass, helping to consolidate it. Thus the deeper layers become firm and compact, though there is a considerable amount of air in them.

The mass, being on the sloping side of a mountain, gradually acquires a gliding movement. The pressure from above, and the narrowing sides of the valley, compress it still further, and this imperfectly consolidated mass, partly ice and partly snow, is then known as névé or firn. The air-bubbles imprisoned within its layers cause it to be less transparent than ice formed from still water. Eventually, however, by the continued and ever-increasing pressure with which it meets in its tortuous passage through narrow defiles, the air becomes expelled, and the final product consists of clear, blue, compact glacier ice.

The dazzling whiteness of the surface of a glacier is due, says J. Y. Buchanan, F.R.S., "to the disintegration of the compact blue glacier ice into its constituent grains under the influence of the radiation of the sun.

"If a block of compact glacier ice be obtained from, say, the extreme end of a glacier ice grotto, from such a distance as to be beyond the reach of direct daylight, when brought out and exposed, in 20 to 30 minutes it will fall

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A DISTORTED AND CREVASSED GLACIER (THE MORTERATSCH).

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into a heap of irregularly shaped pieces of ice, each of which is a grain and a single crystalline individual."

In this compact and perfect form the glacier moves much in the same manner as a river, though far more slowly; indeed, it may be described as a river of ice, carrying away the unmelted snow from mountains.

"The entire mass of snow and glacier," says Ruskin, "pass gradually and by infinite modes of transition one into the other," and he goes on to describe it as "one great accumulation of ice-cream formed on the top and flowing to the bottom."

Rate of Travel

"The first great fact," says Ruskin, "to be recognised concerning them is that they are fluid bodies, sluggishly fluid indeed, but definitely and completely so; they do not scramble down, nor tumble down, nor crawl down, nor slip down, but flow down, like what they are made of, water."

Tyndall also refers to them as "issuing from the hollows of the eternal hills, and stretching like frozen serpents through the sinuous valleys."

The speed at which a glacier travels is governed by the angle of its slope and the amount of pressure from above.

In summer the melting of the ice causes more water to flow through the cracks and crevasses, carrying fine matter with it, and this, with the more yielding nature of the ice under the influence of the warmth, no doubt accounts for the increased movement in summer as compared with winter. In winter the supply of water reaching the bed is cut off by the frost, and the ice, at least to a certain depth, is frozen hard and has greater resistance.

It has also been found that the upper portions or layers of a glacier move more quickly than the lower ones, and the middle travels faster than the sides, which are retarded by friction against the rocky walls. This may be proved by driving a row of stakes into the ice in a straight line across a glacier thus . . . . It will be found in time that those in the centre have outstripped those at each end of the row, and the stakes, instead of being in a straight line, form a bow, thus . . . . . across the glacier. The result is that the medial moraine is compressed longitudinally and is spread out laterally, which explains the widening of the medial moraine. The movement is like that of a viscous body, the centre flowing past the sides, the top flowing over the bottom; and glacier motion through a curved valley corresponds with fluid motion.

The space at our disposal will only admit of reference to a few of the most prominent glaciers and their rate of travel, but the information given will apply to all glaciers generally.

The Mer de Glace of Chamonix travels at the rate of 209 feet per annum at the source of the Arveiron; at the base of the Montanvert, 822 feet. The motion is twice as fast in spring and summer as in winter. The mean daily rate of the Mer de Glace is, in summer and autumn, from 20 to 27 inches in the centre, and from 13 to 19½ inches near the sides.

If a spike were driven into the centre of this glacier on a summer day, it would be found to move at the rate of 1 inch in an hour.

It is estimated that the mass of ice of the Aar Glacier requires 133 years to descend from summit to extremity—a distance of 10 miles.

The average velocity of the Alpine glaciers varies from 50 to 120 yards a year, or from 6 to 15 inches a day.

Professor Hugi built a hut upon the glacier of the Unteraar in 1827. In 1830 (3 years) it had moved down 330 feet; in 1836 (9 years) it was 2354 feet lower; and in 1841 (14 years) the hut was found to have travelled 4712 feet from its first position.

The ice-tongues of Erebus Bay travel at the rate of 3½ feet per month.

The Ferrar Glacier (Greenland type) travels in winter 5 feet per month, in summer 12 feet; the Ross ice-sheet (Antarctic) 100 feet, Spitzbergen (Garwood) 800 feet, Karajak Glacier (Drygalski) 1500 feet per month.

In Greenland the ice-field from the interior is constantly relieving itself in the shape of icebergs, some over 400 feet high.

The breadth of this glacier (Jacobshavn) is 14,760 feet; the dip is less than half a degree; the centre part in summer travels at the rate of 65½ feet a day; midway between the sides and the middle, 49 feet; and close to the sides, only half a foot a day.

The lowest ends of glaciers are found to advance and retreat according to the greater or smaller fall of snow on the mountains, and the increase or decrease of temperature in the regions into which they advance. The speed of travel of the sides of the glacier is regulated by the curves in the valley down which it is passing. At one point the western side is moving the faster, at another point the eastern side has a quicker motion, the pace being retarded always on the inside of the curve.

Ruskin says: "Never an instant motionless—never for an instant without internal change, through all the gigantic mass, of the relations to each other of every crystal grain. That one which you break now from its wave-edge, and which melts in your hand, has had no rest day nor night since it faltered down from heaven when you were a babe at the breast; and the white cloud that scarcely veils yonder summit—seven-coloured in the morning sunshine—has strewed it with pearly hoar-frost, which will be on this spot trodden by the feet of others, in the day when you also will be trodden under feet of men in your grave."

Extent of Glaciers

Notwithstanding the fact that all the glaciers have their periods of advance and retreat, yet they are considerably smaller than they were in ages gone by; this diminution is no doubt steadily going on now, but glaciers of enormous extent still exist.

There are in Switzerland 471 glaciers, which cover a total area of 800 square miles. Austria claims 462. Of those in Switzerland 138 are large, being over 4¾ miles long. The longest glacier in the Alps is the Gross Aletsch (Bernese Oberland), 15 miles long, which has a basin of 49·8 square miles and a maximum breadth of 1968 yards; the next in length is the Unteraar Glacier, 10·4 miles long. The Görner and Viescher are each 9·4 miles. The lowest point to which they descend is 3225 feet; this was attained by the Lower Grindelwald Glacier in 1818.

We can form but a vague idea of the amount of ice contained in these, which may be termed small glaciers, but it has been calculated that the ice of the Görner Glacier would be enough to build three Londons. The depth of the Alpine glaciers varies, and some writers have estimated that in certain instances it is as much as 1600 feet.

In the Himalayas we have enormous glaciers which have their origin in the towering peaks some 29,000 feet high; these rivers of ice extend in some cases 60 miles in length, filling the valleys.

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REFLECTIONS ON GLACIER LAKE, ARCTIC NORWAY

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GLACIER, ARCTIC NORWAY.

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Chimborazo, only 2° from the Equator, sends forth glaciers in all directions.

The glaciers of North America are of enormous extent; here there is a belt of snow-capped mountains over 3000 miles long and 80 to 100 miles broad, in which glaciers are of common occurrence.

The glaciers of New Zealand are also very interesting, the chief being Tasman, 13,664 acres in area, 18 miles long, 1¼ miles average width, and nearly 2¼ miles greatest width.

The New Zealand glaciers, like those of nearly all countries, including the Arctic, are receding. The Clyde Glacier, between 1866 and 1871, had receded 305 feet; and in 1880, when again visited, the shrinkage was very evident.

The giants of this branch of nature's work are found in the Polar regions.

The area of Greenland is about 700,000 square miles. Of this area 600,000 square miles are buried beneath a glacier of the continental type, the central part of this covering being 8000 feet above sea-level. Professor Russell says the central ice-sheet is many hundreds of feet thick, and possibly 7000 or 8000. This ice is drained off in ice-streams, some from 10 to 30 miles broad; one, the Humboldt Glacier, which flows westward into Baffin's Bay, has a breadth of 45 miles where it enters the sea, and gives birth to enormous icebergs.

Nearly all the Greenland glaciers are tongues from the internal ice-cap, and terminate in vertical faces from 100 to 1000 feet high. The glacier movement at the ice-borders varies from a foot per day to a foot per week.

In Franz Josef Land the Great Dove Glacier is 60 miles wide.

One of the broadest glaciers known is in North-East

Land, Spitzbergen (area 6200 square miles). The island appears like a broad plateau covered by an ice-sheet 2000 to 3000 feet in thickness, slowly moving towards the east. This immense sheet of ice discharges into the sea by a huge ice-wall, unbroken by any promontories for 150 miles, and is known as Dickson's Glacier.

We see therefore that, in comparison with the enormous glaciers in Greenland, and in the South Polar regions, those formed in the Alps are mere streaks of ice.

Tributary Glaciers

Tributary glaciers meet and form a large one just as small streams combine to form a large river, but here we are dealing with ice instead of water. Professor Tyndall says they are "tributary valleys, which pour their frozen streams into the great trunk valley." Let us take one instance only, for it is interesting to see how they become compressed in the process of formation.

Tributary Glacier du Géant .	1134 yards wide.
,, ,, de Lechand .	825 ,,
,, ,, Talefre . .	638 ,,
	2597

"At Trelaporte these three rivers of ice are forced through a gorge 893 yards wide, or one-third of their previous width, at a rate of 20 inches a day" (Tyndall).

One of the above tributaries, Glacier de Lechand, has to suffer a still greater compression, for from a width of 825 yards it has to pass a granite vice at Trelaporte 88 yards wide, or about one-tenth of its original dimensions.

In this process the ice is changed in form only, not in volume; it has to adjust itself by altering in shape from  to , in exactly the same manner as water would

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TRIBUTARY GLACIERS

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accommodate itself to the same circumstances. This alteration in form of the solid mass, from the horizontal to the perpendicular, is accounted for by the viscous qualities of the ice particles of which it is composed, and the mighty force necessary to effect the change is provided by the weight of the vast superincumbent mass of the ice above.

Plasticity and Regelation

Plasticity, as the word implies, is the quality of "taking form," and regelation, or re-freezing, is a name given to the phenomenon presented by two pieces of melting ice, brought into contact either in the air or in water, when congelation and cohesion (more simply, joining and re-freezing) take place; this will occur if the atmosphere, or the water in which the operation is being conducted, has a temperature of so much as 100° F. It is stated that this was first observed by Faraday.

Ruskin sarcastically remarks: "Let good Professor Faraday have all the credit of showing us that, and the human race in general the discredit of not having known so much as that, about the substance they have skated upon, dropped through, and eaten any quantity of tons of—these two or three thousand years; that the wonderful phenomena of congelation, regelation, degelation, and gelation pure, without preposition, takes place whenever a schoolboy makes a snowball; and that miraculously rapid changes in the structure and temperature of the particles accompany the experiment of producing a star with it on an old gentleman's back."

In order to find the temperature of a mass of glacier ice, an interesting experiment was carried out on the Hintereisferner (Tyrol). Here a boring was made into the glacier situated 8530 feet above sea-level, through 500 feet of ice, the precaution being taken to wash out the borings with water to prevent their freezing again. It was found that the temperature of ice, throughout the mass, is at the melting point, and that the surface moves more quickly than the bottom (*Geographical Journal*).

Water, when subjected to great pressure, freezes at a lower temperature; so when ice is subjected to pressure it melts, and when the pressure is removed the water again solidifies.

This may be demonstrated by placing a block of ice on two supports and hanging an iron wire, weighted at each end, over it. The weighted wire pressing on the ice melts it and cuts its way through the block; the water freezes again behind the wire, and fills up the space, leaving no trace of its passage beyond a few bubbles of air.

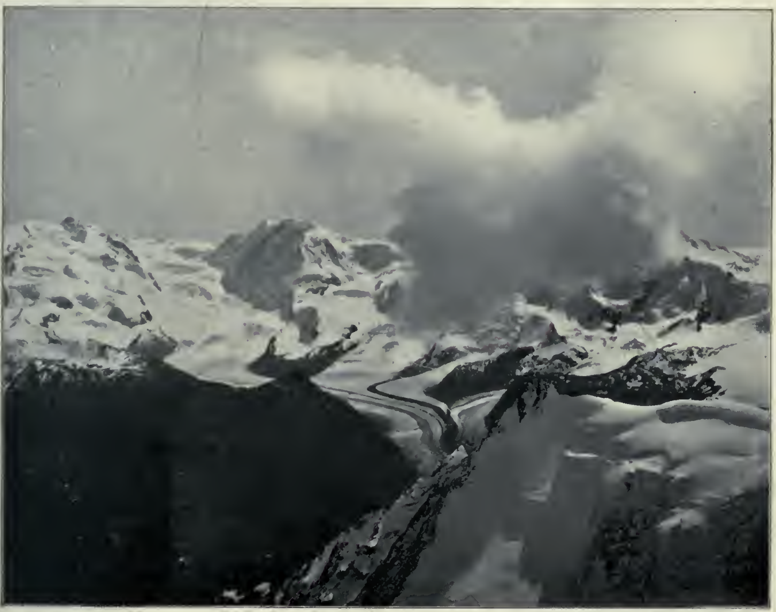
If ice is strained in any way, as by the travel of a glacier, it relieves itself in the above manner and a similar regelation follows.

This proves that ice, though hard and brittle, possesses the property of plasticity to a remarkable degree, and enables glaciers to adapt themselves to their tortuous paths.

This, which is called the viscous theory of glaciers, has been explained satisfactorily by Professor James Thompson by the phenomenon of the melting and re-freezing of ice.

This gives, I hope, a complete explanation of the plasticity of glaciers, and shows that, though imperceptible, melting and re-freezing are continually going on, which will account for the yielding at the points of stress. It will also enable us to understand better how the glacier slides not only on the bottom and sides of the rocky valley, but slides more readily on itself, the centre moving faster than the sides and bottom; also how it winds its way, hard and brittle though it be, squeezing through narrow valleys,

Mrs Aubrey Le Blond.
NEAR TOP OF MONTE ROSA—TRIBUTARY GLACIERS AND MORAINES JOINING.



Mrs Aubrey Le Blond.
THE MONTE ROSA GROUP FROM WELLENKUPPE—GLACIER PASSING THROUGH A NARROW GORGE.

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turning at sharp angles, passing over rough, uneven surfaces, always on its downward path.

The opportunity to watch this movement is given only to a few; we can, however, all do as Ruskin did. At Hôtel du Mont Blanc was a pot of Chamonix honey, stiff and white; he says: "It gave him command of the best possible material for examination of glacial action on a small scale."

"Pouring a little of its candied contents upon my plate, by various tilting of which I could obtain any rate of motion I wished to observe in the viscous stream, and encumbering the sides and centre of the said stream with magnificent moraines composed of crumbs of toast, I was able, looking alternately to table and window, to compare the visible motion of the mellifluous glacier and its transported toast, with the less traceable, but equally constant, motion of the glacier of Bionnassay and its transported granite."

Another simple experiment of his was to put a little hot water on a lump of sugar in a teaspoon, and obtain an artificial thaw of the mass, which he describes as "subsiding, by a series of, in miniature, magnificent and appalling catastrophes, into a miniature glacier, which you can pour over the edge of your spoon on to your saucer."

It is worthy of notice how great men find the simple articles of food upon their tables useful in helping to unravel some of the greatest scientific knots. The late Lord Kelvin took a raw and a hard-boiled egg, suspended them, and set them spinning, and observed that one revolved longer than the other; from this he drew certain conclusions as to whether the centre of our globe has a solid or a liquid core. And Professor Tyndall, in studying crystallisation, found that "in the formation of a bit of common sugar-candy, there are agencies at play the contemplation of which, as mere objects of thought, are sufficient to make the wisest philosopher bow down in wonder, and confess himself a child."

Moraines

Moraines are formed on the surface of glaciers by the fragments of rock which fall from the side of the rocks and are carried down by the ice.

When two or more tributary glaciers meet, a medial moraine is formed, each moraine keeping its individuality distinct, though the mass of ice has by compression formed one solid mass.

Irrespective of the distance they have to travel, and the narrow defiles through which they have to pass, these separate moraines maintain their distinct positions, and are eventually deposited at the lower end of the glacier; there they are called terminal moraines.

The ancient glaciers, no doubt, moved more rapidly than their diminutive descendants of the present day, but at the existing rate some of the large erratics would have taken from 2000 to 4000 years on their journey.

It is from the terminal moraines, which we find left behind in the valleys, that the original or maximum length of any glacier can be calculated and its diminution noted. These boulders are known as erratic blocks.

Erratic Blocks

" As a huge stone is sometimes seen to lie
Couched on the bald top of an eminence;
Wonder to all who do the same espy,
By what means it had hither come, and whence."

J. C. Shairp.

Erratic blocks are huge boulders strewn on the tops of promontories, carried by long-vanished glaciers, and deposited in their present positions.

Mrs Aubrey Le Blond.

ROTHHORN, FROM NEAR UNTER GABELHORN, SHOWING THE MORAINE.

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These blocks of stone receive their name (erratic) from having wandered so many miles from their original homes; for instance, the Pierre-a-Bot, near Neuchatel, at a height of 2200 feet, is 62 feet long, 48 feet wide, and 40 feet high, and came from the Mont Blanc Range.

An erratic block of 24,000 cubic feet can be seen at Mattmark Lake. It was left there forty-four years ago by the Schwartzberg Glacier, which has now receded half a mile from where it deposited its huge burden.

To come nearer home, at Wolverhampton there is a wonderful concentration of thousands of granite blocks, covering an area of 15 miles long and 4 miles broad. These were, no doubt, deposited ages ago by glaciers.

Referring to these interesting wanderers, Tyndall states: "On the solid waves of that Amazon of ice, the perched boulders, the spoils of distant hills, quarried from summits far away, and floated to lower levels like timber logs upon the Rhone."

We find also, as the result of the work of glaciers, *roches moutonées*, *i.e.* sheep-rocks, or stones scratched and smoothed, rounded and polished; and deeply grooved striated rocks, and many other indications which prove the previous occupation of valleys by these rivers of ice in past ages.

Sand-Cones and Glacier-Tables

Another interesting and curious result of the sun's rays melting the surface of the glacier ice is seen when sand-cones are formed. One of these is shown in the accompanying picture, to the left of the erratic block that is in the first stage of forming a glacier-table, being raised on its icy pedestal only a little above the surface of the glacier.

The manner in which these cones are formed is worth a passing notice. They have the appearance of consisting of sand alone, but they are really solid ice, with merely a covering of sand.

If dirt or sand be deposited by a mountain stream on the surface of the ice, according to the thickness of the sand, so will the sun's rays in proportion be prevented from melting the ice; therefore, where the sand lies thickest, the melting will be least, and this point will form the apex of the cone, being left higher and higher as the general melting and lowering of the surface of the ice continues.

Under certain conditions they form groups and miniature mountain ranges; and if the action referred to be sufficiently prolonged, they will attain a height of 20 feet.

It is this protective action that also causes the moraine-ridge, which has the appearance of having been raised by pressure, but is really caused by the general lowering of the surface of the ice around, leaving the ridge higher, through having been protected from the direct rays of the sun by the debris forming the moraine.

Small isolated stones, pebbles, or spots of dirt, however, sink into the surface of the ice, by the action of the sun; the ice has then a honeycombed appearance.

Large isolated slabs of rock are frequently seen on a glacier, standing on a pedestal or column of ice; these columns are formed by the action of the sun and rain on the ice surrounding them, for it is apparent that the sun's rays cannot reach the ice underneath the rock, nor can the rain wash it away.

The remainder of the surrounding ice gradually melts, leaving the table of stone higher and higher in the air.

From the height of this pillar, the amount of ice that has disappeared, since the stone first occupied that position, can at once be seen; eventually, however, the pillar becomes so tall, and, by the action of the air, so thin, that it gives way under the weight of the stone, which

Mrs Aubrey Le Blond.

THE GÖRNER GLACIER AND MORAINE.

Mrs Aubrey Le Blond.

A GLACIER TABLE, MORTERATSCH GLACIER.

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falls on to the glacier, only to repeat the process again and again, until it is finally deposited at the end of the glacier.

As will be seen in the illustration, the stones do not lie horizonally upon the pillar of ice; it is found that the degree and direction of the slope varies with the latitude, owing to the position of the sun at noon, which melts the ice on one side of the table, the other side being in shadow, thus causing the stone to dip towards the sun.

It is in the heap of debris which forms the terminal moraine that we find the polished and striated or scratched stones, which tell us of their journey under the ice, where the enormous weight above pressed them against the surface and sides of the rocky valleys beneath the glacier.

"Although executed ages ago, they are as fresh and unmistakable as if they had been executed last year."

Crevasses

A crevasse is a huge crack or opening formed on a glacier, the result of the ice being severely strained.

Before leaving glaciers, we must spare a space for a short description of a crevasse with its walls of clear blue ice, which Tyndall mentions as being "filled with *cœrulean* light, which deepened into inky gloom as the vision descended into it, the edges of which were overhung with fretted cornices from which depended long, clear icicles, like spears of crystal."

There are three kinds of crevasses, each due to a different action, viz. the transverse crevasse, the marginal crevasse, and the longitudinal crevasse.

When glaciers are subject to tension, the ice breaks and a report is heard like the firing of a gun. After a search of some time a crack is seen, not sufficiently wide to insert the blade of a knife; however, it widens out, owing to the fact that the centre of the glacier is moving faster than the sides, as we have already seen. When some change in the channel occurs, altering or reversing the stresses and strains, the old crevasses close up, and, under the pressure, the sides freeze together again; the glacier thus preserves its continuity, a new crevasse forming at the point of stress, and the process is repeated continually during the passage of the glacier.

This can easily be proved. For, as already mentioned, two pieces of ice placed together in water, above freezing point, will freeze at the point of contact. Place several pieces together in a line: they will all freeze together, and can be moved as one piece, notwithstanding that each separate piece is thawing.

Sometimes the crack will widen into one of those awful gaping chasms (some being 500 to 700 feet deep) which have claimed so many lives. A well-known instance is the melancholy accident that occurred when Dr Hamel's guides perished in a crevasse on the Grand Plateau (Mont Blanc) on 20th August 1820. The bodies of these three poor fellows were found in 1861, or forty-one years after they were swallowed by this awful crevasse. Tyndall, describing his first ascent of Mont Blanc in 1857, predicted the finding of these bodies, which really occurred about four years after the following statement: "They are still entombed in the ice, and some future explorer may perhaps see them disgorged lower down, fresh and undecayed." They were found, I believe, in perfect preservation, at the end of the Glacier des Bossons, having moved some 4 miles in forty-one years, or 500 feet a year.

To-day a crevasse still exists at this same spot, scarcely distinguishable from the one that existed in 1820.

On 23rd August 1905 the remains of a tourist were

Mrs Aubrey Le Blond.

A BIG CREVASSE ON A SNOW-COVERED GLACIER.

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discovered on the upper Grindelwald Glaciers, below the ice-fall. It is supposed to be the body of a German student from Sax-Weimar, who fell into a crevasse higher up the glacier fifteen years before.

Mrs Aubrey le Blond, in *True Tales of Mountain Adventure*, tells us how "a travelling seller of hats, crossing the Tschingel Glacier on his way from the Bernese Oberland to Valais, had fallen into a crevasse. Eventually his body and his stock of merchandise were found at the end of the glacier. Near the Grimsel the remains of a child were discovered in the ice. An old man remembered that many years before a little boy had disappeared in that locality, and must doubtless have been lost in a crevasse."

The same writer has kindly given me permission to quote extracts from the account of the Mont Blanc catastrophe given in her book:—

"In the year 1866, Henry Arkwright, a young man of twenty-nine, aide-de-camp to the Lord-Lieutenant of Ireland, was travelling in Switzerland with his mother and two sisters. One of his sisters went with him as far as the hut at the Grands Mulets, and they were accompanied by the guide Michael Simond, and the porters Joseph and François Tournier. Another party proposed also to go up. It consisted of two persons only, Sylvain Couttet and an employee of the Hotel Royal named Nicolas Winhart, whom Sylvain had promised to conduct to the top when he had time and opportunity. It was the 12th October when they left Chamonix, and all went well across the crevassed Glacier des Bossons, and they duly reached their night quarters.

"While the climbers were absent next day, Miss Fanny Arkwright employed herself in writing and finishing a sketch for her brother.

"Meanwhile the two parties, having set out at an early hour, advanced quickly up the snow-slopes. Sylvain Couttet has left a remarkable description of the events which followed, and portions of this I now translate from his own words as they appeared in the *Alpine Journal*:—

'We had been walking for about ten minutes near some very threatening séracs, when a crack was heard above us a little to the right. Without reasoning, I instinctively cried, "Walk quickly!" and I rushed forwards, while some-one behind me exclaimed, "Not in that direction!"

'I heard nothing more; the wind of the avalanche caught me and carried me away in its furious descent. "Lie down!" I called, and at the same moment I desperately drove my stick into the harder snow beneath, and crouched down on hands and knees, my head bent, and turned towards the hurricane. I felt the blocks of ice passing over my back, particles of snow were swept against my face, and I was deafened by a terrible cracking sound like thunder.

'It was only after eight or ten minutes that the air began to clear, and then, always clinging to my axe, I perceived Winhart 6 feet below me, with the point of his stick firmly planted in the ice. The rope by which we were tied to each other was intact. I saw nothing beyond Winhart except the remains of the cloud of snow and a chaos of ice-blocks spread over an area of about 600 feet.

'I called out at the top of my voice—no answer. I became like a madman. I burst out crying, I began to call out again. Always the same silence—the silence of death.

'I pulled out my axe, I untied the rope which joined us, and both of us, with what energy remained to us, with our brains on fire and our hearts oppressed with grief, commenced to explore in every direction the enormous mountain of shattered ice-blocks which lay below us.

Mrs Aubrey Le Blond.

ICE-FALL, PERS GLACIER
(Formed by glacier passing over steep rocks.)

Mrs Aubrey Le Blond.

AN ERRATIC IN THE FORM OF A GLACIER TABLE, WITH SAND-CONE.

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Finally, about 150 feet farther down, I saw a knapsack—then a man. It was François Tournier, his face terribly mutilated, and his skull smashed in by a piece of ice. The cord had broken between Tournier and the man next to him. We continued our search in the neighbourhood of his body, but after two hours' work could find nothing more. It was vain to make further efforts! Nothing was visible amongst the masses of débris, as big as houses, and we had no tools except my axe and Winhart's stick. We drew the body of poor Tournier after us as far as the Grand Plateau, and with what strength remained to us we descended as fast as we could towards the hut at the Grands Mulets, where a terrible ordeal awaited me—the announcement of the catastrophe to Miss Arkwright.

'The poor child was sitting quietly occupied with her sketching.

'"Well, Sylvain!" she cried on seeing me, "all has gone well?"

'"Not altogether, Mademoiselle," I replied, not knowing how to begin.

'Mademoiselle looked at me, noticed my bent head and my eyes full of tears: she rose, came towards me—"What is the matter? Tell me all!"

'I could only answer, "Have courage, Mademoiselle."

'She understood me. The brave young girl knelt down and prayed for a few moments, and then got up, pale, calm, dry-eyed. "Now you can tell me everything," she said, "I am ready."'

"Thirty-one years had passed when, in 1897, Colonel Arkwright, a brother of Henry Arkwright, received the following telegram from the Mayor of Chamonix: '*Restes Henry Arkwright, peri Mont Blanc* 1866, *retrouvés.*'"

During these thirty-one years the body of Henry Arkwright had descended 9000 feet in the ice, and now the glacier had once more given up its victim, whose remains were rendered back to his family at the foot of the glacier.

Many articles belonging to the lost one came to light by degrees. A pocket-handkerchief was intact, and on it, as well as on his shirt-front, Henry Arkwright's name, and that of his regiment, written in marking-ink, were legible. Though the shirt was torn to pieces, yet two of the studs and the collar-stud were still in the button-holes and uninjured. The gold pencil-case opened and shut as smoothly as it had ever done, and on the watch-chain there was not a scratch. A pair of gloves were tied together with a boot-lace which his sister remembered taking from her own boot so that he might have a spare one, and coins, a used cartridge, and various other odds and ends, were all recovered from the ice.

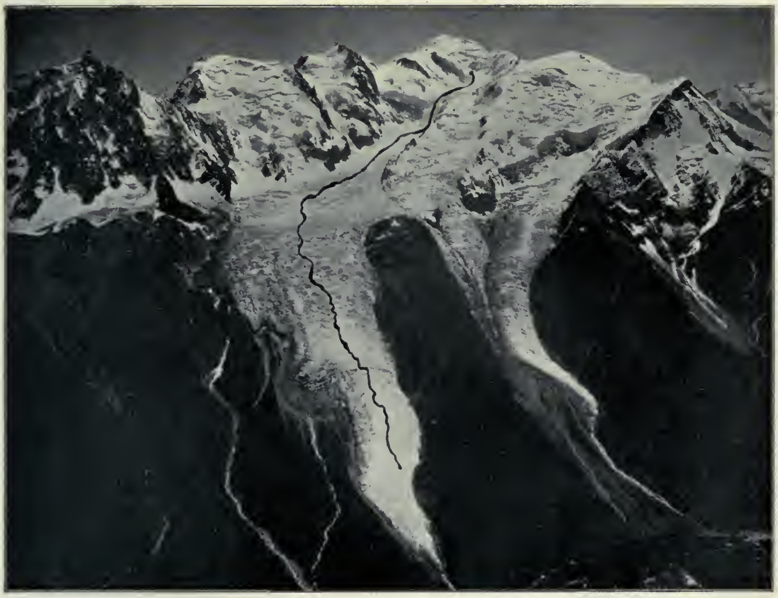
The remains of the guides had been found and brought down soon after the accident, but that of Henry Arkwright had been buried too deeply to be discovered.

In 1906 a letter appeared in the *Times* from Lady Florence Dixie saying that, according to a telegram from Geneva, it was expected that the body of Lord Francis Douglas, who lost his life forty years ago, during the first ascent of the Matterhorn, would be delivered up by the slowly moving glacier during the summer of that year.

It may be interesting to recall a few facts concerning this first ascent of the well-known peak, renowned for its steep, gaunt, granite summit towering to an altitude of nearly 15,000 feet.

On 13th July 1865, Edward Whymper, Lord Francis Douglas, the Rev. Charles Hudson, Mr Hadlow, and three guides started off on what was to be one of the greatest successes in mountaineering as well as one of the most thrilling tragedies of the Alps.

After much laborious climbing, attended by the usual



Mrs Aubrey Le Blond.

MONT BLANC.

(The black line shows the probable course followed during nearly half a century by Captain Arkwright's body in the ice.)

Mrs Aubrey Le Blond.

THE OVERHANGING CORNICE OF SNOW—A FREQUENT SOURCE OF ACCIDENTS.

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dangerous experiences, the following day saw the hitherto unconquerable task accomplished, Whymper and the guide Croz reaching the summit first.

Having spent an hour enjoying a view never before seen by human eyes, the return journey was commenced, all being roped together, as is the usual custom.

Mr Hadlow unfortunately slipped, and fell upon his guide Croz, knocking him off his feet; both fell over the precipice, pulling Hudson and Lord Francis Douglas with them, when the rope broke, thus saving the lives of the remainder of the party, who saw their companions dashed to pieces 4000 feet below.

Three bodies were eventually recovered, but that of Lord Francis Douglas has never yet been seen; having fallen into one of the innumerable crevasses, it is no doubt preserved, frozen solid, in the glacier, which will some day yield him up again to those dear friends who may be spared to receive his body.

A ladder was lost in a fissure on the Mer de Glace (Mont Blanc) in 1788, and was discovered in fragments in 1832, forty-four years afterwards, having travelled at the rate of 130 yards each year.

Moulins

"The glacier to-day filled the air with low murmurs, which the sound of the distant moulins raised to a kind of roar."—TYNDALL.

Moulins are formed on glaciers in the summer, when little rills and streams of water rush down the cracks in the ice, forming deep shafts. These move forward with the glacier, and new ones are continually being formed, approximately in the same place, and so a succession of moulins is formed. One on the Finster Aar Glacier had a depth of 760 feet.

The water finds its way to the base or bed of the glacier, and carries with it any fine particles of matter which have been ground down by the action of the glacier on its rocky bed, issuing from the terminal end of the glacier as a muddy stream. For it is found that the layer of ice in contact with the bottom and sides of the rocky valley, by pressure of the enormous weight above, is usually in a state of thaw or melting, and the water from the surface of the glacier mingles with that of the bed. The Rhine, Po, Ganges, and many other rivers owe their origin to glacier streams.

It is this action that wears and grinds the rocks away. The Rhone, for instance, which has its source in the Rhone Glacier, carries a load of debris or matter into the Lake of Geneva, where it is deposited, and the Rhone quits the lake clear and blue. In the course of time this action of glaciers will fill up the lakes.

Here again we see the wonders of the work of water continually altering the configuration of the earth.

The water that gains access to the rocky bed of a glacier, either through a moulin or a crevasse, frequently comes into contact with large stones; the combined action of ice and water causes them to revolve; this whirling in time shapes and smooths the stones, at the same time wearing in the rocky bed large pot-holes or "giants' cauldrons" as they are termed in Scandinavia, where they are found of considerable size.

In the glacier garden of Lucerne, which formed at one time the bed of a glacier, there are a considerable number of these interesting holes, with the stones *in situ*—one pot-hole or cavity measuring, it is said, 28 feet in width and 33 feet in depth.

Similar cavities are formed in the beds of swift streams, where a large stone gets into a whirl of water or an eddy;

Mrs Aubrey Le Blond.

AN ACTIVE MOULIN OR GLACIER MILL.

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they are also frequently formed at the base of a waterfall. These are sometimes called "Devil's punch-bowls."

There is an old saying, "Continual dropping wears away a stone"; large quantities of water, falling from a height, certainly excavate and polish enormous cavities.

Ice-Barriers

When a glacier moves past the end of a tributary valley, it sometimes dams back the stream, and the water thus accumulated forms a lake, which continually increases in extent until the barrier gives way under the pressure of the water.

A lake of this description was formed in the valley of the Dranse, Switzerland. Here an ice-barrier, half a mile long, 400 feet high, 600 feet wide, stretched across the valley, impounding 5,000,000,000 gallons of water.

To avoid a serious catastrophe, a tunnel was driven through the ice and much of the water was drawn off; but before the lake was empty, the barrier gave way, causing an immense amount of damage.

Other barriers of ice are of a semi-permanent kind, and remain as long as the glacier is in existence. The beautiful Märjelen See, on the Great Aletsch Glacier, with its floating icebergs of snowy whiteness, is an instance of this.

When one of these reservoirs burst at Gietroz in 1818, 1,110,000,000 gallons of water were suddenly set free.

Crête Sèche in 1894 and 1898 discharged 220,000,000 gallons, and in 1878 the Märjelen See evacuated in nine hours 1,709,400,000 gallons.

Similar instances are more or less common to all countries where glaciers of any magnitude exist; sometimes the reservoir is formed on or in the glacier itself. In most instances, however, they eventually burst with most serious results, generally causing a flood, which sweeps down the valley, carrying all before it.

Lakes formed by Glaciers

Several reliable authorities are of opinion that many rock-basins, in which beautiful lakes are formed, were scooped out by the grinding action of an ancient glacier. The lakes of Killarney and many other well-known lakes were doubtless hollowed out by this means.

"When glaciers teemed from the shoulders of Snowdon," says Tyndall, "and when the Reeks of Magillicuddy sent down giant navigators to delve out space for the Killarney Lakes, and to saw through the mountains the Gap of Dunlow."

All these now lovely spots were once held in the chilling grip of ice, and it is supposed by some that these severe conditions were passed long before the world was inhabited.

The pressure a glacier exerts on its bed is enormous. In a glacier 600 feet deep, and allowing (according to Professor Tyndall) 12·20 metres (or about 40½ feet) of ice to an atmosphere, we find that on every square yard of its bed a glacier presses with a weight of about 300,000 lbs.

Advance and Retreat of Glaciers

The terminal ends of some glaciers may remain stationary for many years, and then advance or recede.

Lord Avebury tells us that "during the Middle Ages the Swiss glaciers appeared to have been increasing in size, and to have reached a maximum about the year 1820; after that they retreated till about 1840. They then again advanced until about 1860, since which time they have again greatly diminished; though some are now commencing the

Mrs Aubrey Le Blond.

A SHATTER OF BOULDERS, ARCTIC NORWAY.

(Illustrating how fragments of the peaks, loosened by the frosty air, poured in granite avalanches down the mountains.)

Mrs Aubrey Le Blond.

GLACIER LAKE, WITH POLISHED AND STRIATED ROCKS, ARCTIC NORWAY.

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advance again. Those of Northern Europe appear to be also increasing."

In 1858 Tyndall visited the Görner Glacier, of which he states: "As is well known, the end of this glacier has been steadily advancing for several years; and when I saw it, the meadow in front of it was partly shrivelled up by its irresistible advance. In thus advancing the glacier merely takes up ground which belonged to it in former ages, for the rounded rocks which rise out of the adjacent meadow show that it had once passed over them."

Between the years 1845–1883 the end of the Vernaght Glacier receded 2000 yards. This glacier has advanced and retreated ten times since the beginning of the seventeenth century.

That these oscillations occur at irregular periods is beyond doubt; and it is an accepted fact that, however they may advance and retreat, the final result is a continuous retreat.

In many of the Swiss valleys the pressure of the ice must have been very great. The Rhone Glacier at one time not only occupied the basin of the Lake of Geneva (170 miles below its present limit), but rose on the Jura to a height of 3000 feet. This lake is 1100 feet deep, so that the thickness of the ice must have been 4100 feet.

It is also agreed that the great ice-cap of the Antarctic is but a remnant of its former self.

The Glacial Period

"It is a world disinterred by the sun from a sepulchre of ice."—Tyndall.

We cannot leave this interesting subject without some short reference to the Glacial Period or Ice Age, during which both the old and new world, north of latitude 50°–40°, were covered with ice and glaciers, probably as thick as that now found in Greenland. The mountains of Scotland and Wales were covered with ice; similar conditions existed and were more or less general over Northern Europe and North America. Where, as Tyndall states, "the valleys were gorged by the frozen material incessantly poured into them."

"A scene of unspeakable desolation it must have been, when Europe was thus encased in frozen armour, and when even the showers of her western isles fell solid from the skies."

The Glacial Period has left us many traces of its existence. The vanished glaciers scratched and polished the surfaces of the rocks, and by studying these their thickness and the direction in which they moved can be calculated approximately; and no doubt can exist as to the circumstances under which they were formed, and of their enormous extent. The vast sheet of ice buried North-west Scotland 3000 feet; the hill-tops of the Cheviots, 2300 feet high, are distinctly glaciated; this sheet of ice thinned away to the south and east.

The great Scandinavian glacier occupied the North Sea from Flamboro' Head to the mouth of the Thames. Erratic blocks from Norway travelled on this ice-sheet and were deposited at Cromer.

Coming nearer home, similar traces can be seen through Borrowdale in Cumberland, the valleys near Beddgelert in Wales, and many other places.

The British Isles at this period were almost wholly covered by an immense glacier, as thick as that at present to be seen in Greenland, on the recession of which England and Ireland were found to be joined to the Continent.

"We see," says another authority, "the conditions as existing in North Greenland extended to Middlesex, Wales, and south-west of Ireland, vast fields of ice passing over the Scottish Highlands, covering in the plains of Perthshire to a depth of at least 2000 feet. The North Sea was chilled with ice, and England and the north-west of France were united."

In this period of the greatest cold 700,000 square miles of Northern Europe was buried under a vast sheet of ice, which, over Scandinavia, was said to lie about 6000 feet thick.

Another authority states that in Norway at this period the ice must have been 7000 feet thick. "The high table-land of Scandinavia," says W. A. Brend in his excellent book on ice, "became a great centre of dispersal, from which the ice radiated in every direction, north into the Arctic, west into the Atlantic, south and east the glacier pushed across Denmark and the Baltic, and invaded Northern Europe."

Distinct traces of the mighty glaciers of the past are also to be seen in the valley of Hasli, Switzerland; here the marks and polishing of the ancient glaciers can be seen 2000 feet above the present valley beds.

"All around," writes Tyndall, "are evidences of the existence and might of the glaciers which once held possession of the place. The rocks are carved, fluted, polished, and scored; here and there angular pieces of quartz, held fast by the ice, inserted their edges into the rocks and scratched them like diamonds."

In the Bernese Oberland the valleys were filled to the brim with ice. Water, in the form of ice, played at this period such an important part in both the old and new world's history, that we must give some consideration in our story to the probable cause of its action.

The climatic conditions of this period were probably caused by some eccentricity in the movement of the earth in its orbit; which may occur again, bringing about a repetition of the same conditions.

According to Mr Croll, cold periods recur regularly every 10,000 or 15,000 years. The last great glacial period occurred about 240,000 years ago, and endured with slight alterations of climate for about 160,000 years.

Some writers suggest that there may be a recurrence of these conditions in 21,000 years; others are of opinion that, if it be due to astronomical reasons, it probably began 200,000 years ago, and that existing conditions only commenced to return 50,000 years ago: thus, as imperceptibly as it began, the Ice Age came to an end.

At this period the mammoth and other animals migrated to these shores, and in all probability man accompanied them, and this was no doubt the first occupation of these islands.

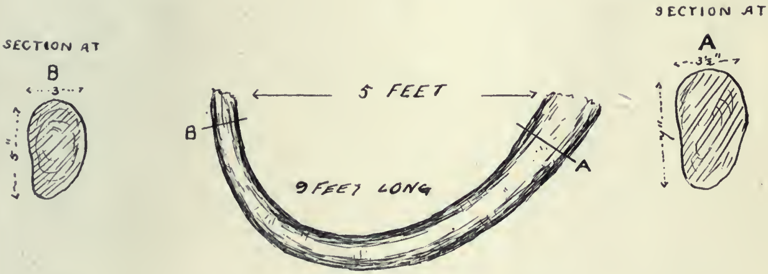
We know that among the remains of the first human settlers those of the elephant, hippopotamus, rhinoceros, horse, bison, deer, bear, etc., and all the smaller animals, have also been discovered.

"Grand indeed was the fauna of the British Islands in those early days. Tigers as large as the biggest Asiatic species lurked in the ancient thickets; elephants of nearly twice the bulk of the largest now existing in Africa and Ceylon, roamed in herds; the lakes and rivers were tenanted by hippopotami as bulky and with as great horns as those of Africa."

Geology points out to us the successive changes the earth has undergone, and in its various rocks we find embedded and preserved remains of the various forms of life which have passed away; "the successive creation of which," says Hugh Miller, "was to introduce man upon the surface of our globe. Man is the end towards which all the animal creation has tended from the first appearance of the first Paleozoic fishes."

He also tells us of the tusks and grinders of 500

ONE OF THE MAMMOTH TUSKS FOUND IN THE DRY CHALK VALLEYS.



SKETCH, SHOWING CURVE AND SECTIONS.

[*To face p.* 240.

mammoths dredged up by the oyster-dredgers on the Norfolk coast from a tract of submerged drift.

The remains of several of these gigantic animals have been found in the glacial drift in one of the dry chalk valleys in Kent. The portion of the tusk shown in the accompanying photograph was 9 feet long, and the writer was unable to remove it, as it was too fragile. When the tusk was cut through, each ring of ivory could be seen distinctly; they were perfectly white, and fell apart separately; the ivory, which in substance resembled very soft chalk or hard soap, could be cut through easily with a sharp knife.

Five of these enormous tusks were found, but could not be removed, and about twenty large teeth were found. Those in the brick earth near the tusks fell to pieces upon exposure to the air; those about 3 feet lower down, in a mixture of rubble chalk and earth, were in splendid condition; several enormous bones, apparently of the legs, were also found, in good preservation.

All these were more or less scattered, and pointed to the fact that the animals did not die there, but that these remains had been deposited or carried there by the action of water.

This goes a long way to prove that these dry valleys were formed under severe conditions, similar to those that must have existed in the Glacial Period.

A relic of this period was lately excavated in Russia by M. Herz—a male mammoth in complete preservation. Portions of undigested food were found in the stomach and between the teeth, so perfectly had the ice preserved it for so many years. It was taken to St Petersburg in its frozen state.

"The remains of the *Elephas primogenius*," says Hugh Miller, "are so abundant in the frozen wastes of Siberia, that what have been, not inappropriately, called ivory quarries, have been wrought among their bones for more than a hundred years."

Referring to these and similar discoveries of the remains of prehistoric animals, Dr Buckland writes:—

"We have seen that the surface of the land, and the waters of the sea, have, during long periods and at distant intervals of time, preceding the creation of our species, been peopled by many different races of vegetables and animals, supplying the place of other races that had gone before them."

How these enormous creatures became extinct has always been a subject of contention. "The old notion," says Darwin, "of all the inhabitants of the earth being swept away by catastrophes at successive periods, is very generally given up. On the contrary, we have every reason to believe that species and groups of species gradually disappear, one after another, first from one spot, then from another, and finally from the world. Certainly no fact in the long history of the world is so startling as the wide and repeated exterminations of its inhabitants."

Other proofs exist in these valleys of a considerable amount of water having found its way to the sea by these channels. In several the solid chalk is not reached until about 50 feet of rubble chalk has been passed through, which has the appearance of having been rolled and washed by water, and re-deposited.

Here again, on one side of the valley, dry chalk banks are found, with but little soil to cover them; on the opposite side of the valley, and at the junction of the two valleys, rich earth has been deposited; and brick earth is found to a depth of over 20 feet.

This must have been deposited at about the termination of glacial conditions.

The reader will probably ask, What has this to do with our subject? Surely water in the form of ice at this period did far more than we can comprehend in making and forming this and other lands to be a fitting habitation for man.

In the Glacial Period elements that occupied different districts were by its action mixed together as well as disintegrated, carried over, and deposited on the hard chalk, rock, and other formations, covering them with rich soil well adapted for the growth of vegetation.

Had it not been for the Glacial Period, many vast districts now rich in the production of fruit and flowers would have been almost barren wastes, and of little value for agricultural purposes.

Here again the work of water in the Glacial Period was to prepare the surface of the earth and provide a source of agricultural wealth, so that posterity could sow and plant, reap and gather into barns, the necessaries of life, which, but for its influence, could never have been produced.

CHAPTER X

SPRINGS

"Then sing along the gushing rills,
And the full springs from frost set free,
That brightly leaping down the hills,
Are just set out to meet the sea."

BRYANT.

A SPRING is an outflow of water from the earth, or a stream of water at the place of its source.

Having followed atmospheric water through the process of evaporation and in the various forms in which it reaches the earth, let us now trace its passage through the soil and rocks, on its way back to the sea. It may fall on the land, evaporate from its surface, be absorbed into the tissues of animal life, or be built into the structures of plants; it may fulfil many mechanical duties, but the sea is its ultimate destination, for these are but delays, transformations, and changes; eventually, by rivulet or stream, it returns to the mighty reservoir, the ocean, from whence it came.

"Thus," says Dr Buckland, "in the whole machinery of springs and rivers, and the apparatus that is kept in action for their duration, through the instrumentality of a system of curiously constructed hills and valleys, receiving their supply occasionally from the rains of heaven, and treasuring it up in their everlasting storehouses, to be dispensed perpetually, by thousands of never-failing fountains, we see a provision not less striking than it is important."

A TYPICAL SURFACE SPRING, HOLLINGBOURNE, KENT, ISSUING FROM THE FACE OF THE NORTH DOWNS.

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From the surface of the ocean a continuous stream of vapour is rising up into the atmosphere, to be re-condensed and precipitated as rain, snow, sleet, etc. It is estimated that $\frac{8}{11}$ of these precipitates returns directly to the ocean (falling into the sea); the remaining $\frac{3}{11}$ falls on the land, collects, forms pools, lakes, rivers, or penetrates into the earth, to appear again as springs, or to form our supplies in underground reservoirs, into which we sink deep wells.

Surface Springs

We have already seen how the rain percolates, forming surface and deep-seated springs.

These springs of various types vary in strength from time to time in proportion to the amount of rainfall, for it is evident that as much water comes out of the earth in the form of springs (visibly or invisibly) every year as soaks into it; for, like a sponge, when full it can hold no more.

Dr H. R. Mill states that "one-third of the rain which falls upon the surface of the earth, in a region like Great Britain, for example, sinks into the ground, and the greater part of it returns to the surface at a lower level than it started from."

Dr John Murray calculates that 130 million million tons of water, or about one-fortieth of the whole mass of the atmosphere, are transferred from the sea surface to the land, and find their way back again in streams and rivers every year.

The manner in which these streams burst from the sides of the rocks is as follows:—

Where the outcrop of clay or other impervious deposit has above it a porous rock, as Chalk or Sandstone, the water passes from the surface through these strata, forming subterranean reservoirs at various depths. On reaching the clay its course is stopped, when the water accumulates, and, by means of some natural channel, issues from the base of the porous formation as a surface or crop spring, so termed from the fact that it issues at the outcrop of the underlying formation. (*See* Geological Section.)

Around these springs and the streams formed by them are the ancient villages. These spots were no doubt selected by our ancestors in consequence of the plentiful supply of pure water.

Many springs of this description may be seen issuing from the southern face of the North Downs, at the base of the Chalk formation overlying the Gault clay, around which luxurious vegetation thrives.

Deep-seated Springs

For an example of deep-seated springs, we cannot do better than confine our attention still to the North Downs. A part only of the water that falls on this formation issues from its southern face as surface springs.

The slope or dip of this formation is in a northern direction. Before the mighty dome or arch of chalk, reaching over the Weald and joining the South Downs, was removed by denudation, the rainfall ran in this direction, forming what are now the innumerable dry chalk valleys.

True, they are dry, no surface stream is to be seen. Every valley possesses its watercourse, but here it is only to be found at a considerable depth from the surface, where not only is every crevice or cavern filled with water, but every minute space; the small interstices of all permeable strata beneath the line of saturation are charged with water, forming a plentiful source of water of great purity, which, when not interfered with by man, secretly discharges into the rivers and seas.

PLAN SHOWING THE DRY CHALK VALLEYS, NORTH DOWNS.

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All over the earth large streams of water flow through the natural cavities of the earth's crust unseen and unknown, in a manner similar to that seen in the caves of Adelsberg, the mammoth Cave of Kentucky, and innumerable other caves found in the limestone regions.

Many disappear and reappear on land, but many vanish altogether, ultimately, no doubt, to well up from the bottom of the sea.

Many suggestions as to the manner in which these dry chalk valleys were formed have been put forward, but to me the explanation given by Professor Phillips appears the most probable; he says: "The numerous undulations upon the surface may be traced into connection as so many ramifications of greater valleys, which themselves unite, and pursue a considerable course without enclosing even the smallest rill, or showing even the mark of a watercourse. These dry valleys descend from their origin in regular slopes and are clearly the work of water, operating with great force, and for some time, but in the present system of nature the watery agent has wholly disappeared."

In the *Geographical Journal* (vol. xv. p. 215) Dr Mill also states that their formation came about at the end of the Glacial Period, when the whole mass of chalk was frozen into a hard and impervious rock, in which the torrents resulting from the melting of the higher snow cut out the valleys.

If the reader will look carefully at the hill-shaded map showing these dry chalk valleys, this will be most apparent. The winding courses of these valleys can be seen distinctly, converging into the principal valley, like so many tributary streams; this principal valley itself leading direct to the sea, it follows precisely the same winding course that it would do if it were a river of water instead of a dry valley. That these valleys were once occupied by running streams of considerable force is apparent; and the large water-worn chalk boulders, already referred to as having been redeposited by water in these valleys 30 to 50 feet below the present surface, also point to this conclusion.

Others attribute the cause to the fractures in the formation by the upheaval of the soil, followed by ages of excessive percolation, causing the destruction of the chalk chiefly by the carbonic acid in the water dissolving it and carrying it away.

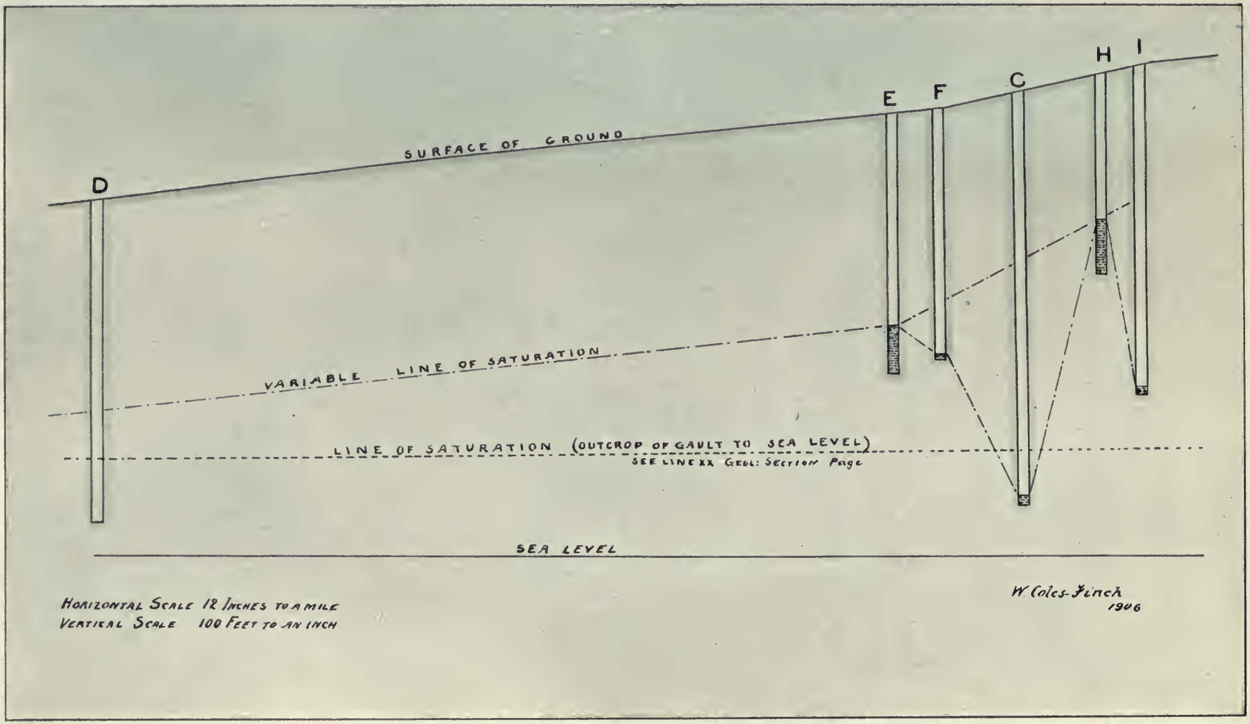
In this formation it is generally found that watercourses follow the valleys, also that percolation is quicker in the valleys. This is due to the fact that in ancient times, in severe weather, they carried a large amount of water over their surface, and at the termination of the frost absorbed an enormous amount of water during the remaining seasons of the year.

Again, these dry chalk valleys have, by the above means, had several hundreds of feet of their surface removed (by denudation). The water therefore reaches the line of saturation with less rock to impede its progress downward.

From actual experience I have found that percolation is quicker in the valleys, and that the watercourses of the different valleys are generally separate and distinct from one another. This has been proved in the chalk valleys between Chatham and Boxley, in Kent.

Here the well, marked "A" on the plan, is fed by a powerful spring, which has for about fifty years supplied a very large community with water.

More water being required, a well, "B," was sunk in the adjoining valley to the westward, about ¼ mile distant, where a very considerable amount of water was found.



SECTION OF WELLS OF DRY CHALK VALLEYS.

[To face p. 248.

When wishing to connect the two wells "A, B" together by means of adits from the bottom of the first well, the water was found to come from separate sources.

For the purposes of driving this adit, the water in well A was kept down on the bottom. During the work the water in well B stood at a level 60 feet above A, and remained so until the adit from A was within about 10 feet of well B.

Again a well was sunk in another valley ⅓ mile to the south of well A, and the previous experience was repeated. A very large watercourse was intercepted, which was proved to be separate from both A and B.

We will now take the valley in which well A is sunk. Here we find that all the wells throughout the valley, which runs in a south-easterly direction, are influenced by the pumping at A.

This influence has been felt for a considerable distance. These separate valleys are therefore, as experience proves, divided by masses of harder chalk, almost impervious.

Should a well be sunk in one of these harder masses, the result would be disappointing.

This was done (at D), and the yield of water was practically nil, notwithstanding that the depth was below the line of saturation, that adits were driven, and water diviners predicted running streams.

I might also mention that two diviners were consulted. Both predicted a supply, but gave different directions as to the way in which the adits should be driven to intercept the "flowing water," a term they frequently use. The instructions of both were followed and both directions tried, but both failed. This, I think, proves that "the days of miracles are past," and that to predict the presence of water successfully the hazel twig should be supplanted by a geological knowledge of the district, coupled with experience and common sense.

Another interesting experience in connection with wells in the Chalk formation, bearing upon the same subject and proving the density of these masses, is worth recording.

Several wells, indicated on the plan and section by the letters E, F, G, H, I, exist close to each other and alternately on either side of a little village street.

The depths of these wells are most remarkable, and prove how, in some places, these blocks or bands of hard and practically impermeable chalk will upset the most careful calculations when searching for water. Curiously, the deeper wells are not in use, owing to their great depth, and yet the water never rises above the levels shown in the section.

These dry chalk valleys are nevertheless a splendid source of supply. They are bountifully provided with deep-seated springs. They give us a pure, cool, refreshing supply of water of a uniform temperature both summer and winter.

This water, being naturally pure, requires no filtration or other treatment, and under the modern methods of pumping and distribution, does not see the light of day from the time it leaves the underground natural reservoirs in the chalk until it is drawn from the domestic tap.

How these wells are sunk and the water obtained will be more fully described in Chapter XVIII.

Fault Springs

When a water-bearing stratum, bearing a hydrostatic pressure (due to its "head"), is imprisoned between two impermeable beds, and finds its way to the surface through a fault in the upper impermeable strata, it is called a fault spring.

Here the conditions are similar to an artesian well or spring, the fault taking the place of the hole bored in the formation.

In every formation there are faults, which vary in importance according to the geological conditions, their extent, and the effect produced; the smallest fault, in certain cases, will cause a spring of water to issue in a dry and barren land, bringing fertility; other enormous faults produce but little apparent results.

These great cracks are caused by upheaval on the one side, or by the formation having been thrown down on the other, in some instances the difference amounting to thousands of feet.

Darwin, in his *Origin of Species*, mentions the Craven Fault, which is 30 miles in length, the displacement varying from 600 to 3000 feet; also a downthrow of 2300 feet in Anglesey, and one of 12,000 feet in Merionethshire; yet on the surface there is nothing to indicate these vast differences, so completely has subaerial and littoral action, through the lapse of endless centuries, smoothed down and obliterated all surface indications of these mighty movements of our earth.

Darwin mentions this to impress on the mind of the reader the vast duration of time, whereby agencies, "which seem to work so slowly, have produced great results."

Submarine Springs

A "submarine" spring, as the name implies, is a fresh-water spring bursting up from the bottom of the sea.

The manner in which these are formed will be seen by reference to the geological section marked A, and described as a submarine spring. Also by the larger sketch, which shows it more distinctly.

These springs are pouring their contents into the seas around our coasts. Some may be seen at low tide, but many are never seen.

"Where the rainfall percolates," says Dr Fischer, "it forms underground reservoirs for the supply of springs and underground rivers: in some cases these are connected by channels with the sea. Here the pressure of the salt water holds up the water in the above channels to a height above the sea-level corresponding with the lower specific gravity of fresh water.

When, however, the upper level of the fresh water is raised, equilibrium is disturbed and fresh-water springs rise up near the shore. Such are found in all parts of the world.

Millions of gallons of water also escape from fissures in the foreshore of St Margaret's, East Kent, and in Dover Harbour fresh water rises up below the sea-line in great volumes.

The amount of water passing into the sea around our coasts in this manner is enormous.

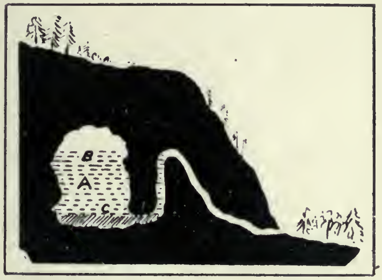
Professor Dawkins states that in the course of a survey of the estuary of the Humber for a projected tunnel, vast volumes of clear water were noted rising like the head of a column in the muddy tidal waters between Barton and Hessle, locally known as the Hessle Whelps.

Innumerable underground caves, and rivers flowing through them, have no visible communication with the surface, and can never be discovered unless by chance, as at the Strood Waterworks, Kent, when well-sinking operations cut through the natural cavities. The sources of similar supplies are the percolation of rainfall on the mountains and hills in the limestone and other porous rocks; and, unlike the caverns caused by disappearing rivers, are hidden from our sight.

These underground channels change their course, as

THE ORIGIN OF SPRINGS (after Prestwich).

The curved lines show the varying line of saturation.
s s s, the variable springs.



SECTION TO ILLUSTRATE INTERMITTENT SPRING.

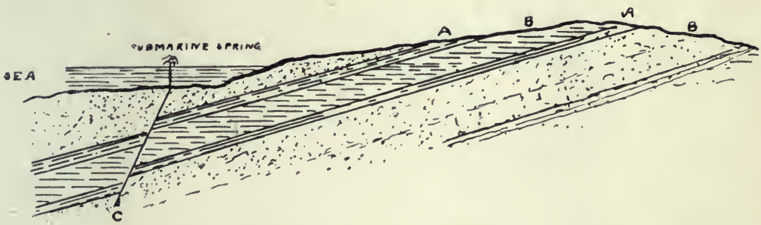


DIAGRAM SHOWING HOW A FAULT MAY CAUSE A SUBMARINE SPRING TO BE FORMED.

A A, rock impervious to water.
B B, permeable rocks.
C, fault by which water escapes under hydrostatic pressure.

[*To face p.* 252.

surface streams do, by altered geological conditions, disruption, etc.; an instance of this can be seen in the Adlesberg Grotto.

Hartwig tells us that in the Gulf of Spezia and in the Port of Syracuse "large jets of fresh water mingle with the brine."

Another author mentions this notable example, which he describes as the Polla di Cadimare, in the Gulf of Spezia. It shoots up to a height of 60 feet from the sea bottom and forms a small hillock on the surface; the water that feeds it falls as rain on the Apennines three miles distant.

Humboldt mentions a still more remarkable submarine fountain on the southern coast of Cuba in the Gulf of Xagua, a couple of sea miles from the shore, which gushes through the salt water with such vehemence that boats approaching the spot are obliged to use great caution.

Sailing vessels are said sometimes to visit these springs in order to provide themselves, in the midst of the ocean, with a supply of fresh water.

> "And in the middle of the green salt sea
> Keeps his blue waters fresh for many a mile."
>
> TENNYSON.

In the West Indies, $\frac{1}{3}$ mile off the coast of the Dutch island of Saba, fresh water can be seen bubbling up in small circles.

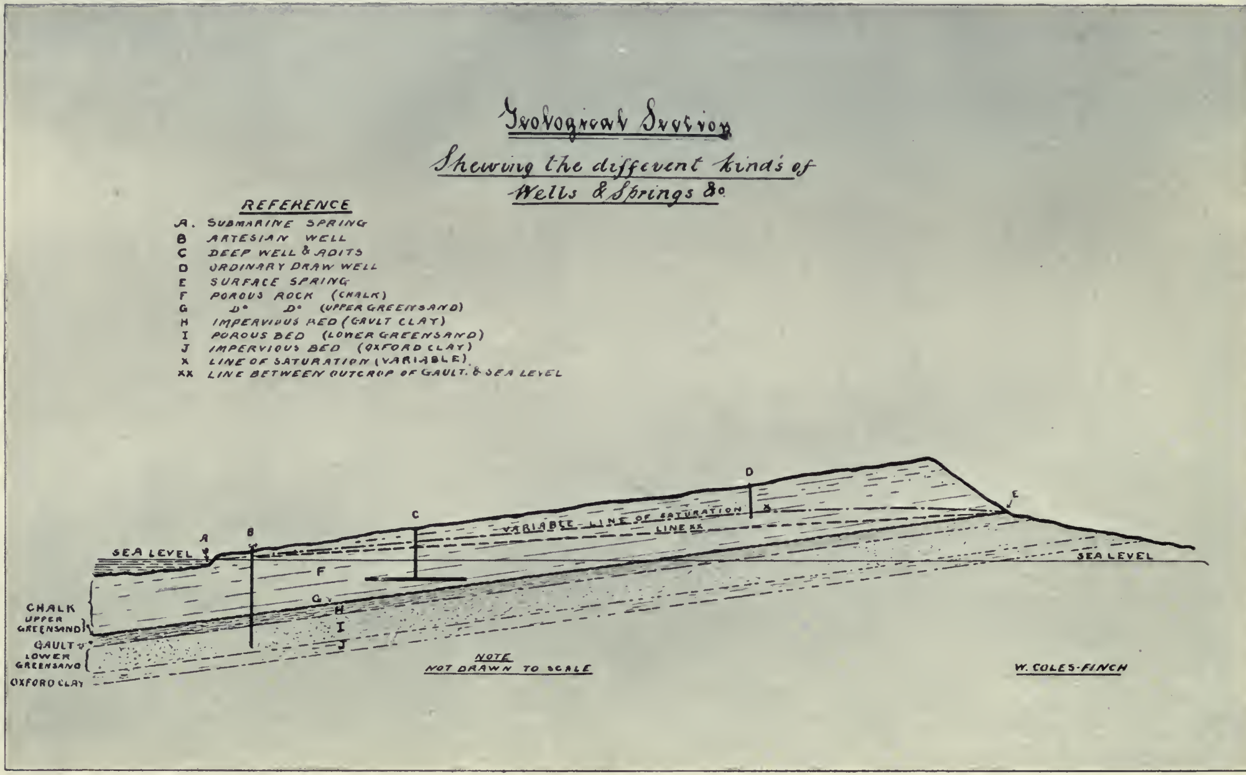
In a paper by H. Benest (*Geographical Journal*, 1899) on this most interesting subject, we find: "Imagine such a subterranean river as that of Bramabiau in the department of the Gard, France, with its seven cascades, its tributaries of Le Bonheur, De la Trouche, and La Rivière du Sud, with its four miles of galleries, great halls, basins, tunnels, fissures, avenues or swallow holes, and ramifications of bewildering extent. Then the subterranean river of Padirac, 2 miles long, at a depth below the Plateau du

Causses de Gramat of 350 metres;—and only think that such discoveries may yet be made as may probably outdo these in extent, then it will not be wondered at that submarine outbursts of pent-up waters occur below sea-level."

"It is shown," says M. Benest in the same paper, "that the hottest region of the earth is the south-west coast of Persia, bordering on the Persian Gulf. The thermometer during July and August never falls below 100° during the night, while in the daytime it rises to 130°; little or no rain falls, and yet, in spite of this terrific heat, a comparatively numerous population contrive to live, slaking their thirst from the copious springs of fresh water which burst forth from the bottom of the sea."

Capillary Attraction

This is the name given to certain phenomena exhibited by fluids, the scientific explanation of which is outside the scope of this work; but briefly, it is molecular action between liquids and solids, and plays a very prominent part in nature; it is by this means that the blood circulates through the smallest blood-vessels in our body, even to the very roots of our hair; that the sap rises in plants; that moisture is absorbed by roots and leaves of trees; that water rises in the sponge, oil in the lamp-wick, etc.;—and if we bear in mind these examples when we consider the phenomenon of the height to which water rises in the earth above its "natural" level, we shall be enabled in some degree to grasp how it is that the line of saturation varies in height in the various watersheds, causing the water to stand higher than the theoretical line of saturation.


Geological Section
Shewing the different kinds of
Wells & Springs &c.
REFERENCE
A. SUBMARINE SPRING
B ARTESIAN WELL
C DEEP WELL & ADITS
D ORDINARY DRAW WELL
E SURFACE SPRING
F POROUS ROCK (CHALK)
G D° D° (UPPER GREENSAND)
H IMPERVIOUS BED (GAULT CLAY)
I POROUS BED (LOWER GREENSAND)
J IMPERVIOUS BED (OXFORD CLAY)
X LINE OF SATURATION (VARIABLE)
XX LINE BETWEEN OUTCROP OF GAULT & SEA LEVEL
SEA LEVEL
VARIABLE LINE OF SATURATION
LINE XX
SEA LEVEL
CHALK
UPPER GREENSAND
GAULT
LOWER GREENSAND
OXFORD CLAY
NOTE
NOT DRAWN TO SCALE
W. COLES-FINCH

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Line of Saturation

The line of permanent saturation is that point in any formation to which the water rises and whence it flows out in the shape of surface and submarine springs. The rainfall percolates to the line of saturation but does not permanently raise it.

The line of saturation is usually considered as being an imaginary straight line, drawn from the base of the porous formation at the outcrop of the impervious stratum to the sea-level.

This is hardly so, for the resistance of the rock and the capillary attraction cause the water to rise to a higher level in the formation, as shown in the accompanying diagram, called the line of variable saturation.

These interesting phenomena, variable and intermittent springs, are generally due to the temporary raising of the line of variable saturation, by abnormal rainfall, or by the melting of snow.

Intermittent Springs

A continuation of dry years, therefore, affects surface springs, and when the line of saturation becomes reduced to any considerable extent, they cease to flow. When it returns to its normal level, they burst forth again. Where this is of frequent occurrence, they are called intermittent springs.

There is another kind of intermittent spring. This will be more easily explained by the sketch in the accompanying diagram. These springs discharge a large amount of water for a time and then cease. The water percolates and accumulates in the natural reservoir A, from which is an outlet in the form of a syphon. The water rises in this reservoir to the level of the top of syphon B. The discharge then takes place, the whole of the water is syphoned out of the reservoir down to level of C, and the spring ceases to flow; when the reservoir is again filled up the operation is repeated, and the contents of the reservoir are again poured out.

Professor Prestwich, F.R.S., in writing of springs of this description, states that "where the ridge of an anticlinal curve in a water-bearing stratum is lower than the outcrop of the bed, the water ascends the curve, which acts as a syphon, there being no communication with the surface, and drains off all the water between, and the spring ceases to flow until recharged, which explains the origin of the intermittent springs of Lavant, in Sussex; the Bourne, near Croydon; and several at the foot of the chalk downs at Folkestone, in Kent."

Intermittent springs are also formed in districts where the rainfall is at times abnormal. The line of saturation is then temporarily raised, and water flows out at a higher level, ceasing as soon as the conditions again become normal.

Variable springs are those which do not entirely cease to flow, but yield a greater or less quantity of water according as the climatic conditions are either wet or dry.

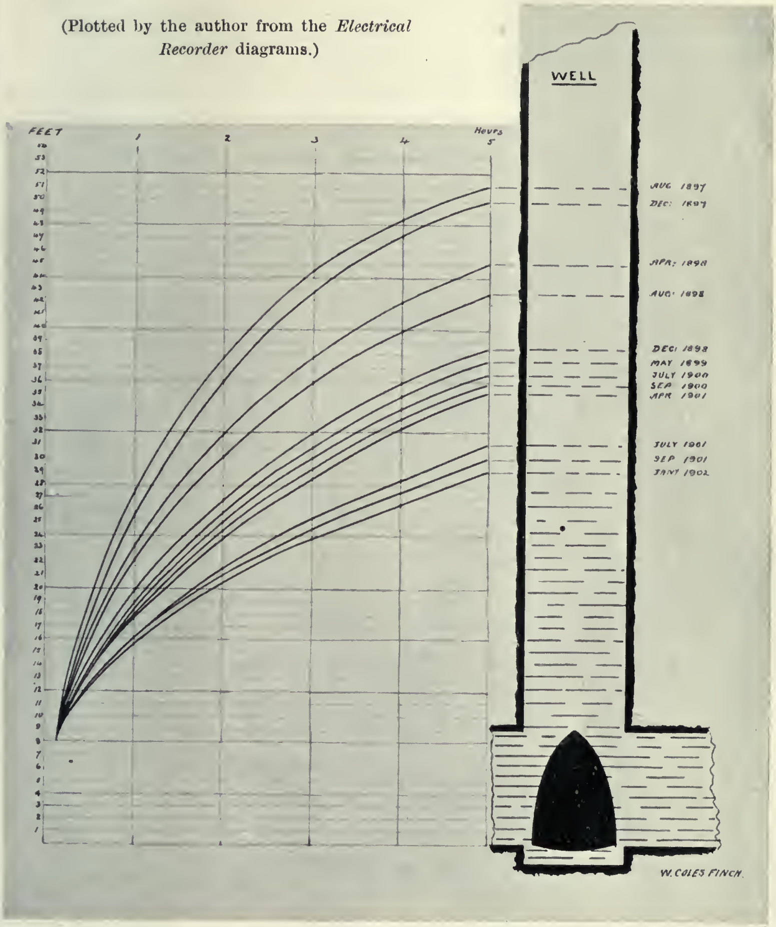
Effect of a Drought on Springs

Before leaving the subject of springs, let us note the effect of a long-continued drought on deep-seated springs in the Chalk formation.

A series of careful observations, extending from August 1894 to January 1902, showed that there was a deficient rainfall, more fully given on the diagram on the opposite page.

DIAGRAM SHOWING THE EFFECT OF A SUCCESSION OF DRY YEARS (1895–1902) ON THE DEEP-SEATED SPRINGS IN THE DRY CHALK VALLEYS OF THE NORTH DOWNS, LUTON, CHATHAM.

(Plotted by the author from the *Electrical Recorder* diagrams.)



RECORD OF RAINFALL (1895–1902) IN INCHES.

1894	1895	1896	1897	1898	1899	1900	1901	1902
28·41	22·38	23 69	21·88	17·86	21·56	24·53	17·58	18·16

During this period there was a deficiency of one and a half year's rainfall, the average for this district being 26 inches. The following year, 1903, was, however, a record year, 32½ inches being recorded.

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The diagrams from which these curves were plotted are recorded daily by an ingenious invention called the electric water-level recorder.

These curves show the gradual diminution in the strength of a large, deep-seated spring, in the chalk, as the dry years followed with marked regularity.

The well is shown, and the adits at the bottom branching off in various directions.

The curves plotted on the section are only given from 9 feet from the well bottom, so as to avoid the adits; and only that portion of the curve is given (five hours' duration) that was covered by the daily variations of the water for the entire period under observation, and throughout the period the daily amount of water pumped was practically uniform or constant.

It will be seen that on cessation of pumping during August 1897, in five hours the water rose in the well from 9 to 51 feet, or 42 feet rise, whereas in January 1902, in the same number of hours, it only reached 29 feet, or a rise of 20 feet.

No curves are given since January 1902, as from that date there was an alteration of conditions, which would cause them to be of no value for purposes of comparison.

These curves show the disastrous effect of a long-continued drought when the pumping at last exceeded the amount of annual percolation of rainfall. This caused the reduction in the rest-level, so far below the line of saturation.

Influence of Rain on Springs

It will also be interesting to find out, as nearly as possible, how soon after the end of a drought the deep-seated springs begin to feel the benefit of the renewed rainfall.

Some writers give three or four months as the time that will probably elapse before the rainfall reaches the line of variable saturation in the chalk hills. The following observations were made with the view of finding some reliable data as to what happens in the chalk valleys, where the line of permanent saturation is about 169 feet from the surface, and the variable line of saturation in abnormally wet seasons 147¾ feet from the surface (surface level 160 feet above sea). [There had been removed, by denudation, probably 200 feet of chalk from this valley, the surrounding hills varying in height from 300 to 400 feet above sea-level.]

A deep well was sunk in the chalk by the writer in 1902, after the eight years of deficient rainfall already mentioned, the records of which are of sufficient importance to be recorded in detail.

The average rainfall for Chatham, Kent, is 26 inches. From 1895 to 1902 there was a deficiency of 41 inches, or an amount equal to about nineteen months' rainfall.

This well was finished late in 1902, when it contained 91 feet of water. This depth continued constant up to the termination of the drought, and represented the reduced line of saturation due to the drought, which came to an end in May 1903. The following table shows both the rainfall and the varying depth of water in the wells, and demonstrates how quickly the rainfall reaches the line of saturation.

Date.	Rainfall in inches.	Depth of water in well. In feet.
1903		
January . . .	2·09	91
February . . .	1·27	91
March . . .	1·88	91
April	1·82	91
May	2·40	91

Date.	Rainfall in inches.	Depth of water in well. In feet.
1903		
June	5·88	92
July	4·70	93
August	2·91	94
September	1·66	96
October	4·15	97
November	2·42	100
December	1·34	103¼
	32·52	
1904		
January	3·31	104
February	2·84	109
March	1·4	112¼

The improvement apparently commences from about one month after the break-up of the drought. The well in question was not influenced directly or indirectly by any pumping operations, neither was any water abstracted from it during the period tabulated.

These figures were taken by the writer personally, and no trouble was spared to ensure accuracy.

For measuring the depth of water in this well, a special instrument was designed by the writer which has since proved to be most reliable.

Infiltration and Pollution

Before leaving the subject of springs, we must give a passing notice to infiltration of sea or river water, etc., into pure-water springs.

The cause of infiltration is usually excessive pumping. That is to say, that an amount of water in excess of the annual percolation has been drawn from the wells, the level of the water being reduced until the natural order is reversed. Instead of surplus water from the well passing on to the sea, the sea or river water flows back into the well and pollutes it.

This occurrence is not unusual, even in wells at a considerable distance from the source of contamination, for it is apparent that the channels by which the pure surplus water from the well flows into the river or sea will, if conditions be reversed, as readily conduct water in the opposite direction.

It is frequently found that at high tide the sea-water dams up the fresh water in the subterranean channels, causing it to rise in wells and springs, so that more water is obtained at high than at low tide. In some wells water can only be obtained when the tide is high: the water is pure and fresh. The tide here merely raises the level of the spring water in the well by preventing its escape from a lower outlet; but if the distance from the sea or river be considerable, the time occupied by the water in reaching the well or boring produces the opposite result. For instance, a boring at Fulham, 318 feet deep, yields less water at flood-tide than during the ebb.

Darwin found that the natives of Keeling Island obtained their pure water from "ebbing wells" or wells sunk in the sand or porous coral rock, which is saturated by sea-water. The rain which falls on the surface displaces the sea-water as it sinks into the rock, the fresh water rising and falling with the tides. These ebbing wells are common, he states, in the low islands of the West Indies.

In some wells sunk in the sandy deserts of the southern borders of Algeria fish have been found, proving that water travels many leagues from where it has leaked into the crevices and tunnels of the earth from lakes or rivers.

In the Argostoli peninsula, in the island of Cephalonia,

The Author.

A DEEP-SEATED SPRING IN THE DRY CHALK VALLEYS OF NORTH DOWNS.

This spring is bursting through the face of the rock into the artificial adit 240 feet below the surface (100 feet below the line of saturation). It is yielding about 1,500,000 gallons per day.

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2,000,000 cubic feet of sea-water disappear through the fissures of the rock, and it is presumed that this reappears in the brackish springs of the island.

Referring to the percolation of sea-water, Dr K. Natterer concludes that, as a general rule, sea-water is percolating through the capillary pores of the mud on the ocean bottom, being sucked in by the underlying rock strata.

When sinking artesian wells, water of inferior quality is often met with, and tubes are forced into the boring to prevent it from contaminating the pure supply.

Under certain circumstances, water from a stratum having a hydrostatic pressure will rise in the earth and disappear in the porous formation at a higher level. Deep borings have frequently been sunk and a larger source of supply tapped, but the water has failed to rise to the surface. This proves the necessity for water engineers to study the geology of their district; a boring of this kind would apparently be yielding nothing, when a plentiful supply might be obtained by inserting tubes in the bore-hole to convey the water through the porous rock, to the surface, without loss.

Geysers

"Into the sunshine,
  Full of the light,
Leaping and flashing
  From morn till night!

Into the moonlight,
  Whiter than snow,
Waving so flower-like
  When the winds blow!

Into the starlight,
  Rushing in spray,
Happy at midnight,
  Happy by day!"

J. R. Lowell.

We will now pass on to the springs of a very different kind, viz. "geysers." This word is derived from the Icelandic name of *geysa*, from *gerso*, to gush or rush forth.

Geysers are boiling fountains, which spout intermittently. They are usually situated in volcanic districts.

The enormous power required to eject the mass of water is supposed to be steam generated and accumulated in a large cavern in the earth.

When the pressure sufficient to overcome the weight of the water has accumulated, the water is ejected periodically.

Referring to the geysers of Iceland. "Blasts of superheated steam," says Professor E. Suess, "entering the tube laterally at great depths, are subjected to the pressure due to the column of water in the tube, which raises the boiling point, let us say, from 100° to 124° C. Successive hot blasts eventually raise the temperature to 124° C. and the explosion follows; the upper column of water is blown into the air."

The "Bunsen" and other theories are put forward to account for this enormous pressure.

In the south-west of Iceland, about 30 miles from the crater of Hecla, there are over one hundred geysers within a circuit of 2 miles. Rising through a bed of lava, they throw their columns of boiling water into the air.

Few play for more than five or six minutes at a time, and the periods of inactivity vary from about two hours to thirty hours.

The principal one, which is called the Great Geyser, discharges a column of boiling water from the summit of a mound of siliceous deposit over 20 feet high.

The discharge is nearly always announced by rumbling noises like distant firing of cannon, as a prelude to the approaching activity.

Of this geyser it is stated that it spouted eleven times a day in 1770; in 1814 every six hours.

The height to which this column of water ascends has also been variously stated as 360 feet in 1770 and 100 feet in 1864: the latter was an actual measurement.

Since this date a height of 200 feet has been recorded. The water spouts higher and higher with each successive pulsation until the maximum is reached.

The display occupies about 7½ minutes, and the height of the eight jets in which the water issues would average about 45 feet.

The natural pipe or outlet through which the water is ejected is 10½ feet diameter, quite cylindrical, and no irregularity was found to a depth of 68 feet; but from 68 to 80 feet it is irregular. No measurements beyond this depth are recorded.

One display, therefore, is equal to about 1,410,000 gallons, or over 6000 tons of boiling water, which is hurled into the air in 7½ minutes.

Silica and soda are the chief constituents of this water; the specific gravity being 1·0008 (Faraday). The temperature of the water at the surface is 187°. At a depth of 78 feet down the pipe it increases to 257° F.

The Earl of Dufferin visited this geyser in 1856. "After watching over it for three days, he was at last rewarded. He considered it a magnificent spectacle, the display lasting seven or eight minutes. The height of the column did not exceed 60 or 70 feet; he considered 100 feet as the probable maximum. Many trustworthy records give 200 feet, but he considered 300 feet as fabulous."

If the heights recorded in 1770 and other years are correct, it is evident that the powers of this mighty fountain are waning; we may then expect it to degenerate eventually into a boiling spring only, and this is a reasonable conclusion.

Boiling springs, many ages since, may have been geysers; if so, there is no reason to suppose that this fountain was not much more powerful 130 years ago than it is to-day.

Another most interesting geyser is "The Old Faithful," in the Yellowstone Park in the United States. This national reserve is 55 miles wide, 65 miles in length, and comprises 2,288,000 acres.

It is entirely a region of thermal waters; scarcely a foot of the 3575 square miles but has been honeycombed by active, passive, or extinct fountains; there are now seventy-one geysers and some 3000 hot springs in this district.

The eruptions of "Old Faithful" begin with a few spurts lasting about four minutes; they then become more powerful, and jets rise with a roar in rapid succession to a height of 130 feet, the steam ascending 500 feet. The beauty of the display is often greatly increased by rainbows.

Geysers and hot springs are found also in New Zealand, Arkansas, California, Nevada, British Columbia, Mexico, Thibet—in fact in nearly all parts of the globe.

The geysers of New Zealand deposit much common salt and other mineral matter, which forms pools of flinty rock of beautiful shape and colour, covering many square miles with siliceous deposit, to which we shall refer presently.

Water as a Solvent

Water is the most powerful and general solvent found in nature, hence it is never found quite pure, for it will hold in solution almost all bodies, and as a rule it holds in solution a greater quantity while hot than when cold: on cooling, the surplus matter is precipitated in the form of crystals, and if the remainder be evaporated, more crystals will appear.

There is probably no terrestrial substance which, under proper conditions, is not to some extent soluble in water.

All surface rocks contain water. No mineral substance is strictly impervious to the passage of this liquid.

"Even in the rain which falls on the chalk hills and passes into the deep-seated springs, about 1¼ tons of material per million gallons of water pumped is found, and when this is abstracted additional storage is provided for 110 gallons of water" (De Rance).

Thermal or Hot Springs

Thermal springs, as the name implies, are either hot, warm, or tepid, which issue from the earth in a similar manner to the ordinary surface springs, having a temperature far above that of the atmosphere. For instance, there are the thermal waters of Carlsbad 165°, Wiesbaden 158°, Baden-Baden 111° to 154°, Bath 104° to 120°, Aix-les-Bains 109° to 112°, and Buxton 82°.

Referring to "The Student's Lyell," it is stated that "the comparatively small spring 'Bath' has relieved the earth's crust, in 2000 years, of as much heat as was dissipated in the eruption forming Monte Nuovo during three days in 1538. Nor was the actual amount of matter brought from the earth's interior, and deposited on its surface by the Bath spring, less than that resulting from the outburst that produced the Monte Nuovo; but while in the latter case the materials were piled up round the volcanic orifice and remain to our view, in the former they were carried into the Avon, from the Avon into the Severn, and by the latter delivered to the ocean.

This is given as illustrating how much may be effected by slow, continuous action, as contrasted with violent and spasmodic activity."

It is an interesting fact that life is possible in these waters: in the waters of Hamman-Meskoritin the little beetle Hydrobius lives and thrives in a temperature of 130° F.

Thermal springs are not confined to volcanic districts. The hot springs of Bath, for instance, are 900 miles from the Icelandic volcano on one side, and 1100 from those of Italy and Sicily on the other.

In many parts of the world hot springs issue from the earth heavily charged with carbonate of lime, which cover the country around with beds of calcareous tufa or travertine.

The pink and white terraces of Rotomahana (New Zealand) formed one of the most marvellous sights of the world. These consisted of a series of basins formed by the deposit of the siliceous matter in the water in the hot springs, which fell in cascades from basin to basin, forming a series of terraces with a flinty surface like polished marble. These basins were fringed with stalactites and filled with clear blue water of various temperatures.

The district covered by the hot lakes measures 120 miles from north to south by 20 miles in width, the surface is hot and crumbling, and it is an easy matter to get immersed in boiling mud.

On 10th and 11th June 1886, Mount Tarawera burst into activity, and a series of volcanic explosions occurred. Mountains were uprooted and hurled from the centre of a range 2½ miles long and to a depth of 1400 feet. With these mountains disappeared the pink and white terraces and springs of Rotomahana, and many of the natives in a neighbouring village were overwhelmed.

THE PINK AND WHITE TERRACES AND SPRINGS OF ROTOMAHANA, NEW ZEALAND.

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In the Grand Soufrière of Dominica there is a lake in an active state of ebullition, 2400 feet above the sea. It is 600 feet wide, and no bottom was touched at 195 feet.

In Palestine there are many springs of hot water, which issue forth on both sides of the Jordan Valley, the temperature of which ranges from 109° to 144° F.

Thermal springs, with an average temperature of 80° F., exist on each side of the Sea of Galilee. Hot baths south of Tiberias include seven springs, the largest having a temperature of 137° F.

In New Zealand, within a short distance of the terminal face of the Fox Glacier, is a hot spring the temperature of which is over 100° F. On the ice-bound top of Mount Ruapehu (in the North Island), 9100 feet high, there is a boiling lake in the centre of the crater, into which the surrounding ice melts.

Another remarkable instance is that of Chillan in the province of the same name on the western flank of the Sierra Nevada, 2050 feet above sea, where icy-cold and boiling springs exist in close proximity to one another.

There are also the hot wells near Suez called "Eyoon Moosa," or the "Fountain of Moses"; also those called "Hamman-Pharaoon," or the "Bath of Pharaoh," whose waters resemble in their constituents those of the Dead Sea.

At Hot Springs, a village in Arkansas, U.S.A., there are sixty hot springs which together have a flow of 500,000 gallons per day, the temperature varying from 93° to 150° F. Many of the hot springs of Iceland have a temperature of 208° F. and smell strongly of sulphuretted hydrogen.

Earthquakes frequently influence mineral and thermal springs. The springs of Cauquenes (Central Chili), after the great earthquake of 1822, ceased to flow for nearly a year; the earthquake of 1835 also caused the temperature of the water to fall suddenly from 118° to 92° F. (Darwin).

Climatic conditions have no influence on hot springs—they gush out even from under the snow in the Himalayas.

Coming near home, we have within a short distance of one another, at Buxton, both hot and cold springs, the former at a temperature of 80°, which supply water at the rate of 60 gallons a minute.

Thermal and Mineral Waters

In referring to these waters, Hartwig says: "How truly wonderful is the chain of processes which first raises vapours from the deep and eventually causes them to gush forth from the entrails of the earth, laden with blessings and enriched with treasures more inestimable than those the miners toil for."

The water in descending, percolating, and rising through various mineral masses becomes impregnated with gaseous saline or metallic admixtures which impart to them particular properties. These waters are called mineral waters, and are named according to the predominant constituent.

There is apparently great difficulty in classifying these waters, for nearly every spring contains some proportion of the characteristic ingredient of another group.

One writer sarcastically remarks that "nature of her bounty has furnished us with innumerable healing springs, to help us to remedy the ills we have brought upon ourselves by errors of diet and living." He speaks feelingly, and as if from experience, and his rough classification of these waters, with their principal element, is of interest.

1. Thermal	.	Heat.
2. Muriated	.	Common salt.
3. Alkaline	.	Carbonate of sodium.
4. Sulphated	.	Sodium sulphite (Glauber's salt) or magnesium sulphite (Epsom salts).
5. Chalybeate	.	Iron.
6. Arsenical	.	Arsenic.
7. Sulphur	.	Sulphuret of hydrogen, sodium, calcium, potassium or magnesium.
8. Calcareous	.	Earthy substance.

Springs of this description, like all nature's gifts to man, are more or less common in all countries.

We in England may be forced to travel to see many of nature's wonders, but the spas of England, the remedy for many ills, are fortunately near our doors, and of such variety as to be unsurpassed by those abroad.

The very fact of their being near to hand, like other things and scenes, seems to bring them into contempt, the result being that our own mineral waters have been, and still are, greatly neglected, people who can afford to do so preferring to patronise those in other countries.

In the *Daily Telegraph* on 5th June 1906 a correspondent gave some interesting news of an accidental discovery of mineral water in boring for water for the new public baths in Camberwell.

The water was found to assume a rusty tinge on exposure to the air, and to be rich in iron, comparable in this respect to the water of Tunbridge Wells.

In 1678 Dulwich Wells were held in high repute, the chalybeate waters being largely used medicinally. A writer of that period describes them as being "a certain cure for every ill to which humanity is heir."

Streatham is also stated to have possessed mineral springs in the middle of the seventeenth century; these waters were supplied to many of the London hospitals as late as the beginning of the nineteenth century.

Other famous springs existed in the environs of London, including Hampstead, whose springs were in great request in the seventeenth and eighteenth centuries (Well Walk exists to-day), and at a period of their greatest popularity were advertised and described as "inexhaustible fountains of health." The same writer, however, tells us that when George III. bestowed his patronage upon Harrogate and Cheltenham, these waters declined sadly in popularity.

Harrogate is especially favoured, having, it is said, eighty different wells which cannot be equalled for variety and efficacy.

The muriated waters of Homburg and Wiesbaden are also to be found at Llandrindod Wells and Woodhall Spa.

Sulphated waters, somewhat similar to those of Carlsbad, Apenta, Hunyadi Janos, Friedrichshall, and Rubinat, could also be obtained at Cheltenham and Leamington.

Chalybeate waters, more or less similar to Homburg and Rippoldsan, can be found at Harrogate, Llandrindod, Tunbridge Wells, and Buxton.

Indifferent waters are found at Wildbad, Baden, Gastein, etc., also at Buxton.

Earthy waters such as Bormio, Dax, etc., are found at Bath.

Saline springs as at Salzungen, Ischl, Reichenhall, etc., are to be found at Droitwich.

The cold sulphur springs of Challes, Enghein, etc., have their equivalents at Harrogate.

Warm sulphur springs appear to be about the only kind that are not to be found in this country; they are not so widely diffused, and for them we must go abroad, many existing on the borders of the Dead Sea.

No hardship should, however, be experienced by those who, by force of circumstances, have to take their British remedies with British scenery, for the few instances quoted show how blest we are here, if we will only avail ourselves of the benefits around us and leave our more wealthy brethren to combine foreign scenes with foreign waters.

Mineral springs are found on the Alpine heights, under the snow in the Himalayas, and arising from the bottom of the ocean, as at Baiae and Ischia.

The warm salt springs of Caldas de Mombay, near Barcelona, have a temperature of 158°, and Jemez Waters, in New Mexico, carry a temperature of 168°. Mineral springs abound in Austria in greater numbers than in any other country, there being no fewer than 1500, the principal being Carlsbad, Marienbad, Franzenbad, Teplitz, Pullna, and Seidlitz.

At Kissingen, Bavaria, there is a salt spring which rises to a height of 58 feet above ground from a depth of 1878½ feet; this is not a natural spring: the boring was completed on 12th August 1850.

Indifferent waters, at a temperature of 85°–95° F., are found in the Pyrenees (Panticosa), 5110 feet above sea-level.

Warm earthy waters 93° to 104° F. are found at an altitude of 4400 feet at Leuk, Switzerland, and Bormio, in Northern Italy.

Iron waters at St Moritz, Switzerland, at an altitude of 4464 feet.

Warm sulphur springs 113° F. at an altitude of 4100 feet at Barèges and other spots in the Pyrenees.

Alkaline waters 100° to 125° F. at Mont Doré and Bourboule (Auvergne), 3300 and 2800 feet in altitude respectively. Also at 4000 feet in Lower Engadine (Trasp).

Many mineral springs have their waters heavily charged with soluble salts. Where lime is present it is kept soluble by the carbonic acid gas; when this is given off by heat or exposure to air, the lime is deposited in the form of rock.

At San Filippo, in Tuscany, there is a spring of this description, which deposits lime at the rate of 12 inches a month; this spring has formed a bed of rock 250 feet thick, 1¼ miles long, and ⅓ mile broad. The well-known building-stone called travertine or Tiber stone, largely used in Italy, is a mineral-spring deposit, being a concretionary limestone, hard and semi-crystalline. The Colosseum and a large proportion of ancient and modern Rome was built with it.

The Carlsbad springs produce a considerable amount of matter every year. Dr Schuman Leclercq of Carlsbad, in a letter to the writer, states that there are fifteen of these springs and that their combined yield is 870,000 gallons of mineral water per twenty-four hours. The "Sprudel," with a temperature of 163·6° F., is the principal spring, which deposits about 110 lbs. per twenty-four hours of "Sprudel Sinter." Each of the other fourteen springs has a distinct temperature, varying from 47·6° F. to 147·6° F., no two of them being identical. The waters of these springs also contain a considerable amount of calcium carbonate and carbonate of magnesium (a portion only of which is deposited).

The hot springs and ponds of Tuscany deposit native boracic acid called sassolin, which was first discovered in the province of Florence, at a place called Sasso.

Springs of chloride of sodium exist in the Eastern Cordilleras, and stretch from Princeima to the Llanoes de Meta, a distance of 200 miles.

Water heavily impregnated with sulphur, from the sulphur springs of Iceland (Krisuvik), is worth a passing notice in our story.

In many places the surface of the ground is covered with a crust of almost pure sulphur 2 or 3 feet thick. The water from which this sulphur is derived is ejected with a hissing noise, to a height of from 5 to 8 feet, accompanied by steam impregnated with sulphuretted hydrogen and sulphurous acid gas. The sulphur was at one time mined for export, the surface clay containing 15 to 90 per cent. of sulphur.

These springs are due to the infiltration of water on vast beds of pyrites, for it is found that after a continuance of wet weather, the amount of steam, etc., issuing from the springs is always greater.

In Chili there are numerous thermal saline and sulphurous waters, at temperatures from 50° to 212° F., at an altitude of from 1150 feet to 10,690 feet.

Bagnères-de-Luchon, a small town in the province of Haute-Garonne, at the foot of the Pyrenees, is celebrated for its sulphurous thermal springs, which have a temperature of 88° to 180° F.

Some springs, like the "Wildbader" of the Continent, and the Malvern Springs, are purely thermal; there is an entire absence of dissolved solids, the water being pure, clear, soft and limpid.

Many waters are found to be naturally impregnated with carbonic acid gas, which is found to aid digestion.

Some artificial table waters contain only carbonic acid gas, others but little dissolved solid matter in addition.

Figuier says: "The last phase of volcanic activity is the disengagement of carbonic acid gas, without any increase of temperature.

"In places where the continued emanations of carbonic acid gas manifest themselves, the existence of ancient volcanoes may be recognised, of which these discharges are the closing phenomenon.

"This is seen in the most remarkable manner in Auvergne, where there are a multitude of acidulated springs; that is to say, springs charged with carbonic acid."

The greatly esteemed selters water, more commonly known as seltzer, is a natural mineral water found in the village of Niederselters, in the German province of Hesse-Nassau and elsewhere; it contains chiefly carbonic acid, carbonate of soda, and common salt. Artificial substitutes for this water are largely manufactured.

Apollinaris is a natural aerated acidulated soda water, obtained from a spring in the valley of the Aar, near the Rhine: this water is in great demand as a beverage.

CHAPTER XI

RIVERS

> "Ten thousand rivers poured at his command,
> From urns that never fail, through every land;
> These like a deluge with impetuous force,
> Those winding modestly a silent course."
>
> WILLIAM COWPER.

A RIVER system consists of a number of small streams or tributaries that drain a certain area, united and forming one main stream, and the land drained thereby is called the river-basin, the watershed being the higher ground which divides or parts the basins of neighbouring river systems from one another, each river system discharging its water into the sea independently.

Rivers are among the most important of the natural features of our globe. As important highways of communication they are only equalled by the sea, and are intimately connected with the history and condition of mankind.

For transport of merchandise to inland towns their utility is also unequalled, and tidal rivers especially form in this aspect one of a country's greatest assets.

Rivers are the vehicles by which the atmospheric precipitates (rain, etc.) falling on the land are returned to the sea. Rivers formed the most important consideration in past ages, in the selection of a site for a settlement by our ancestors as may be noticed on reference to a map.

This was, no doubt, a very wise move on the part of man; unfortunately, however, he no sooner set up his abode there than he began to contaminate the very stream that by its purity attracted him. This seemed an unimportant or far from serious matter to him, and in his ignorance the fouling of the stream continued, and to our shame let us acknowledge the fact, that in our wisdom we do likewise in an exaggerated degree, with the result that many of our beautiful rivers, in which at one time salmon thrived, are now only capable of supporting the commoner fishes; and even the delicious oyster may convey to us the dreaded typhoid, the outcome of sewage contamination.

Charles Kingsley's *Clear and Cool* describes the present state of our rivers admirably.

Some rivers have for their source a lake, or flow from under glaciers.

In the accompanying illustration we see a typical source of the glacial stream. It is an arch of enormous dimensions, a perfect vault of crystal ice, with its blue horizontal veins showing distinctly, from which issues the turbid glacial stream. This arch is in the terminal end of the Loen Glacier, Norway, and is 50 feet high; with the aid of a magnifying glass, groups of persons can be seen at the entrance.

> "Where from their frozen urns, mute springs
> Pour out the river's gradual tide."
>
> LONGFELLOW.

The Rhone has its source in and flows from under the large Rhone Glacier (5581 feet above sea), turbid with suspended matter, due to the grinding of the glacier on its bed, to the Lake of Geneva, and on to the sea.

This river, at St Maurice, like the Rhine at Rheineck, and most glacier-fed streams, is warmer than the air in winter and colder in summer. In the months of April

Mr H. Wingent.

A NEARER VIEW SHOWING STREAM ISSUING FROM THE ICE-TUNNEL.

ICE-CAVE FORMED IN THE SNOUT OF THE LOEN GLACIER (NORWAY) BY THE GLACIER STREAM.

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and October the temperatures of air and water are equal. The Arveiron is another of the many rivers which arise from glaciers, issuing from an arch of crystal ice similar to that depicted in the Loen Glacier.

It may interest the reader to know that the influence of the glacier on the temperature of its stream is considerable, varying of course according to the different conditions; but as far as the Rhone and the Rhine, which are typical of many other rivers, are concerned, its influence is distinctly recognisable 84 miles from the glacier of the former river and 99 miles from that of the latter river.

Streams that originate in the melting of snows are subject to periodical floods, and at times overflow their banks and do much damage. Other rivers, which are formed by rain falling on impervious rock, forming streams and torrents, cut into the earth, and carry solid matter into the sea.

Some rivers owe their origin to springs, where the water falls as rain on a porous stratum, sinks into the earth, bursting out at a lower level, forming numerous tributary streams, which unite and form a river.

All rivers, whether swift or slow, are continually assisting in the work of denudation in proportion to their size and velocity.

Dr Hutton, referring to this part of the work of rivers, says: "The summits of mountains are degraded, the solid and weighty materials of the mountains have everywhere been carried through the valleys, by the force of running waters."

"Amidst the din of rushing waters," says Darwin, "the noise from the stones as they rattled one over another was audible from a distance. All were hurrying in one direction: the ocean is their eternity, and each note of that wild music told of one more step towards their destiny."

The soil that is produced in the destruction of the solid earth is gradually transported by the moving waters, and is as constantly supplying vegetation with its necessary aid. This drifted soil is at last deposited upon some coast, where it forms a fertile country.

Length of Rivers

Before proceeding further with the work of rivers, let us try to obtain some idea of the immensity of the rivers of other countries, by comparing them with a river we all know well, the Thames.

	Length in miles.
Thames, England	210
Tagus, Spain	510
Loire, France	570
Vistula, Prussia	630
Rhine, Switzerland	760
Danube, Germany, etc.	1700
Indus, Hindustan	1800
Volga, Russia	2100
Obi, Siberia	3000
Congo, Africa	3000
Yang tse Kiang, China	3200
Nile, Egypt	4300
Mississippi, America	4400
Amazon, America	4700

Compared with these lengths, the Thames is but a little rill.

When we remember that from Southampton to New York is about 3000 miles, we may perhaps better comprehend the enormous length of such a river as the Amazon.

The length of a river, however, does not always denote its comparative importance; the area of its basin would be a better guide. The area of the Thames basin is 6000 square miles, that of the Amazon 2,230,000 square miles. Therefore, although the Amazon is only 23 times as long as the river Thames, it drains an area 370 times as large. When we are dealing with the work accomplished by some of these mighty rivers, it would be as well to bear in mind that the longest and largest river in the world (Amazon) drains an area equal to four times that of the whole of England and Wales.

Velocity of Rivers

The velocity of rivers forms the key to many statements that will be made in reference to the work and destruction caused by rivers.

The velocity of a river depends upon the inclination of its bed, and partly on the volume of the water, and varies throughout its course accordingly.

The swiftest portion of a river is about one-third of the way below its surface, the mean velocity about one-tenth of its depth; at the bottom the velocity is least.

The velocity of the Thames is 2 to 3 miles an hour, and the gradient of its bed is 21 inches per mile.

The Nile below Cairo has only a fall of 3¼ to 4½ inches per mile, while the Arve at Chamonix thunders down a slope of 1 foot in 616, or 102 inches per mile.

The Danube, in the upper part of its course, falls 26 feet in 2½ miles. The Amazon, in the last 700 miles of its course, falls only one-fifth of an inch in a mile.

Another remarkable river is the river Jordan, the largest river in Palestine, whose valley forms one of the most remarkable depressions in the world. Its several streams unite in the Bahr-el-Huleh, where it flows rapidly in a narrow rocky bed into Lake Tiberias; from here, over a straight line of 70 miles, it manages to cover, by innumerable windings, a length of 200 miles, or nearly three times the distance covered, before falling into the north end of the Dead Sea. The total fall is 2300 feet, the Dead Sea being 1292 feet below the level of the Mediterranean Sea.

Some rivers disappear into the earth by percolation. The river Murray (Australia), for example, loses on its course vast quantities of water in this manner. It is calculated that between Albany and Howlong alone 5,000,000 gallons per day percolate into the earth.

This same river at Mildura contains only 10 per cent. of the rainfall over its basin, whereas higher up the stream 20 per cent. flows in its channel.

The loss by percolation in this district is so great that the proportion of the rainfall visible here in the form of rivers is smaller than in any other part of the world.

In Northern Chili (Copiapo) Darwin discovered a valley, the bed of a streamlet; following it up, he came to good water. He found that, owing to the decrease in the evaporation and absorption during the night, the stream flowed a league further then than during the day.

The swiftest river in the world is the Sutlej, one of the tributaries of the Indus, in the Punjab, British India, which has its source in a lake in Thibet, at an elevation of 15,200 feet, and pierces the Himalayas through a gorge with heights of 20,000 feet on either side. At one part of its course it descends 12,000 feet in a distance of 180 miles.

Several Swiss rivers run through narrow gorges of great depth. The Via Mala, from Schams to Thusis, in Switzerland, is 5 miles in length and 1600 feet deep, and not more than 30 to 50 feet in breadth.

We shall now better understand the enormous amount

Mrs Aubrey Le Blond.

THE NATURAL BRIDGE AND GORGE, CONSTANTINE—CUT OUT BY WATER.

[*To face p.* 280

of solid matter these monsters carry to the sea each year.

Every river has its own peculiarity of some kind. Some are too swift for transport purposes, as the Hoang-ho; some are liable to floods, as the Loire; some are very shallow, as the Elbe; others are subject to alteration by various substances, gathered up by them on their course. The Salt River of Australia and many others owe their salinity to the soil over which they pass.

The Vinegar River of New Granada, in Central America, owes its character to the presence of sulphuric acid in its water.

In Algeria there is a stream one tributary of which is strongly impregnated with iron, while another, from a district of peat marshes, is rich in gallic acid; and when the two streams meet they form a river black as ink, for its tributaries contain the two principal ingredients of that fluid.

The Hoang-ho or Yellow River of China derives its name from the yellow earth it carries in suspension. In 1887 this river burst its banks 300 miles from its mouth, causing a loss of life estimated at at least 1,000,000.

The Tiber has been designated the " Yellow Tiber " from the yellow mud held in suspension in times of flood.

Solid Matter in Suspension

The foregoing particulars as to the velocity of rivers lead us to ask what substance water will carry at various velocities.

At the rate of 3 inches per second it carries fine mud.
,, 6 ,, ,, fine sand.
,, 8 ,, ,, sand the size of a pea.

At the rate of	12	inches per second	it carries	fine gravel.
,,	24	,,	,,	round pebbles 1 inch in diameter.
,,	36	,,	,,	angular stones as large as an egg.

The reader must bear in mind that stone or other body when submerged does not require so great an effort to move it as when it is in the air; its actual weight under water depends on its specific gravity; if it be twice as heavy as an equal bulk of water, it will lose half of its weight when submerged; if three times the weight it will lose one-third; if four times, one-fourth; and so on. (*See* Specific Gravity.)

The following table gives the amount of mud, etc., in suspension, in the water of a few of the principal rivers, in parts per 100,000.

Thames at Battersea .	parts per 100,000, solid matter	3
Rhine	,, ,, ,,	50
Mississippi . . .	,, ,, ,,	146
Nile . . .	,, ,, ,,	160
Ganges . . .	,, ,, ,,	194
Tiber	,, ,, ,,	456
Hoang-ho . . .	,, ,, ,,	500

(The low figure for the Thames is probably due to the fact that by the time the water has reached Battersea it has passed over many weirs, and the greater part of the solid matter in suspension has been deposited on its way.)

The Ganges, in the 122 days of the rainy season, carries to sea, a distance of 500 miles, 340,000,000 tons of mud.

Livingstone described the Zingesi, a river 60 or 70 yards wide and waist deep, as being made up of as much sand as water.

Water is continually moving stones and soil from higher

A BEAUTIFUL NORWEGIAN WATERFALL NEAR TRONDHJEM CARRYING ON ITS WORK OF DENUDATION.

[*To face p.* 282.

to lower levels, where it is deposited and forms deltas, etc., to which we shall refer.

Were it not for the rivers, the valleys would gradually be filled up.

We must not confound suspension with solution: the former word refers to matter temporarily held up, principally by the velocity of the water, and continued agitation; in solution the solid matter is dissolved in the water.

Matter in Solution

All rivers are carrying matter in solution to the sea. This is especially the case with rivers which flow through calcareous districts.

The Thames, for instance, carries down no less than 450,000 tons of salts in solution annually.

The English rivers are now carrying down, in solution, enough solid matter to lower the general surface of the country by about 1 foot in 12,000 years. To this must be added, of course, the amount previously mentioned as in suspension, so that the total denudation in England from both causes is about 1 foot in 3000 to 4000 years.

If so enormous a mass is carried by a comparatively small river like the Thames, what must be the amount of matter moved by all the rivers in the world in combination? This problem is beyond the powers of the most profound thinker to imagine.

As a typical instance of the outcome of this removal of matter by rivers, we may instance the Grand Cañon of the Colorado River, U.S.A., cut by the action of the water. The river now runs for a distance of 300 miles more than a mile below the level of the surrounding country, at the bottom of a trough in places 10 miles wide, with perpendicular walls 6200 feet high! This will give us perhaps a faint idea of the enormous amount of solid matter carried to sea by this means. The Colorado rises in the Rocky Mountains and flows down to the Gulf of California.

If so small a river as the Colorado works such mighty changes, what are the larger rivers doing in this respect? The mighty Amazon alone delivers into the ocean on an average about 500,000 tons of water every minute, and the countless streams and rivers all over the globe are similarly engaged, each bearing its quantum of the solid earth to the ocean depths.

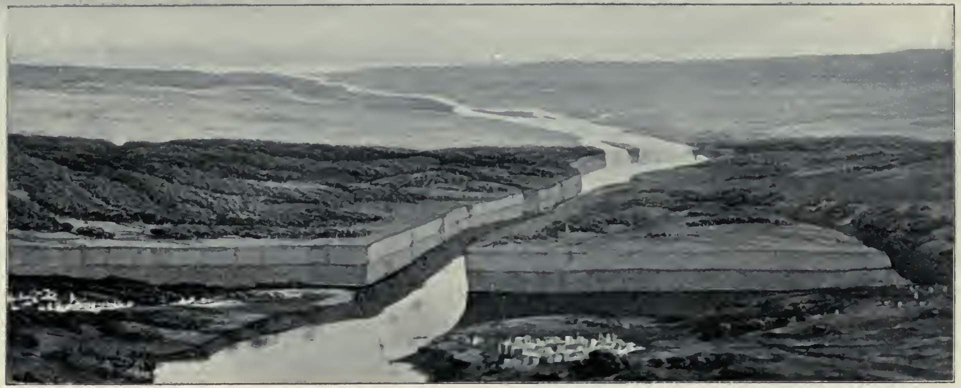
Here indeed one can see how water carries away the material from one place, only to deposit it in a new position, and slowly raises new continents, and so, gradually but surely, alters the configuration of this apparently unalterable globe.

"Daily it is forced home on the mind of the geologist," says Darwin, "that nothing, not even the wind that blows, is so unstable as the level of the crust of this earth."

Recession of Waterfalls

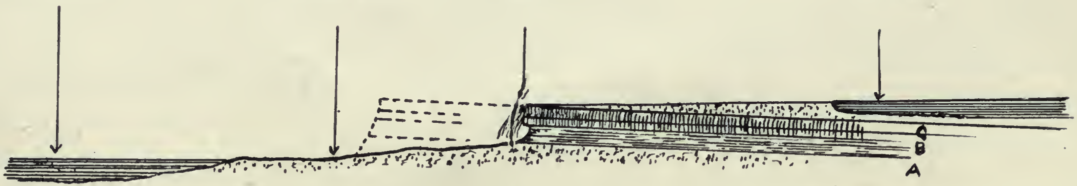
The erosive power of rivers is, as we have seen, enormous, and is only equalled by that of the sea, and as a typical instance of erosion we will take the recession of the Falls of Niagara.

These falls at one period were at Queenstown, 7 miles nearer Lake Ontario than at present. This retrograde movement is still going on, it being estimated at from 1 to 3 feet per annum; and considering that nature has an eternity in which to carry out her work, the day will no doubt come when the Falls of Niagara are no more, and there will be one continuous gorge, reaching from Lake Erie to Lake Ontario, through which the water from the



From an old print.

TO ILLUSTRATE THE RECESSION OF NIAGARA.



SECTION SHOWING THE ROCKS AT THE FALLS OF NIAGARA.

A, sandstone. B, shale. C, beds of limestone.

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great American lakes will rush, forming a rapid, about 36 miles long, with a fall of 9½ feet per mile.

In addition to the erosion of the bed, huge masses fall in from time to time through being undermined by both the running and falling water. In 1818 a mass covering an area of 9000 feet collapsed. In 1829 two masses of a similar size fell in. There was also a huge fall in 1850, and others are also recorded at more recent dates.

It has been calculated that the time occupied by the water in cutting this gorge (7 miles long) must have been anything from 10,000 to 35,000 years.

Professor J. W. Spencer, who has made extensive observations of the physical history of Niagara, concludes that "the age of the Niagara Falls is 31,000 years, and of the river 32,000 years; also that the Huron drainage turned from the Ottawa River into Lake Erie less than 8000 years ago. Lastly, if the rate of terrestrial deformation continues as it appears to have done, then in about 5000 years the life of the Niagara Falls will cease, by the turning of the waters into the Mississippi."

The great element of uncertainty indicated by these figures is due to the fact that no one can say definitely that the rate of erosion has always been constant.

The recession of waterfalls is more or less universal; the St Anthony's Fall, in Minnesota, has receded over 900 feet since the year 1680, in which year it was discovered.

Deltas, etc., formed by Rivers

The Po and the Nile, and the other rivers that flow into the Mediterranean, bid fair to extend their deltas, so as to form a chain of lakes by alluvial deposits. The Po has produced, and is still producing, great geological changes in its basin. The town of Adria, between the Po and the Adige, now 17 miles inland, was once on the sea-coast.

Professor Flinders Petrie tells us that in the valley of the Euphrates, Babylon is now 400 miles from the river's mouth; and that sea-shells are found there, and that the Plain of Babylonia has been extended by silting up, at least from this point. The rivers of this valley now discharge their waters into the Persian Gulf, some 350 miles further seaward than in 10,000 B.C., 12,000 years ago, having added this distance to their course.

The Mississippi and other great American rivers are at work in a similar way. The delta of the Mississippi has an area of 12,300 square miles, and that river carries down and deposits 6,000,000,000 cubic feet of solid matter per annum. Nearly all the erosion by rain, snow, frost, glacier, waterfall, and torrent is thus removed by water.

Between Bâle and Bingen the Rhine has deposited 6 feet of mud in 100 years, and all rivers are proportionately energetic.

The amount of solid matter only (not matter in solution) deposited by some rivers has been calculated as follows:—

				Cubic feet.
Thames in	one year	carries and	deposits	1,865,000
Mississippi	„	„	„	6,000,000,000
Ganges	„	„	„	6,368,000,000
Danube	„	„	„	67,000,000
Rhone	„	„	„	600,000,000

In Egypt, Memphis, which was on the borders of the sea in the time of Herodotus, now stands 100 miles inland; the intervening land is composed of the disintegrated rocks of the mountains of Abyssinia, brought down by the Blue Nile and Atbara. These instances of the wonders of the power of water could be multiplied indefinitely did space permit.

The depth of the deposit forming these deltas is somewhat astounding: a well was sunk in the Mississippi delta as high up as at New Orleans, to a depth of 620 feet, and the bottom of the alluvial deposit was not reached.

The united deltas of the Ganges and Brahmapootra cover an area of 60,000 miles, and the bottom is not reached at a depth of 481 feet; that of the Po is quite as thick.

The formation of deltas also of necessity causes a corresponding increase in the length of the river. To give one instance only, the Shat-el-Arab mouth of the Tigris and Euphrates has added 100 miles to its course since the dawn of history.

The Po, Nile, Mississippi, Thames, etc., run between embankments, partly of their own creation, and all periodically break their banks at times of flood, and would leave their courses and begin again in a new direction the work of widening, filling, and raising for themselves new beds or courses, continually repeating the process, unless prevented by man. The mouth of the Mersey, for instance, was formerly at Widnes, and was considerably wider and deeper than the present river at Runcorn.

Gaur, a ruined city in Hindustan, which from 1212 to 1574 was capital of Bengal, was on the old Ganges, and its decay dated from the change of the course of this river.

Within our own time the Ganges has changed its course: the main channel formerly passed Rajmahol, but it now runs in a new direction, leaving this town 7 miles from its banks.

The change, which is sometimes so gradual as hardly to be noticeable in a lifetime, is due to the fact that the water which flows along the concave parts of river-bends has a greater velocity, and therefore exerts more pressure and friction than that on the convex sides, the consequence being a loss of soil at the inner side and an accumulation at the outer side of the bends.

More rapid and destructive changes, of course, are occasionally due to the bursting of the banks, geological disturbance, etc., but nature generally carries out most of her greatest works so slowly as to be scarcely apparent except to the practical eye of the student of her works.

"At Lima," says Darwin, "is the dry course of a considerable river. But a river has not flowed there for years; a ridge had been uplifted across its bed, and the water had been thrown back and a new channel formed."

The lower Colorado River, in Southern California, suddenly broke through its banks, deserting its old channel, and flowed into the Salton Sink, a low-lying area of considerable extent on the borders of the United States and Mexico. This area is considerably below sea-level, and has hitherto been desert. Of late years successful irrigation schemes have rendered much of it fertile, and it is partly in consequence of these irrigation operations that the Salton Sink has been converted into the Salton Sea. A dam is now being constructed that will eventually divert the river, but in the meantime a deep lake some 2000 square miles in area has been formed.

Some rivers, like the Thames, form submerged deltas; these form the various sandbanks, etc., requiring a skilful pilot to navigate vessels in safety through the proper deep channels, which represent so many different river-mouths.

Every little river is doing its share with its larger neighbours; matter from the land has been, and is steadily being, accumulated in all the river-mouths, except where they are swept by the ocean tides and the matter is carried far away.

This accumulation has gradually blotted out all evidences of the former inhabitants of the banks and creeks forming the river-mouth.

In the Kentish marshes, which are but the result of silting up, remains of the ancient occupiers of these lands are continually brought to light; quite recently I dug out a coin dated A.D. 286, and this very week one dated A.D. 296. To some minds these are ancient relics buried in the river mud; but, indeed, they cannot lay claim to antiquity in a study such as this, for we are dealing with such vast ages that the Roman occupation of these islands does not take us back any appreciable distance; it was only as to-day, not even as yesterday, in the history of the work of water.

Many lakes are gradually being filled up by the sediment deposited by the rivers which feed them. The Lake of Geneva, for instance, once extended up the Rhone valley to St Maurice, if not to Brieg.

Among the widest of rivers is the Congo, which is 25 miles wide in some parts, where vessels may pass and yet be out of sight of one another.

The Nile is the only great river of Africa which flows into the Mediterranean: for the last 1200 miles of its course it has not a single tributary. It drains an area of over 1,200,000 square miles.

The Zambesi, the only great river of South Africa which flows into the Indian Ocean, has on its course the Victoria Falls, one of the greatest in the world.

The Gambia, a river in West Africa, from June to November becomes a torrent, and rises from 20 to 50 feet, leaving, as it subsides, a rich alluvial deposit on its shores.

Other results of the work of rivers include the formation of bars, estuaries, filled-up lakes, lagoons, broads, and the dangerous sandbanks such as the dreaded Goodwin Sands.

CHAPTER XII

WATERFALLS

Niagara

"There's nothing great or bright, thou glorious Fall!
Thou may'st not to the fancy's sense recall:
The thunder-riven cloud, the lightning's leap—
The stirring of the chambers of the deep—
Earth's emerald green, and many-tinted dyes—
The fleecy whiteness of the upper skies—
The tread of armies, thickening as they come,
The boom of cannon, and the beat of drum—
The brow of beauty, and the form of grace—
The passion and the prowess of our race:
And, till the conflict of thy surges cease,
The nations on thy banks repose in peace."

Earl of Carlisle.

Formation

A waterfall or cataract is the leap of a stream or river over a ledge or precipice occurring in its course.

It is generally caused by an abrupt change in the geological structure of the bed over which a river runs.

The Victoria Falls (Zambesi River)

The most remarkable waterfall in the world is without doubt the one discovered by Livingstone in 1855. He was the first white man to gaze upon the Victoria Falls, and the sight moved him more than any other marvel he had seen.

By permission of H. Garner, Leicester.

NIAGARA IN WINTER.

This remarkable river rises at a distance of 1900 miles from the east coast of Central Africa.

"The upper reaches of the river," says Mr A. J. C. Molyneux (*Geographical Journal*, 1905), "from the falls to its source, a distance of 800 miles, flow through a region of singular beauty, with navigable waters for the greater part of the distance, and it might be said that the river runs along the very top of a plateau 3500 feet in altitude, for the difference between the water level and the surrounding country is very slight."

Across the bed of this river is a deep chasm, probably caused by volcanic action or some other terrestrial convulsion. This rift in the hard basaltic rock is only about 80 feet in width at the ends, increasing to 240 feet in the centre.

Its depth is 256 feet at the western extremity of the chasm, 343 feet opposite the gorge, and 400 feet in the gorge, at the approach of the Grand Cañon, with a further descent of some hundreds of feet during its zigzag course through 40 miles of the Grand Cañon, there being a difference of 1000 feet between the central reaches of the river and the level above the falls.

The Zambesi River, fully a mile wide, flows peacefully along, so peacefully that boats can approach with safety quite close to the brink of the fall. The enormous body of water, which is collected over an area of 600,000 square miles, is suddenly precipitated with a deafening roar into this chasm, escaping through the gorge in an opening only 20 or 30 yards wide, at right angles to the fissure.

The length of the chasm is the same as the full breadth of the river, viz. 1860 yards, but the fall or lip is subdivided by natural features as follows:—

Nearest to the western bank, "Leaping Water," 36 yards wide, described as a sloping mill-race, carrying much water when many other portions are dry. Next comes a break in the fall formed by the island of Barauka, about 200 yards wide, with a fissure passing through it which at flood-time forms a cascade, which pours its contents also into the chasm. Then comes the Great Fall, 573 yards broad, followed by a ledge of projecting rock called Livingstone Island; then follows the Rainbow Fall, another rocky ledge; and finally the Eastern Cataract, similar to that on the western bank.

There is no difference of level in the bed, as is generally found with other falls, but the river disappears into an open chasm. This fall is of such magnitude that the better-known Niagara is completely dwarfed by it.

The process by which nature formed these falls is apparent, but the time occupied by nature in cutting the 40 miles of cañon is a matter for conjecture. In the case of Niagara its changes have been more or less observed since 1697, when they were first sketched by Father Hennepin; but here there is no such record. But if this fall receded through the 40 miles of cañon at the rate of 1 foot per year, it must have taken about 200,000 years to cut the channel to its present depth.

The spray from this stupendous fall of 347 feet springs back into the air to a height of 1200 feet, and the thunder of its voice can be heard for many miles.

The following lines by James Thomson describe these falls in forcible language:—

"Smooth to the shelving brink a copious flood
Rolls fair and placid, where, collected all
In one impetuous torrent, down the steep
It thundering shoots, and shakes the country round.
At first an azure sheet, it rushes broad,
Then whitening by degrees, as prone it falls,
And from the loud resounding rocks below,
Dash'd in a cloud of foam, it sends aloft
A hoary mist, and forms a ceaseless shower."

By permission of H. Garner, Leicester.

THE HORSESHOE FALL, NIAGARA. THE GORGE, NIAGARA.

(To illustrate the recession of Niagara, showing the cataract, and the gorge—seven miles long—that it has excavated.)

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The columns of spray from this fall can be seen 20 miles off, and at times, when the sun's rays shine on it, a rainbow is formed: sometimes a complete circle can be seen.

I cannot refrain from quoting a description by Colonel Molyneux of this interesting phenomenon.

"No mention of these falls would be complete without some reference to the eternal columns of mist that rise from the grey depths of the chasm, or to the brilliant effects of the rainbows that irradiate them.

"As the vast masses of foaming water are precipitated with the constant roll of thunder into the abyss, they are broken up into comets' tails, again into spray, and still again are comminuted into driven mist; the air forced down with them sets up a current along the cañon, and, ascending in eddies in the chasm, carries with it the spindrift of the dashing spray, and rises in vapoury columns far above the falls. Baines, in July 1862, measured the height by sextant, and found it to be 1144 to 1194 feet above the bottom of the gorge, these misty clouds rising higher in the coolness of the early morning than in the noonday heat, while at the time of high water the spray nearly envelops the whole length of the falls.

"From the hill east of the Matetsi River, 40 miles away, it is especially noticeable against the red gleams of the sunset as a dark smoky column; from other places, and at mid-day, it is of dazzling whiteness.

"At sundown, looking from the west, the ruddy glory of the after-glow warms it up with orange and tints of flesh-colour and seems to quicken it into a blithesome guardian of the falls.

"It is to this constantly lifting and rolling veil of spray that the Victoria Falls owes its most peculiar and elusive charm. No clear and complete view of the depths and distances of the chasm can ever be obtained. The mist throbs and moves across the scene, dimly revealing and again hiding innumerable changing sights. Thus there is always the suggestion of shadowy beauties beyond this gossamer veil, a feeling that we but just touch the glories of this earthly paradise, yet shall never grasp and understand them, stay we never so long.

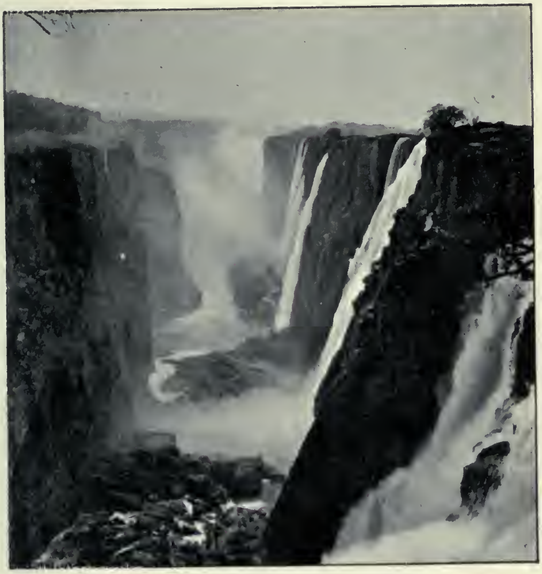
"And amidst this sunlit vapour is born the crowning spectacle of the falls. At every turn and in every view of the water, green foliage, and dazzling foam, the glorious double rainbow follows one, whether in the rich prismatic colours of the day-time or the neutral tints of the moonlight. What wonder that the more ancient native term was "Seonge," the place of the rainbow, for here surely all the rainbows of the world must come to play in the sunlight before they follow the thunderstorms across the land to bless the rain-chilled beasts and birds.

"To the condensing vapour is also due the rich and evergreen Rain forest and the trees of the Palm-kloof. This vegetation includes a wealth of ferns, orchids, and palms, rich treasure for the botanist, who must, however, be prepared for a quick and thorough wetting from the never-ceasing rain that descends from the foliage above.

"From the grey turmoil of the gorge below rises the continuous diapason of rumbling thunder, grand chords and voices are in the air, and under the deep-blue skies the might and majesty of the falls sink deep into one's soul. With the homage-paying native who comes here to worship the deity, we too must feel the mysterious Presence, and that here, among the greatest of nature's works, we stand upon the threshold of the 'tablelands of God.'"

"It is not noon—the rainbow's rays still arch
The torrent with the many hues of heaven."

BYRON (*Manfred*).



By permission of Dr Mill.

THE ZAMBESI GORGE.

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Niagara Falls

The cataract of Niagara, on the channel between Lakes Erie and Ontario, is only eclipsed in grandeur by the Victoria Falls. This fall is due to the water passing from a hard bed of limestone to one of soft shale.

The enormous quantity of water ceaselessly pouring over these falls comes from some of the largest lakes on the globe, Superior, Michigan, Huron, and Erie. These lakes, with their tributary streams, drain an area of more than 150,000 square miles; their outflow passes over the Falls of Niagara, through Lake Ontario and the St Lawrence River, to the sea.

From Lake Erie to the falls the average depth of the Niagara River is 20 feet, and at some points it is over a mile wide. At the point where it takes its plunge over the precipice it narrows down to 3600 feet, or less than three-fourths of a mile. Between Lakes Erie and Ontario, a distance of 36 miles, there is a fall of 336 feet, made up as follows:—to the rapids above the falls, 15 feet; in the Rapids, 55 feet; over the falls, 161 feet; from the falls to Lewiston, through the gorge, 98 feet; from this point to Lake Ontario, 7 feet.

The enormous amount of water discharging over these falls has been estimated at 1,500,000,000 cubic feet per minute (another authority, 2,400,000,000), or in gallons 9,375,000,000 per minute, or sufficient to supply 1¼ millions of people with water for one year, allowing each person 20 gallons per day.

The amount of water discharging over these falls in twenty-four hours, at the lower estimate, would supply the whole area now under the Metropolitan Water Board for 180 years. For this calculation the report for March 1904 was used. The population supplied was 6,459,048, the amount of water consumed daily being 198,223,000 gallons, equal to 30·69 gallons per head per day (for all purposes).

If the water passing over this fall in one day will supply this enormous population for so long a period, the annual amount passing here must be almost beyond our comprehension, and should cause us to admire nature's boundless prodigality in the matter of water, as well as in all her other gifts to man. It is estimated that half a million tourists visit these falls each season. There is little wonder that so many should be attracted by this gem of nature's masterpieces.

> "Where'er we gaze, around, above, below,
> What rainbow-tints, what magic charms are found;
> Rocks, rivers, forests, mountain, all abound,
> And bluest skies that harmonise the whole;
> Beneath, the distant torrent's rushing sound
> Tells where the volumed cataract doth roll,
> Between those hanging rocks, that shock yet please the soul."
>
> BYRON (*Childe Harold*).

In winter these falls are even more fascinating: here King Frost can display his power to an unsurpassable degree. The mists congeal upon everything, tree, ledge, and rock, covering all with crystal ice and snow, the sun's rays lighting up this gorgeous spectacle and turning the crystal icicles into spears of light.

The scene by moonlight must be equally sublime.

The Great Kaieteur Fall, etc.

Another beautiful fall is the "Great Kaieteur" Fall, in British Guiana, discovered 24th April 1870. Here the Potaro River falls from a hard on to a soft rock; the cataract is 822 feet high and 369 feet broad, and is often encircled by rainbows.

J. N. Bryan.

THE SWALLOW FALLS, BETTWS-Y-COED, NORTH WALES.

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Many falls are due to geological faults. The Yosemite Falls in California are due to this cause.

Another notable waterfall is the Fall of Handeck, near Meyringen, Switzerland, where the river Aar plunges into a chasm 200 feet deep.

There are also the falls on the river Montmorency, a tributary of the St Lawrence, 240 feet high. The cataract on the Rjukan Fos, in Norway, 900 feet high. The cascade of Gavarnie, in the Pyrenees, 13,000 feet, the loftiest in Europe, but the volume is small. The falls at Schaffhausen, on the Rhine, 300 feet broad and 100 feet high. The waterfall "Tivoli," which provides the power for generating the electricity for illuminating Rome, is renowned for its beauty.

There is also the loftiest waterfall in Switzerland, the famous Staubbach, near Lauterbrunnen, variously stated as having a fall of 950 to 1001 feet; it is, however, a mere brook, and almost dried up in summer.

The world abounds with beautiful waterfalls, but we must not overlook those nearer home. The giants of other lands may eclipse them, but they each have a beauty of their own. The Scotch and Welsh falls, though small in comparison, are sublime. The Falls of Foyers, near the mouth of the river of that name, in Inverness-shire, which falls into Loch Ness, are described by many as being the most magnificent in Great Britain. The upper fall is about 30 feet high, the lower is about 90 feet.

The Rheidol Falls, Devil's Falls, and Swallow Falls are but three of the many that all visitors to North Wales endeavour to visit. The writer once saw a splendid rainbow in the spray arising from the fall last mentioned, which proves that even in the smallest of our waterfalls we may find, on a reduced scale, many of the interesting attractions that are common to the more magnificent falls that are not within our reach. Here also—

> "As springing high the silver dew
> In whirls fantastically flew,
> And flung luxurious coolness round
> The air, and verdure o'er the ground."
>
> BYRON (*Giaour*).

One would imagine that every cataract of importance had long since been discovered, and that no fresh laurels were to be won in this direction.

As recently as November 1907, however, Dr Carl Bovallius made an important discovery in British Guiana.

On an affluent of the river Ireng, near the Brazilian boundary, at about 5° N. lat. and 60° 9′ W. long., he found a waterfall which he describes as "rivalling Niagara in height, and worthy of ranking with Kaieteur Fall and the Mount Roraima as one of the greatest scenic treasures of the country."

This new fall, which its discoverer proposed to name the Chamberlain Fall, has a sheer drop of 300 feet, and is some 200 feet in width; it falls over a slightly convex cliff, showing red, highly polished jasper at places, into an oval basin which empties, about a hundred yards from the first fall, over a second, some 30 feet in height.

Mrs Aubrey Le Blond.

WATERFALL, RAGAZ, ON THE ROAD TO PFAFFERS, SWITZERLAND.

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CHAPTER XIII

LAKES

> Clear, placid Leman! thy contrasted lake
> With the wide world I dwelt in, is a thing
> Which warns me, with its stillness, to forsake
> Earth's troubled waters for a purer spring.
>
> BYRON.

Lakes

A LAKE is a body of water lying in a hollow of the land, and therefore is wholly surrounded by land, having no direct communication with the sea or ocean, except by means of a river or rivers. One of the principal functions of a lake is to arrest, equalise, and regulate the flow of water to rivers, and so prevent floods.

Formation of Lakes

The origin of various lakes is, to use the words of Lord Avebury, "a complex question."

Lake basins are due to various causes. All the great lakes, however, are formed in enormous natural depressions on the earth's surface, due to change of level; there are also lakes formed by embankment as well as by subsidence. Crater lakes are among the most interesting, occupying as they do the craters of extinct volcanoes.

Lakes have been formed by the blocking of a stream by a berg-fall, or by the terminal moraine of a glacier, as in the case of Lago d'Alleghe; or by the drift which a tributary has swept down, to which cause Mattmark See is due; and the level of many Alpine lakes has also been raised by this means.

Barrier lakes are formed by an embankment being thrown across a valley through which a river flows, the accumulation of the waters forming a lake.

Landslips and earthquakes have also been known to form lakes of this kind.

Other lakes arise through the subsidence of the surface following on the removal of subterranean masses of soluble salts by the action of the water; typical instances have occurred in Cheshire and Worcestershire, but these are small and of little importance.

According to some authorities, many of the lakes found in the vicinity of glaciers do not appear to owe their origin to the action of ice, the general opinion being that the action of glaciers is to wear away prominences and not to excavate and form lake basins; but there are reliable authorities on both sides, so we will content ourselves with recording their various opinions on the subject.

Lakes are not due to river action, as some suggest; the rivers fill them with water, and also tend gradually to fill them with sediment; they are due principally to change of level, though perhaps some are due to glacial action, the ice forming great hollows, and grinding them deeper for many ages, until, when the glaciers recede, they leave behind them mighty lakes as the result of their erosion.

The only way in which rivers could assist in the formation of lakes would be by the removal of soluble rock, such as salt or gypsum.

The English, Irish, Scotch, Scandinavian, and North American lakes are declared by Sir A. Ramsay to be of

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A LAKE ON THE GÖRNER GLACIER BETWEEN THE ICE AND THE MORAINE.

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A GLACIER LAKE FORMED BY A MORAINE (ARCTIC NORWAY).

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glacial origin, as he has failed to account for their formation by any other means.

The Lake of Geneva is also attributed to this cause; it is 1000 feet deep in the centre.

The altitude of Swiss and Italian lakes varies from Garda, the largest in Italy—which is about 213 feet above the sea and 902 feet greatest depth, 33 miles long, 3 to 11 miles broad—to Brunz, 1850 feet above the sea, and at places as deep as 2150 feet.

River action could not form these depths, but erosive action of glaciers has no doubt formed some of them.

Crater Lakes, etc.

Crater lakes are formed, as their name implies, in the craters of extinct volcanoes, rain and snow having filled them with water; among the most interesting of these is Lake Chala, on Mount Kilimanjaro, a snow-capped mountain in Central Africa, 19,000 feet high. This lake is 3 miles long by 1 mile wide, and lies 400 to 800 feet below the level of the summit. Descent to the water is only possible at one spot. It is fed by melted snow and rain, it is clear and cool and sweet, contains numerous fishes, and is frequented by flocks of birds.

The Lake of Campania in Italy, near Baiae, occupies the crater of an extinct volcano 1½ miles in circumference. It was supposed by the ancients to be the mouth of hell, from the mephitic character of its exhalations, and its gloomy surroundings.

There is a crater lake in Oregon which has an average depth of 1500 feet, and at places is 2000 feet deep. Lonar Lake, between Bombay and Nagpore, is 1 mile in circumference and 300 to 400 feet deep.

The most remarkable crater lake is in the Cascade range, Southern Oregon: it is 7½ miles long by 5 miles wide, and its depth varies from 853 feet to 1996 feet. It is elliptical in shape and is encircled by cliffs 900 to 2200 feet high; the colour of the water is a beautiful ultramarine.

In the centre of this lake is a cone 600 to 700 feet high, which leads to the conjecture that at some period the whole of the top of this mountain was blown off, leaving a portion of the cone projecting in the centre, as occurred during the eruption of Toniboro, in the island of Sumbawa, when from this sharply defined cone, 9000 feet high, the upper 5000 feet were blown away in a single night. This occurred in 1815, and the sky was darkened for about a million square miles.

Lake Nemi, 17 miles south of Rome, 5 miles in circumference, occupies, without doubt, the crater of an extinct volcano.

The Lake of Tiberias (Sea of Galilee), in Palestine, is generally supposed to have been formed by subsidence and volcanic activity, its surface being 682 feet below the level of the Mediterranean Sea.

There are many other remarkable lakes, such as the fresh-water lake of Lusch, on the Heinzenberg, 6391 feet above the sea. This lake has no visible outlet, the surplus water percolating away through hidden channels.

In California the overflow of the beautiful Lake Tahoe, on the summit of the Sierra (alt. 6200 feet), passes off by means of the Truckee River, and enters Pyramid Lake, where it sinks or disappears by evaporation.

Lake Baikal (Abundant Water), the great fresh-water lake of Siberia, 12,500 square miles in area, 1360 feet above level of sea, though fed by several rivers, has only one visible outlet, the Lower Angara.

We have frequently heard of intermittent springs, but a periodic lake is, I believe, a rare phenomenon.

The Eichener See, near Schopfheim, in the Black Forest (*Geographical Journal*, 1900), is a remarkable lake of this description. It makes its appearance sometimes after intervals of several years, at others several times in the same year. At the last high-water period, 1882–3, it reached a depth of 11½ feet, and persons have often been drowned in it. The lake owes its origin to the swelling of the underground watercourses which traverse the "Muschelkalk." The high level is reached only when some weeks have elapsed after the fall of heavy rain.

In the Life of G. A. Henty, already referred to, we find mention of a periodic lake "Zirknitz," near Adelsberg, which is emptied usually once a year, when, in the absence of the water, the natives grow in its fructifying mud, crops of coarse grass, millet, and buckwheat.

"About midsummer the waters of the lake begin to shrink, growing lower and lower, and so rapidly that, after about twenty days in July, the lake is empty, remaining so till September or October, according to the season."

The lake, however, sometimes remains full for three or four years together. Space will not admit of a detailed description of the many interesting features of this strange lake, or of the fish it leaves behind, when it dries up, thus supplying the natives with at least a portion of their food; how it empties and refills, having no apparent inlet or outlet, other than innumerable holes connecting it with the caves, grottoes, and reservoirs in the mountains; or how it sometimes fills in twenty-four hours. I can only refer the reader to Mr Manville Fenn's most interesting book.

Another remarkable lake mentioned by Mr A. T. Drummond (*Geographical Journal*, 1900) exists in Canada.

This is a lake with a subterranean inflow, probably derived from a source 25 or 30 miles distant. It is situated on the top of a cliff 180 feet high, on the south side of the Bay of Quinte, an arm of Lake Ontario, and is described as a fresh-water lake 1½ miles long, ¾ mile wide. Though shallow, in the bottom of the lake is a great rent nearly a mile long by ⅓ mile wide, 75 to 100 feet deep; this rent, it is assumed, accounts for the subterranean connection with the distant source of its supply.

Surface Level of Lakes

The beds of many of the English lakes are below the present sea-level; among them are:—

Coniston . .	143 feet above sea,	184 feet deep.
Windermere . .	130 ,, ,,	220 ,,
Wastwater . .	200 ,, ,,	258 ,,

These are but as pools compared to such lakes as Maggiore (Italy), whose surface is 636 feet above the sea, and its bottom about 1500 feet below sea-level; it has therefore a depth at places of over 2000 feet.

The surface level of some of the larger lakes will no doubt be of interest, the figures representing feet above the sea:—Thun 1856, Geneva 1150, Como 653, Superior and Michigan 627, Huron 595, Erie 565, Ontario 234. The last five form a remarkable chain of lakes, having a total area of 90,000 square miles of fresh water. They form part of the national drainage system of North-West America, discharging into the Atlantic *via* the Niagara Falls, through the river St Lawrence.

Among the highest we have Titicaca, in the Cordilleras of South America, which is 12,500 feet above the sea; it measures 90 × 30 miles, greatest depth 924 feet, bottom temperature 54·6° F.

Lake of Chinchay-cocha, in Peru, 36 miles long, 7 miles wide, is 13,000 feet above the sea.

The reader will probably ask which lake has the lowest

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THE LAKE OF GENEVA.

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surface level, and which is the deepest; these two questions are answered as follows:—

The deepest—Baikal: surface, 1360 feet above sea-level; bottom, 2720 feet below sea; total depth, 4080 feet.

The lowest—the Dead Sea: surface level, 1292 below sea; greatest depth, 1308 feet.

Salt Lakes (Formation of)

Nearly all lakes are fresh, because their waters are continually changing.

Salt lakes are formed when the amount of water flowing into the lake is equalled by the evaporation from the surface, there being no overflow or outlet, such as the Dead Sea or the Great Salt Lake in Utah; the saline materials which have been dissolved out of the soil do not disappear by evaporation, and therefore accumulate in the lake.

Even here life is possible, for Darwin tells us that an annelida, a kind of worm, exists in brine, and may be seen crawling among the crystals of sulphate of soda and lime on the borders of the salt lakes of Patagonia, and that "every part of the world is habitable, whether lakes of brine or those subterranean ones hidden beneath volcanic mountains, warm mineral springs, the wide expanse and depths of ocean, the upper regions of the atmosphere, and even the surface of perpetual snow—all support organic beings."

The Dead Sea

This most remarkable lake is 46 miles long, its mean width averages about 8½ miles, and its maximum depth is 1308 feet; it receives several other tributaries besides the river Jordan, but has no outlet, and it does not require any, as the evaporation even exceeds the amount of water received, although the surface in the rainy season stands 10 or 12 feet higher than in the dry season, and the lake is therefore getting smaller and salter.

The Dead Sea lies deeply embedded in lofty cliffs of limestone, and its shores present a scene of indescribable desolation and solitude, encompassed by the desert sands and bleak, stony, salt hills; sulphur, rock-salt, lava, and pumice abound along its shores. The water is intensely bitter as well as salt. Chlorides of sodium, magnesium, and calcium are the chief ingredients, and its density is so great that the human body will not sink in it.

The presence of so much saline matter is accounted for by the washings of the salt range of Sodom and the brackish springs along the shore, as well as by the excessive evaporation.

The following is the analysis of the water, which has a specific gravity of 1·227, at a depth of 1110 feet:—

Chloride of calcium . . .	3·107
,, magnesium . . .	14·889
,, sodium . . .	7·855
,, potassium . . .	0·658
Sulphate of lime . . .	0·070
Bromide of potassium . . .	0·137
	26·716

A friend has given the writer a short description of his experience of a swim in this salt lake, which is worth repeating.

"The Dead Sea is rightly named: there is nothing but death, in the shape of salt and sand, for miles round its coasts. But have a dip in its waters, and you feel lively enough; in fact, you cannot sink. This buoyancy of its water is due to the enormous quantity of mineral salts held in solution: from 25 per cent. to 28 per cent. is said to be the quantity. Bathing here is particularly unpleasant if there is any wind, the salt being extremely irritating to the eyes; for hours also after your dip, your person is left uncomfortably sticky from the salt.

"The sensation in the water is also curious, the only comfortable position is floating, or swimming on the side. With the breast-stroke your legs and shoulders are forced up high, with the consequence of a feeling that the small of your back is going to break.

"Situated some 5 to 8 miles from the modern Jericho, with a most barren and bleak desert around it, with salt in the air, in the sand, and in the water, this inland sea cannot be said to be an ideal bather's paradise."

The peculiar sensation referred to will be easily understood when we remember that the specific gravity of the water is 1·24, that of the human body being ·89.

Archimedes discovered over 2000 years ago that "a body immersed in a liquid is buoyed up with a force equal to the weight of the liquid it displaced."

Therefore a man would have to displace a greater bulk of water than that of his body before he could sink; he would thus be thrust upward, until a part of his body, equal to the difference between the two specific gravities, was above the water.

The specific gravity as compared with other water is:—

	Specific gravity.	Weight of a cubic foot.
Dead Sea . . .	1·240	77·5 lbs.
Mediterranean . .	1·029	64·3 ,,
Rain water . . .	1·000	62·5 ,,

Great Salt Lake, Utah, etc.

The Great Salt Lake, to the west of the Rocky Mountains, North America, measures 70 miles from north to south, and 48 miles from east to west.

It has an area of 1900 square miles, and, unlike the Dead Sea, is 4200 feet above the level of the sea. Its maximum depth is only 56 feet, and it is subject to a yearly rise and fall like the Dead Sea.

Its water contains 6½ times more than the average solid constituents of sea-water, being almost as heavily impregnated (22·4 per cent.) as that of the Dead Sea (24·5 per cent.), and the salt is so pure that it is used in the city without artificial refining.

Its waters are so salt that 5 gallons water yield on evaporation 14 pints of salt, and its shores are whitened with the salt; and I need hardly state that it contains no fish.

This lake was at one time a fresh-water lake. Time and geological changes have altered the drainage area supplying it, so that now the evaporation more than equals the amount of water running into it, and it has become salt.

The opinion now prevails almost universally among scientists that this body of water, which is 1000 miles inland, is drying up, and is certain, within the course of half a century, to disappear from the map.

The salt lakes of Africa are—Assal Lake, which, like the Dead Sea, is 600 feet below the level of the Red Sea, and Schott Kebir, south of Tunis, a salt lagoon 100 miles long, which dries up in the summer, exposing its bed, which is found to be thickly encrusted with salt; this lagoon lies several feet below the level of the Mediterranean.

In the shallow pools bordering on the Caspian there is a constant deposit of salt. An overflow of this mighty lake, called the Karabughaz, receives through a channel 150 yards wide, 5 feet deep, where flows a continuous stream, 350,000 tons of salt daily, and it has become so salt that the seals have forsaken its barren shores.

The percentages of salt in seven principal salt lakes are given in the following table:—

	Specific gravity.	Percentage of salt.
Kokonor Sea . . .	1·00907	1·11
Aral Sea . . .	No record	1·09
Caspian (open) . .	1·00106	1·30
Caspian (Karabughaz) .	1·26217	28·5
Urumieh Sea . . .	1·17500	22·28
Dead Sea . . .	1·2400	22·13
Suez Canal (Ismailia) .	1·03898	5·1

Some of the fresh-water lakes of North America were originally salt lakes, but the reverse action has taken place; the geological conditions were altered, and the lakes received a larger supply of fresh water, which circulated through them, and so their water speedily lost its salinity, and they became, as we now find them, fresh-water lakes.

There are many other salt-water lakes, though not nearly so salt as the Dead Sea and Utah Lake. The Sea of Aral, in Asia, is a salt-water lake 26,650 square miles in area, 160 feet above the Mediterranean; this lake has also no outlet.

The Caspian Sea, the largest isolated sheet of water on the globe, has an area of 120,000 square miles, its maximum depth being over 3200 feet, and its surface 85 feet below the Sea of Azof; it is a salt lake also, and has no outlet. "On account of the excess of evaporation," says Dr Mill, "the surface of this lake is now 90 feet below sea-level, and its salinity would be greater but for the peculiar circumstance that its shelving shores and the wide, shallow inlet of Karabughaz act as natural salt-pans, evaporating the thin layer of water covering them, and causing a deposit of crystalline salt which is thus being gradually withdrawn from solution, while part of the evaporation is made good by a continual supply of fresh river water."

In Russia we have Lake Balkash, 330 miles long, area 8500 square miles, nowhere over 80 feet deep, extremely salt, and with no outlet. It was formerly much larger, and is still decreasing.

Lob Nor, a lake in the Desert of Gobi, is also without an outlet.

Aullagas, a salt lake of Bolivia, has only one perceptible insignificant outlet, and what becomes of the surplus water it receives is unknown.

Gokcha, a lake in Russian Armenia, 540 square miles in area, 6400 feet above the sea, receives its water from several streams, but has no outlet of proportionate size.

In Australia there are many salt lakes which have no outlet—Eyrie, Torrens, Gardener, and Amadeus—besides many smaller ones, in all of which the size and saltness vary with the seasons. In dry seasons Torrens is merely a salt-marsh.

On the borders of the Mediterranean are several salt lakes, of which Menzaleh is the largest. The Suez Canal passes through this and several others.

From these instances we might naturally conclude that all lakes not having outlets are salt lakes, but there are exceptions.

Lake Tchad, in the Soudan (Central Africa), having an area of about 20,000 square miles, has no outlet; it is a fresh-water lake, in which abound fish, turtles, etc. This lake also varies in size according to the seasons.

Dried-up Lakes

In many parts are found the dried-up beds of lakes that have long since disappeared.

The Desert of Gobi, the "Sand Sea" of the Chinese, in Eastern Asia, which has an area of 360,000 square miles, is said to have been once an inland sea. Its general elevation, however, is now over 4000 feet above the sea.

In Egypt a dried-up lake basin called Moeris exists; this formerly contained a body of water 450 miles in circumference and 300 feet deep.

Many of the mud-flats, the remains of ancient lakes and dried-up valleys of the Sierra in California, prove by the terraces surrounding them that water was formerly much more abundant and stood at higher levels than at present.

In Southern Italy, in the province of Aquila, is an example of an artificially dried lake. Here Lake Fucino, 11 miles long, 5 miles broad, 2181 feet above sea-level, was drained by means of a tunnel constructed by Emperor Claudius, the water being carried into the Garighano, thus reclaiming 36,000 acres of rich arable land.

Area of Lakes

The size of our English lakes, as compared with those of other countries, will help us to grasp some idea of their immensity; the figures given here are square miles.

Windermere, 10; Lomond, 45; Lucerne, 40; Neagh, in Ireland, 150; Maggiore, Italy, 150; Constance, Switzerland, 210; Geneva, Switzerland, 331; Wener, Sweden, 2306; Ladoga, Russia, 7156; Michigan, America, 26,000; Superior, in America, 32,000; and Caspian, in Europe and Asia, 170,000.

When we are told that the Caspian Sea is about 17,000 times larger than Windermere, and that Lake Superior, the largest expanse of fresh water in the world, is as large as Ireland, we can get an idea of the enormous extent of these vast bodies of water.

Temperature of Lakes

The temperature of lakes may vary at their surface from 68° F. to 77° F. in summer according to the atmospheric conditions, decreasing as we descend to a depth of about 400 feet from the surface, after which it is found that the variation of temperature with increasing depth is quite insignificant; in a lake 1000 feet deep the temperature at 400 feet is only one- or two-tenths of a degree higher than that at the bottom.

The Lake of Geneva in autumn is 78° at the surface and 41° at 950 feet; in February the surface temperature is only 42°, while at 1000 feet down it is still 41°: so in all deep lakes, there is a body of water beyond the influence of the sun's rays.

The coldest temperature at the bottom appears to be Lake Constance, 39·6° F., the surface temperature being 64·6° F. This lake is only 394 feet maximum depth.

At the bottom of Loch Lomond there is at all seasons a constant temperature of 42°, which is the mean temperature of the atmosphere during the cold half of the year, the mean annual temperature here being 47·8°. In winter the surface water of lakes cools, contracts, sinks, warmer water rising to take its place; this circulation goes on until the whole lake cools down to 39° F. (if fresh water), the maximum density; further cooling causes the water to expand, and it remains at the surface, forming a thin sheet of ice. Thus no ice can form until the whole body of water has reached 39° F., and it is for this reason that deep lakes rarely freeze, except in countries where long and severe winters are general.

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A TYPICAL MOUNTAIN LAKE.

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Colour of Lakes

Lakes differ greatly in colour. The depth of the intense blue of the Lake of Geneva is almost unequalled in any waters except the Mediterranean and the Grecian Archipelago. This fact was apparent to Byron, for in *Childe Harold* he says,

> "By the blue rushing of the arrowy Rhone
> Or the pure bosom of its nursing lake."

This unusual blueness is of greater transparency in winter than in summer. From October to April a white disc is visible at a depth of 41 feet; during the summer months at 21½ feet only, the thermal stratification of the water keeping in suspension a greater quantity of dust and organic particles.

The Lake of Lucel, in the Val d'Herins, is, however, bluest of all. Glaslyn, on Snowdon, is indigo. Some lakes are bluish green, green, or yellowish, while others are quite colourless.

The bluest lakes are those that are the purest. The green lakes contain in solution a minute quantity of vegetable matter or peat. The varying tone and tint is also due to the light of the sun and reflection of the sky.

CHAPTER XIV

OCEAN AND SEA

The Sea

Roll on, thou deep and dark blue ocean—roll !
Ten thousand fleets sweep over thee in vain ;
Man marks the earth with ruin, his control
Stops with the shore ; upon the watery plain
Time writes no wrinkle on thine azure brow.
Such as Creation's dawn beheld, thou rollest now,
Thou glorious mirror, where the Almighty's form
Glasses itself in tempest ; in all time,
Calm or convulsed, in breeze or gale or storm,
Icing the pole, or in the torrid clime,
Dark-heaving, boundless, endless and sublime,
The image of Eternity."

Byron.

The sea, unlike the land, is unaffected by time. It was the same a million years ago as it is to-day. The mountains disappear, continents alter their shape, rise and fall, islands may arise or be submerged, but the sea remains the sea always.

"We say firm as a rock, old as the hills. But no rock is firm, and no hills are old: granite crumbles away and hills are carried into the sea. The ocean, however, is outside time. If we were to look back 100,000 years, the land would show strange changes; but the ocean would look just as it does to-day" (Lord Avebury).

"The adjustments," says Dr Buckland, "of the relative quantities of sea and land in such due proportions as to supply the earth by constant evaporation, without diminishing the waters of the ocean; and in the appointment of the atmosphere to be the vehicle of this wonderful and unceasing circulation; in thus separating these waters from their native salt (which, though of the highest utility to preserve the purity of the sea, renders them unfit for the support of the terrestrial animals or vegetables) and transmitting them in genial showers to scatter fertility over the earth, and maintain the never-failing reservoirs of those springs and rivers by which they are again returned to mix with their parent ocean; in all these circumstances we find such evidence of nicely balanced adaption of means to ends, of wise foresight, and benevolent intention, and infinite power, that he must be blind indeed who refuses to recognise in them proofs of the most exalted attributes of the Creator."

This forms a fitting introduction to a subject of such absorbing interest as the sea!

It is found that the sea controls and keeps constant the amount of carbonic acid in the air, preventing its accumulation, which would be deleterious to health. This gas is present to the extent of about ·04 to ·06 per cent.; the latter figure should not be exceeded.

The vital properties of the sea-water govern, by a chemical process, this necessary but dangerous gas, which, under varying conditions of temperature and pressure, too complicated for full explanation here, is driven into carbonate of magnesium in the sea-water; if there is a deficiency of the gas, the sea in like manner adds the required amount to the atmosphere, restoring the balance so necessary to our health. The sea varies but little: taking one part of the ocean with another, we may safely conclude that its composition as a whole is constant, subject only to the very slow progressive millennial variation.

Area of Oceans and Seas

"Thou hast set them their bounds, which they shall not pass; neither turn again to cover the earth."

If we deduct the space occupied by Polar ice, the eternal snows, sandy deserts, sterile mountains, marshes, rivers, and lakes, the habitable portion of the globe will scarcely exceed one-fifth of its entire surface.

The oceans and seas comprise the vast body of water which covers nearly three-fourths, or more precisely eight-elevenths, of the earth's surface.

The volume of this mass of water is said to be 308,710,890 cubic miles. "Natural philosophers," says Hartwig, "have endeavoured to calculate the quantity of waters contained within the vast bosom of the ocean; but as we are still very far from accurately knowing the mean depth of the sea, such estimates are evidently based upon a very unsubstantial foundation. So much at least is certain, that the volume of the waters of the ocean as much surpasses all conception as the number of their inhabitants or of the sands that line their shores."

"If we would offer to make a rude estimate," says Goldsmith, "we should find that all the rivers of the world, flowing into the bed of the sea, with a continuance of their present stores, would take up at least 800 years to fill it to its present height."

Darwin, referring to the immensity of the sea, says: "It is necessary to sail over the great ocean to comprehend its immensity. Moving quickly onwards for weeks together, we meet with nothing but the same blue, profoundly deep, ocean."

Depth of Oceans and Seas

The bed of the ocean is in many respects similar to the surface of the land; it has its plains, hills, valleys, ridges, and notwithstanding the great transporting power of water, land-derived materials are not found at a greater distance than 300 to 500 miles from the shore.

If one could stand on the bottom of the North Atlantic Ocean, the shores of the earth would be 11,300 feet high, or as high as Maladetta in the Pyrenees. Submarine peaks exist in the oceans, some as high as Mount Everest. Mighty submarine mountain chains also exist as high as the Alps. Some of these mighty submarine mountain peaks rise from the deepest depths, as Mount Conway, which rises from the bed of the South Pacific to a height of 15,600 feet, and its summit is actually awash, many a ship having been stranded thereon.

These mountains are no doubt as picturesque as our mountain ranges, but no eye will ever behold their splendour.

"The average height of continents is 1000 feet; the average depth of the ocean," Professor Wyville Thompson says, "is not so great as was at one time supposed, and does not appear to average more than 12,000 feet, but is of sufficient depth to cover the whole earth, if spread evenly, to a depth of 8000 feet."

Many writers agree to the figure for average elevation of the land; but as to the average depth of the ocean, 2½ to 3 miles is quoted, and its mass is said to be 1,300,000 million million tons (which agrees with the previous calculation of cubic miles).

Calculations as to the mean depths of the oceans have been made with the following results:—

	Feet.
By Krummel (1878)	11,280
,, De Lapparent (1883) . . .	13,980
,, Dr John Murray (1888) . . .	12,456
,, Heiderich (1891)	11,280
,, Dr Karsten	11,472

The last-mentioned authority also gives details of the average depths of the four great oceans:—

	Feet.
Atlantic Ocean, with Arctic . . .	10,368
Indian Ocean	11,790
Pacific	12,564
Antarctic	4,920

The reader must not test these figures expecting to get an average of 11,472 feet above stated; the varying areas have to be taken into consideration as well as the smaller seas, for the sea with the greatest mean depth is no doubt the Pacific; this mighty ocean is equal in area to half the water of the globe.

In the Atlantic the greatest depths are north of Porto Rico (28,000 feet; over 5 miles).

On the eastern margin of the Indian Ocean is the Sunda or Java Deep (20,000 feet).

Several authentic sounded depths of oceans are given in the *Geographical Journal* (vol. vi. p. 477, and vol. xv. p. 426), as recorded by Commander Balfour, H.M.S. *Penguin*, in South Pacific Ocean, lat. 23° 40′ S., long. 175° 10′ W. The wire broke before the bottom was reached. This occurred at 29,400 feet (5½ miles), which is 1470 feet deeper than the previous record, of the Tuscarora Deep. One hundred miles east of Macarthy Island 30,930 feet was obtained, and specimens were brought up. This is about half a sea mile deeper than the Tuscarora Deep.

Soundings even deeper than these are reported to have been taken off the coast of Chili, but with the few exceptions given, the depth of the ocean, as far as is known, nowhere exceeds 24,000 feet.

The greatest depth found in the North Atlantic was correctly determined by the *Challenger*, sounding 23,000 feet (4·4 miles).

Both on the European and the American side of the Azores are two deep valleys in the ocean bed, 15,000 feet deep.

A short distance from the edge of the shoal of Bermudas (about 300 islands) a like depth exists.

In the Pacific the *Challenger* got soundings of 23,700 and 26,850 feet, or 4½ and over 5 miles.

South-Western Pacific, by H.M.S. *Penguin*, 30,930 feet, lat. 30° 28′ S., long. 176° 39′ W.

The deepest parts of the ocean were in all cases very near land, and not, as one might expect, in the centre of these vast sheets of water. One hundred and ten miles outside the Kurile Islands, which stretch from the northern part of Japan to the north-east, 27,000 feet has been sounded.

Seventy miles north of Porto Rico, West Indies, 27,366 feet; 50 miles from the coast of Peru, 25,050; among the Tonga or Friendly Islands, 27,000; near the Ladrones, 26,888 feet; near Pylstaart Island, 26,568 feet.

Other deep soundings in North Pacific were made by U.S. Survey ship *Nero*, which discovered a depth of 30,960 and 31,614 feet, and a temperature of 35·9° at 30,420 and 36° at 30,606 feet, and at the bottom 35° or 34·9° were obtained. This was named the Nero Deep, and was found in surveying for a southern route to connect Guam with the proposed cable from Honolulu to the Midway Islands.

It is now clear that the greatest ocean depression extends farther below sea-level than the highest mountain ascends above it.

Various theories are advanced as to the cause of these vast depths, but most probably it is more a matter of elevation of the mass (leaving the hollows) than the formation of depths.

Hartwig, referring to the subject, says: "It has been found that the greater the depth of the ocean, the swifter the tide-wave. This affords another means of determining the approximate depth of the sea bottom. According to this method, the depth of the Channel between Plymouth and Boulogne has been calculated at 180 feet; and the enormous rapidity of the flood-wave over the great open seas (over 300 miles per hour) gives us for the mean depth of the Atlantic 14,400 feet, and for that of the Pacific 19,500 feet"; but, as we have seen, these figures are far too low an estimate.

Pressure and Depth

The pressure at an average depth of the ocean, viz. 2 miles, is as much as 320 atmospheres, and yet there is at the bottom of the sea an abundance of animal life.

Referring to the pressure of the sea at great depths, Professor Tait says: "Like fresh water, it suffers but little compression, notwithstanding at the depth of 1 mile the pressure is about 1 ton to the square inch, and so on in proportion; at the bottom of the deepest ocean about 4 tons to the square inch. At this level 11,000 cubic feet of air would be squeezed to 22 cubic feet, but 11,000 cubic feet of water would only be reduced to about 10,000 cubic feet, the density being only slightly increased; upon the pressure being removed, however, the water would return to its original volume."

It is stated that 31,614 feet has been sounded near the Island of Guam; here Mount Everest could be completely submerged, and still the waves would roll 2000 feet above its crest.

At this depth (31,614 × ·43) the waters are pressing on the bottom of the abyss with a pressure of over 13,500 lbs. per square inch, a pressure difficult to conceive; it would crush like paper the strongest ship.

Notwithstanding this pressure, owing to the incompressibility of water, any substance of greater specific gravity than water, which will sink in a shallow pool, will sink to the uttermost depths of the sea. I mention this, for some people imagine that there is a level and a pressure in the ocean at which even iron will not sink further.

Shore fishes which inhabit the sea around the coasts do not usually descend below 1800 feet, and the majority live close to the surface.

Deep-sea fishes, which inhabit the lower depths of the sea, are but little influenced by light or temperature, and are of such construction that they would be unhealthy or out of their element, metaphorically speaking, in surface waters. It is assumed that the effect on a fish from the deeps when brought to the upper water is similar to that on man in entering the higher atmosphere.

It is found that the rays of the sun do not penetrate to a greater depth than 1200 feet, as they do not affect a photographic plate at 220 fathoms (1320 feet). Beyond this depth is considered the home of deep-sea fish.

At a depth of 3000 feet the temperature would be 40° F., and beyond the influence of the surface temperature; therefore temperature has little effect on the deep-sea fishes.

The pressure of the atmosphere on a body at the surface of the sea is 15 lbs. per square inch, but under water the figure would be 1 ton for every 6000 feet.

All deep-sea fishes are carnivorous, for vegetable life ceases with the depth to which the sunlight penetrates into the waters.

All marine creatures are subject to a pressure of 15 lbs. per square inch for every $5\frac{1}{2}$ fathoms in depth; the tissues of deep-sea animals must have a special structure to enable them to exist at greater depths. If a fish from these depths rises to the surface, death generally ensues from rupture through the expansion of the gases on the reduction of the pressure.

Deep-sea fishes, brought up in the traps set for that purpose, sometimes arrive at the surface with their stomachs pushed out of their mouths by the dilation of their swim-bladders, owing to reduced pressure. If two fishes, one from deep and the other from shallow water, attack and seize one another, the one that is carried into the waters for which he is not by nature constructed is certain to perish from this cause.

As far as man is concerned, his system will not withstand more than an additional 88½ lbs. pressure, thus limiting the depth he can descend into the sea to 204 feet. This is a record dive, and death resulted, it is presumed, not from the depth or pressure, but through a too rapid ascent to the surface.

Some pearl-fishers reach a depth of 140 feet, and a celebrated diver named Lambert salved £100,000 at a depth of 160 feet.

The Admiralty, however, adopt 120 feet as the limit mark for their operations.

For experimental purposes two persons have been subjected to an artificial air pressure of 75 and 90 lbs. respectively, and it is assumed that if great care were taken a pressure of seven atmospheres (105 lbs.) might be borne without causing death; the risk, however, is great.

Temperature of the Sea

The temperature of the ocean varies greatly; this is partly due to abrupt changes owing to currents.

An examination of the records of the sea temperatures taken by the *Challenger* renders it highly probable that in the open ocean the mean daily fluctuations of the temperature of the surface water amount to not more than 1° F., forming a striking contrast to what takes place on dry land. The extreme ranges of temperature of the ocean range from freezing point in Polar regions to 96° F. at the head of the Persian Gulf.

The temperature of the sea under the torrid zone is always about 78° F. to 81° F. at the surface, diminishing as the depth increases.

The mean annual temperature of the surface of the sea around the coast of England is 49° F.; of the Indian Ocean, 89° F.; of the Red Sea, 94° F.

The maximum and minimum effects of temperature appear to take place in the water about a month later than in the atmosphere.

Enclosed seas carry a far higher surface temperature than the oceans. In the Red Sea 90° F. to 100° F. has been recorded, but the average is said to be 85° F. in summer and 70° F. in winter. Here it is estimated that the evaporation from the surface is from 15 to 25 feet, and that if it were not for the warm water of the Indian Ocean always pouring in, it would become a mass of solid salt in 2000 years. But we are digressing.

Hartwig says: "The equinoctial ocean seldom attains the maximum warmth of 83° F., and has never been known to rise above 87° F., while the surface of the land between the tropics is frequently heated to 120° F. In the neighbourhood of the line the temperature of the surface water oscillates all the year round only between 82° F. and 85° F."

In the Polar seas we find the temperature of the water higher than that of the atmosphere. Near Spitzbergen the water has never been found below 33° F., and between Norway and Spitzbergen 39° F., while the air only attained 37° F.

In both temperate and tropical regions the temperature of the sea at great depths is usually from 36° F. to 38° F.; but 32° F. has been recorded, while in the high latitudes water at 26° F. has been found.

This phenomenon is accounted for by the supposition that the cold water at the Poles, by reason of its great specific gravity, sinks to the bottom and spreads through the ocean basin, proving that in both hemispheres and at all latitudes the basic waters of the ocean are extremely cold.

The climates of the sea have been systematically determined, and the extraordinary fact has been brought to light that the great mass of the ocean water is cold, or below 40° F.

Even in the equatorial parts of the Atlantic and the Pacific Oceans a temperature of 40° F. is found within 1800 feet of the surface, while at depths of 15,000 or 18,000 feet the temperature is 32·4° to 33° F. (a little above the freezing point of fresh water).

Between Scotland and Faroe Islands a temperature of 29·6°, or 2·4° F. below the freezing point of fresh water, has been found, proving that the cold, heavy Polar water creeps towards the Equator and the upper, lighter, and warmer water moves away towards the Pole.

Off the coasts of Nova Scotia and Newfoundland the streaks of warm and colder water of the Gulf Stream alone vary in temperature as much as 20° F.

South of the Cape of Good Hope the Agulhas current of about 70° F., diverted by land, pours into a mass of water to the southward, 25° F. colder.

The depth of warm surface water of the ocean is small. For example:—

The equatorial current between Africa and South America has a surface temperature of 78° F.; 600 feet down it is 55°; at a depth of 2400 feet, only 40°.

The tropical Pacific has a surface temperature of 82°; 1200 feet down 50°; and at about 3500 feet we get a temperature of 40°. Below this depth the decrease *in temperature* is very slow.

"Ninety-three per cent. of the whole ocean, or 66 per cent. of the whole surface of our planet," says Sir John Murray, "is the vast deep-sea region, and is entirely removed from the direct influence of the sun, where not only is there a constant temperature at any one spot throughout the year, but the sun-rays are believed to be nearly all absorbed by passing through the 600 feet of sea-water by which this whole region is overlaid. Of the entire sea floor 92 per cent. is overlaid with water having a temperature of under 40° F., while of the entire surface of the ocean only 16 per cent. has a mean temperature of under 40° F."

Of the entire bulk of water in the ocean over 80 per cent. has a temperature under 40° F., and less than 20 per cent. has a temperature exceeding 40° F.

The movement of water at great depths is almost imperceptible. Were it not so, the lower water would not remain so isolated and permanently cold: any general movement that could be called motion would tend to equalise the temperatures by causing the lower waters to surmount any ridges on the ocean bed, and so flow to the surface.

The bottom of the North Atlantic is nowhere below 35° F. In the South Atlantic, at a depth of 16,800 feet, the temperature is but a little over 32° F. Ice of the South Pole does not influence the temperature of bottom water; this water, being fresher, though colder, will not sink. Here the water is warmer a few hundred fathoms down than on the surface.

The lowest temperature of the Arctic Ocean was obtained by Sir John Ross in Davis Straits, where at a depth of 4080 feet 25° F. was recorded; but this is doubtful, as the accuracy of the instruments was questioned.

The temperature of the surface in sandy deserts in the tropics rises to between 120° and 140° F., rarely more than 200° F., while during the night the temperature sometimes falls below freezing point.

At Werkojansk, in Siberia, the difference in temperature between the mean of the coldest and warmest months is 120° F.; here in February 1892 the temperature fell to −93·6° F. How different are these variations of temperature from that of the sea!

Colour of the Sea

The sea possesses naturally a pure bluish tint. The apparently clear water we drink, when seen in large quantities of sufficient depth, has this beautiful colour; the factor of quantity is not necessary, it is the depth through which the light penetrates that gives the effect of colour. (*See* Azure Cave, Capri.)

The Bay of Naples is noted for its colour of pure blue, and the Mediterranean and Arctic Seas are both deep blue in colour.

The green tint of the North Sea is partly due to the reflection from its sandy bottom mingling with the blue water.

The pure ultramarine of the Arctic Ocean is often in parts turned into a muddy green owing to the presence of small yellow medusæ, so numerous that a cubic inch has been found to contain sixty-four of these minute creatures.

In the neighbourhood of Callao the Pacific has an olive-green colour owing to the greenish matter at the bottom, 800 feet deep.

The Red Sea is so called from the minute algæ of a beautiful red colour which are sometimes present in great numbers.

In the Bay of Loanga the sea has the colour of blood, caused by the reflection from the red soil forming the bed.

The phosphorescent light that the sea sometimes assumes is also of great interest. Hartwig says: "Many creatures dredged from the North Atlantic off the west coast of Ireland, from depths of 500 fathoms, were brilliantly phosphorescent. In some places nearly everything brought up seemed to emit light."

Darwin, referring to this, says: "While sailing in the latitudes of Cape Horn on a very dark night, every part of the surface glowed with a pale light. The vessel drove before her bows two billows of liquid phosphorus. As far as the eye reached every wave was bright, and the sky above the horizon, from the reflected glare of these livid flames, was not so utterly obscure as over the rest of the heavens."

The minute, gelatinous animal that causes this light is so small that a single bucket of water will contain thousands, and they exist in such quantities that miles and miles of the ocean are often turned by them into sheets of living flames. The number of medusæ in the waters of Greenland seas is so great that in a cubic foot as many as 110,000 of these minute creatures have been found.

> "Flash'd the dipt oars, and, sparkling with the stroke,
> Around the waves phosphoric brightness broke."
>
> BYRON (*Corsair*).

Power of Waves

"O thou vast ocean! ever-sounding sea!
Thou symbol of a drear immensity!
Thy voice is like the thunder, and thy sleep
Is like a giant's slumber—loud and deep."

BARRY CORNWALL.

The sea in its fury is terrible indeed, its power beyond our comprehension. The roller of a ground-swell 20 feet high has a pressure of one ton to a square foot, and this will roll a 5-ton block of stone about like a pebble.

The horizontal pressure exerted by a strong Atlantic wave is said to be equal to 3 tons to a square foot, and when confined between the walls of the rocks it acts like a hydraulic ram.

"The movement of the sea," says Humboldt, "is of a threefold description; partly irregular and transitory, depending upon the winds and occasioning waves; partly regular and periodical, resulting from the attraction of the sun and moon (ebb and flood); and partly permanent, through the unequal strength and rapidity at different periods (oceanic currents)."

"The strongest storm," says Hartwig, "cannot suddenly raise high waves: they require time for their development. The wind blowing over an even sea sets water particles in motion all over the surface, and this gives the first impulse to the formation of small waves; numberless oscillations unite their efforts and create visible elevations and depressions. As the strength of the waves rises gradually, it also loses itself by degrees, and many hours after the tornado has ceased to rage the mighty billows continue to remind the mariner of its extinguished fury.

"The turmoil of waters awakened by the storm propagates itself hundreds of miles beyond the space where the howling voice was heard, and often during the most

TYPICAL ROUGH SEA AND COAST SCENE.

[*To face p.* 328.

tranquil weather the agitated sea proclaims the distant war with the elements."

The waves of the ocean have been known to reach a height from trough to crest of 40 to 90 feet, according to some authorities. Probably 50 to 60 feet is a more correct figure. These are termed storm or wind waves, as distinct from waves set in motion by earthquakes, which have been known to exceed the former considerably. "The eruption of Krakatoa (27th August 1883) disturbed the sea, producing waves 100 feet high, which rushed upon and overwhelmed the neighbouring coasts of Java and Sumatra, stranding ocean steamers, destroying lighthouses, washing away and drowning over 36,000 persons."

These waves, which were of great length, moved, it is stated, with the almost incredible velocity of 350 miles an hour, and their crests were about that distance apart, as they arrived on the shore at intervals of about an hour.

Similar waves reached Cape Horn, having travelled 7500 and 7800 miles in their course on either side of the South Polar land, and were only 5 inches above mean sea-level; other waves reached the south of Africa, 5000 miles distant, and were from 1 to 2 feet high.

The maximum speed of storm or wind waves is said to be 80 miles per hour.

What a helpless thing even a powerful ship is when at the mercy of such waves! it is little wonder that the loss of life by shipwreck is so great.

> "Down came the storm and smote amain
>   The vessel in its strength;
> She shuddered and paused, like a frightened steed,
>   Then leaped her cable's length."
>
> LONGFELLOW (*The Wreck of the Hesperus*).

It is not only at sea that the loss of lives is to be deplored; many disasters have been caused by storm waves on shore. For instance, at Masulipatam, on the Bay of Bengal, a storm wave swept over the town in 1864, destroying 30,000 lives. Many similar catastrophes have unfortunately occurred.

The depth to which the ocean is disturbed by a violent gale is said by various writers to be not more than from 300 to 500 feet; beyond this depth all is still, the most dreadful hurricanes leave these depths undisturbed.

> "There is no sound, no echo of sound, in the deserts of the deep,
> Or the great grey level plains of ooze where the shell-burred cables creep."
>
> KIPLING.

A block of limestone weighing 7 tons is known to have been carried by the sea a distance of 150 feet. This will give an idea of its power; and it has been stated that in the erection of the Eddystone lighthouse, the engineers provided in their design for a probable pressure of over 3000 lbs. per square foot, this pressure being the power exerted by the waves in a storm.

With such forces continually at work, there is little reason to wonder at the general destruction going on around our coasts.

The church at Reculver, in Kent, now on the verge of the cliffs, was, in the time of Henry VIII., nearly a mile from the sea.

The Lofoden Islands, on the north-west coast of Norway, is a typical instance of the manner in which the sea has swallowed up the solid land. Here groups of rocky islands are all that remain. It has been appropriately called "the sea of vanished lands."

These mighty waters and the amount of denudation they effect is beyond our comprehension: the waves break continually against the solid earth, until the sea claims it for its own, forming the rugged coast-lines, with which we

COAST EROSION AT SOUTHWOLD, SUFFOLK.
(The work of one heavy sea.)

THE SAME SPOT TWO DAYS LATER.
(After a second high tide and sea.)

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are all familiar. "Here also water appears as the beautifying element decorating inanimate nature with picturesque forms."

The apparently mighty works of the ocean and seas enumerated here are but as trifles when we remember that, without doubt, at a remote period of the earth's history, Australia was joined up to and connected with Asia, and that the mighty seas that roll between represent but a lost continent, claimed by the sea which now rolls over it.

The forces of the sea, however, are not solely employed in destruction, for, as if by way of compensation, it is continually adding to some part of our coasts.

Romney Marsh (24,000 acres) is an example of this kind. In the ages gone by, this was the open sea, and ships once sailed over the spot where we can now walk on dry land.

We have another instance of this kind in the Norfolk Broads, and there are many similar tracts of land due to the same process, which begins with the formation of a bar of sand, drifted by the tide across the mouth of an estuary; this is followed by the silting up of the sediment deposited by the river inside the bar.

In this manner many square acres are added to our coasts, but the extent of this restoration is small in comparison with the enormous destruction worked by the waves in various parts of the earth.

In a lesser degree the tides do their part in the destruction and reconstruction of the land.

No description of the wonders of the ocean and sea would be complete without at least some short reference to the work of the reef-building Actinozoa and their work of forming new lands with the carbonate of lime separated from the waters of the sea. There are three kinds of coral reef: the atoll or lagoon reef, the barrier reef, and the fringing reef. Some are of considerable extent; the Suadiva Atoll, for instance, is 44 miles in diameter, while groups of atolls in various parts of the world cover thousands of square miles; barrier reefs are found up to 400 miles long, and fringing reefs of enormous extent are common.

Referring to coral islets, Darwin states: "Let the hurricane tear up its thousand huge fragments; yet what will that tell against the accumulated labour of myriads of architects at work day and night, month after month? Thus do we see the soft and glutinous body of a polypus, through the agency of the vital laws, conquering the great mechanical powers of the waves of an ocean which neither the art of man nor the inanimate works of nature could successfully resist."

While thinking of the awful power exerted by the ocean, we should also give some consideration to the results and benefits we derive indirectly from this source. Without doubt the healthfulness of the ocean is greatly due to its constant motion, which prevents stagnation and corruption.

How refreshing too is the sea breeze after a storm! The endless churning of the waves, every breaker imprisoning the air, beating it down under its crested head, sends it in endless repetition rushing through the water to gain the surface. In this process it becomes washed and purified, and probably electrified to some small degree: hence the benefits derived from a sea-trip, where nothing but the well-washed and purified, invigorating air can be breathed.

Notwithstanding all the benefits we derive from the sea, it is curious to note what Hartwig says of its composition.

"Besides chloride of sodium (common salt) and other chief ingredients, the sea-water contains lead, copper, and silver, and sufficient arsenic to poison every living thing."

Ocean Currents

An ocean current, so called, is a sensible movement of the water in the ocean in a particular and traceable direction.

The currents of the Indian Ocean, and of the sea off the coast of Central America, are produced solely by the prevailing winds, or trade winds, and they change their direction twice yearly, with the monsoons. It is partly due to the prevailing west winds that the waters of the Gulf Stream reach our shores.

These variable currents, propagated by the winds only, and varying with them, are more correctly described as "surface drifts." The true ocean current, however, flows steadily and continuously in a definite direction, keeping itself distinct from the ocean through which it passes, as distinct as a river is from the land through which it flows. The primary cause of the motion of these currents is the heat of the sun, which raises the temperature of the waters in the tropical oceans, causing expansion and so setting up circulation; excessive evaporation and great rainfall also cause an alteration of density and level, and the action of the wind, already referred to, also affects the ocean. All these and many other circumstances, including the irregular coast-lines, tend to promote and keep constant the ocean currents.

Thus we see that every cause which tends to promote circulation in the oceans, just as in the atmosphere, has its origin in the centre of our universe, the sun. In addition to holding the planets in their courses, millions of miles away, it creates the ocean currents on this diminutive earth of ours, and fulfils all the important duties to which we have referred so frequently, and endless work that has not been mentioned, as well as much that cannot be conceived by us, and it was for this reason that in the commencement of this book so much time was devoted to the sun and solar heat.

There are numerous currents in the vast oceans of the globe, the most celebrated of which is the Gulf Stream, and we shall refer to it at some length, as it is a typical example of an ocean current.

The equatorial current is very shallow, only about 50 fathoms. It flows at a speed of 18 miles a day on the surface, which decreases to 9 miles at a depth of 50 fathoms (300 feet). The surface temperature varies from 75° to 80°. At a depth of 100 fathoms the temperature falls to 60°. The temperature of this current is kept down by the continual rising of the Polar water from below.

The Guinea current runs at the rate of 30 to 50 miles per hour, and occasionally at 80.

The contiguous bands of water forming current and counter-current retain their respective temperatures quite distinctly; for it has been found, in crossing these bands of water coming from different parts, that the temperature at the bow of the ship has registered 70°, while that at the stern only recorded 40°.

"It has been calculated theoretically," says Captain Wharton, F.R.S., "that winds blowing steadily in one direction, with the ordinary force of the trade winds, would, in 100,000 years, by friction between the particles, put the whole of a mass of water 2000 fathoms deep, not otherwise influenced, into motion in that direction."

"An instance of the underrunning of one current by another," continues Captain Wharton, "is brought plainly to our notice in the North Atlantic, to the east of the great banks of Newfoundland, where the icebergs borne by the Arctic current from Baffin's Bay pursue their course to the southward across the Gulf Stream running eastward. These great masses of ice, floating with seven-eighths of their volume under the surface, draw so much water that they are all but wholly influenced by the undercurrent. A large berg will have its bottom 600 to 700 feet below the surface. The only reason that these bergs continue their journey southwards is the action of the cold undercurrent."

The Gulf Stream

The hot water of the Mississippi forces the water forming the Gulf Stream from the Gulf of Mexico, where the tropical sun has heated it to a temperature of 86°, through the Florida Channel. Here its breadth is 60 miles, and it is about 350 fathoms, or over 2000 feet, deep (other authorities, however, give 600 feet as the limit of its depth), and it travels at the rate of 90 to 120 miles per day (4 to 5 miles per hour). The velocity varies with the course of the current: within the Florida Channel it attains a mean of 65 miles per day; off Charlestown, 56 miles; 36 to 46 off Nantucket; and 28 miles to the south of the Newfoundland banks; 300 miles to the eastward of Newfoundland its movement is hardly perceptible.

From the Gulf of Mexico, which has a coast-line of 3000 miles, it travels through the Strait of Florida across the Atlantic. In the Florida Channel its temperature is 34° F. at the bottom, 80° to 84° F. at the surface; in winter 77° F. But as it travels it gradually suffers a loss of temperature. Off Charlestown, 75° F.; off Cape Hatteras, 72° F.; south-east of Nantucket shoals, 67° F.; south of Nova Scotia, 62° F. In winter, therefore, between these points there is a loss of 15° F.; in spring, 11° F.; summer, 5° F.; autumn, 13° F. In mid-Atlantic it has a temperature of 75° F. Here its breadth increases and its speed diminishes.

In the Atlantic it divides: one current flows in the direction of and follows the coast of Africa and is lost in the equatorial waters; the other current, millions of times larger than our largest English river, washes the shores of England and Ireland, bringing with it some of the warmth of the West Indies.

Continuing its journey by the coast of Iceland and Norway, it is lost in the Arctic regions, where, Sir Archibald Geikie says, "the Gulf Stream is distinctly traceable by its warmth into the Arctic seas."

The effect of this stream is that it brings us a temperature 10° F. higher than we are entitled to by our latitude. Norway by 16° F. and Spitzbergen by 19° F. also benefit by its genial warmth.

Were it not for this stream, the maritime borders of Europe, where now a temperate climate prevails, would be cold and frost-bound, like Southern Siberia and the coast of Labrador, the latter being in the same latitude as the British Isles.

How this body of water preserves so high a temperature even when it reaches the Azores is little short of marvellous, but we have already seen that though water does not get heated so quickly as other substances, it will retain its warmth longer. (*See* Latent Heat of Water.)

Water being able to absorb more heat, without having its temperature unduly raised, is the only substance that could possibly bring so enormous an amount of heat such a distance, and give it out in the process of cooling. It thus forms a mighty heating apparatus, distributing the heat of the tropics to lands requiring warmth.

If the surface of the earth were entirely dry land, there would be no transfer of heat by oceanic or atmospheric

Mrs Aubrey Le Blond.

VEGETATION IN NORWAY, 200 MILES WITHIN THE ARCTIC CIRCLE, DUE TO THE GULF STREAM.

Mrs Aubrey Le Blond.

ICE-LAKE IN ARCTIC NORWAY, 2000 FEET ABOVE THE SEA, WHERE THE ICE SELDOM WHOLLY MELTS IN SUMMER.

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currents, and the result would be a temperature of about 130° F. at the Equator, while at the Pole it would be 108° F. below zero.

The mean temperature day and night at the Equator is about 80° F., while that at the Pole is only 0° F., or zero.

Consequently, the effect of the circulation of the ocean and the atmosphere together is to depress the temperature at the Equator about 50° F. and to raise it at the Pole by no less than 100° F., and so make the earth fit for habitation.

The Polar Stream

Every ocean current has a corresponding counter-current, in this instance called the "Polar Stream."

This stream flows from the Arctic zone, down Baffin's Bay, past the shores of Greenland, bearing on its bosom the icebergs detached from the glaciers and ice-fields of the Polar regions, bringing them down to the point off the coast of Newfoundland, where the Polar Stream meets the Gulf Stream. The difference between the temperature of the Gulf Stream and this cold current sometimes amounts to from 20° to 30° F.

During the drift of the *Fram* across the Polar seas, exhaustive tests of the temperature at various depths were carried out. It was found that the surface water of the entire Polar basin is very cold, seeing that it keeps to about the freezing point of salt water (29·3° F. to 29·12° F.). When penetrated, however, to a depth of 110 fathoms, the temperature was from 32·9° F. to 33·44° F.; this continued to between 220 and 270 fathoms, after which it sank slowly, though without reaching the cold temperature of the surface water. Near the bottom it again rose quite quickly. Of this Nansen remarks, referring to the influence of the Gulf Stream in these latitudes: "Great, however, was my astonishment when, as far east even as the sea north of the New Siberian Islands, I found undoubted traces of such a warm current."

It is the Polar Stream which brings the bitter cold and ice of the Polar regions to the coast of Newfoundland in the summer.

Here, by the greater density due to its low temperature, the Polar Stream sinks beneath the Gulf Stream, and thus completes the circuit of these two ocean currents.

The joining of these two streams of different temperatures, and the meeting of the warm air accompanying the Gulf Stream with the cold aerial counter-current accompanying the Polar Stream, causes condensation; thick clouds of mist arise and hang over the surface of the sea in these parts, forming a source of great danger to shipping.

Among the many other ocean currents, each having a separate course, are the Cold Peruvian, the Equatorial, the Japanese, the North African and Guinea, the South Connecting current, the Southern Atlantic, the Cape Horn current, Rennel's current, the Arctic and Greenland.

The assistance rendered to navigation by these currents can only be appreciated fully by those who spend their lives on the great oceans.

We must also remember that these apparently permanent ocean currents are subject to the general evolution that is going on universally, for Darwin tells us that during the height of the Glacial Period the ocean currents were widely different from what they are now.

If this be so there can be no doubt that the changes which brought about the present state of things are still working, and further changes will probably take place as time goes on.

Harvests of the Sea

"O Lord, how manifold are thy works! in wisdom hast thou made them all: the earth is full of thy riches; so is this great and wide sea, wherein are things creeping innumerable, both small and great beasts."—Psalm civ. 24, 25.

The harvests of the land must be sown, and the increase is great; but it is insignificant when compared with the unsown harvest of the sea.

The reproductive powers of the fishes are enormous: take one example only, the cod-fish, the roe of which has been found to contain 9,344,000 eggs.

The universal distribution of fish is also of interest. They are found in the lakes at altitudes of 11,000 to 15,000 feet, and in many parts at the line of perpetual snow; but the sea is the world's storehouse of this most valuable food.

In the waters of the sea we get the minute medusa and the mighty Greenland whale (*Balœna mystacocetus*), the largest of all living animals. It has been known to measure 60 to 70 feet in length by 30 to 40 feet in girth, and to weigh 70 tons, yielding 30 to 40 tons of blubber.

Then we have the precious pearls, sponges, corals, and the seaweed from which we obtain iodine, besides many other products too numerous to specify.

The work of the ocean in the transport of vegetable seeds must not be overlooked. It has been found that very many seeds can endure immersion in the sea for a long period without damage, and in this way numerous plants have been introduced into countries many miles from those in which they are indigenous.

Marine Caves

"It is here the sea, which stamps the seal of its might on vanquished rocks, scoops out wide portals and hollows out deep caverns in their bosom."—HARTWIG.

What work of man's devising can equal that superb piece of ocean's architecture, Fingal's Cave, in the Isle of Staffa, which is composed chiefly of basaltic pillars, resting upon a substratum of rugged rock?

Here we have a grotto 250 feet long, 53 feet wide at the entrance, spanned by an arch 117 feet high, with walls and roof of hexagonal basaltic pillars, even at the farthest end maintaining a height of 70 feet, the sea having slowly excavated and formed "a magnificent temple of nature," with the sea for a floor, on which boats may venture safely in calm weather.

Hartwig also tells us of the Azure Cave or Blue Grotto at Capri, which, owing to its small entrance, the top of which is only a few feet above the sea, was only discovered by accident in 1826 by two artists, who were swimming in the neighbourhood.

Within this narrow portal the cave widens out to 125 feet long by 145 feet broad. All the light that enters the grotto must penetrate the whole depth of the waters (several hundred feet) before it can be reflected from the clear bottom. It thus acquires so deep a tinge that the dark walls of the cavern are illuminated by a radiance of the purest azure.

The visitor will find, should he arrive by steamer, a number of small boats waiting for their harvest. The day must be a calm one, for the aperture through the rock into the cave is only large enough to admit a single boat. The boats are small, and never carry more than two passengers at a time, one in the bow and one in the stern. On approaching the entrance, the boatman has to

THE AZURE CAVE, CAPRI, ITALY.

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wait for a wave, and time it. With a shout to his passengers to lie down flat, he gives two short strokes with the sculls, and lies flat on his back. With a swish the wave bears us to the mouth, and with a dig of the oar on the side of the cave we are soon inside.

Inside the cave the colouring is one blaze of azure. Naked boys are generally waiting for coins to be thrown, for which they dive, stirring up the water, which sparkles and scintillates in the light which penetrates from its only point of access, the entrance.

The grotto of Antro di Nettuno, in the island of Sardinia, also described by the same writer, must be an awe-inspiring spectacle.

Here access is only possible on four or five days in the year, on account of the prevalent adverse winds.

"The first vaulted cavern, forming an ante-chamber about 30 feet high, has no peculiar beauty; but on crossing a second cavern, in which there are about 20 feet of beautifully clear water, one finds oneself in an intricate navigation among stalactites, with surrounding walls and passages of stalagmites of considerable height.

"Proceeding westerly, one reaches another cavern with a natural column in its centre, the shaft and capital of which support the immense and beautifully fretted roof, which reminds one of those in the chapter-house of the cathedral at Wells, and the staircase in the hall at Christ Church, Oxford.

"In parts are corridors and galleries 300 and 400 feet long, reminding one of the Moorish architecture of the Alhambra; one of them terminates abruptly in a deep cavern, which it is impossible to descend.

"Some of the ceilings are covered entirely with delicate stalactites, and the sides with fretted open work, so fantastical that one might almost imagine that it was a boudoir of the Oceanides, where they amused themselves with making lime lace."

In concluding a graphic description of this wonderful cave, he says: "Some of the columns are 70 to 80 feet in circumference, and the masses of drapery, drooping in exquisite elegance, are of equally grand proportions."

An interesting sea cave formed by the Mediterranean waves is mentioned by Mr E. A. Martel. He considers it of unusual size, and unparalleled, at least in Europe. It is called the Dragon Cave, situate in the island of Majorca, 8 miles east of the town of Manacor. This cave has been visited by only two persons since 1878, and contains about 1¼ mile of stalactite and stalagmite galleries and lakes. In September 1896 Mr Martel found here one of the largest underground lakes known, to which he gave the name of Lago Miramar, 570 feet long, 100 to 125 feet wide, 15 to 30 feet deep. The vaults and walls are covered with millions of thin, sharp stalactite needles, pure and white as ermine.

Innumerable caves of this description exist in many parts of the world, but are scientifically unexplored at present.

A passing reference may also be made to the beautiful fjords or sea lochs in Scotland and Norway. They are in no way similar to the caves, neither is their formation due directly to the sea. They are probably of glacial origin; at least it is certain that they were formed in remote epochs of the earth's history.

They are usually of great depth, but barred from the sea at their entrance by a rocky sill, rising, as in the case of Loch Nevis, to within about 40 feet of the surface. The Sogne Fjord, in Norway, well known to tourists, is 4200 feet deep and over 100 miles long.

The water in these fjords is much fresher than in the

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HARDANGER FJORD, NORWAY.

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SOR FJORD, NORWAY.

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sea, owing to the streams that flow into them from the mountains which rise along their sides. The mixture of rain water with the sea presents some curious and interesting phenomena. Fresh water being lighter, keeps at the surface; the salt water forms the lower stratum.

"Where the Amazon, the La Plata, the Orinoco, and other giant streams pour their vast volumes into the ocean, the surface of the sea is fresh many miles from the shore; but this is only superficial, for below, even in the bed of the river, the bitterness of salt water is found" (Hartwig).

Truly, "they that go down to the sea in ships, and occupy their business in great waters; these men see the works of the Lord, and his wonders in the deep."

CHAPTER XV

MOUNTAINS AND VOLCANOES

"There is silence on the tall mountain peak, with its glittering mantle of snow, where the panting lungs labour to inhale the thin bleak air; where no insect murmurs, and no bird flies, and where the eye wanders over multitudinous hill-tops that lie far beneath, and vast dark forests that sweep on to the distant horizon, and along deep valleys where the great rivers begin."—Hugh Miller.

The reader will probably wonder what mountains and rocks have to do with water: we will try, without trespassing unduly on the domain of geology, to trace briefly its work in this connection.

"There was a period," says Ruskin, "or a succession of periods, during which the rocks which are now hard were soft, and in which, out of entirely different positions, and under entirely different conditions from any now existing or describable, the masses, of which the mountains you now see are made, were lifted and hardened in the positions they now occupy."

We may at once dismiss the igneous rocks, or rocks that were once in a molten condition and have cooled down, such as lava and the granites; metamorphic rocks we will also pass over, as it is doubtful if water had much to do with their formation; we must confine ourselves to stratified or aqueous rocks, which in past ages were thrown up into mountain masses by mighty subterranean movements.

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THE MATTERHORN FROM THE ZINAL RIDGE OF THE ROTHHORN—TYPICAL MOUNTAIN SCENERY.

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Formation of Mountains

"The dust we tread upon was once alive."—BYRON.

Many rocks and mountain ranges were formed mainly by the action of water in the first instance, and, as all mountains are being destroyed by water, slowly but surely, we are bound, in this story of water and its work, to devote some little time to them.

The building of mountains is even now going on: the stratified rocks owe their very existence to water. They contain, in a fossil state, the remains of animal and vegetable life, principally the remains of marine life, and were once sediment deposited at the bottom of the seas and lakes.

Shells, fish, weeds, corals, etc., became embedded in the sediment, and by process of time became the fossils we now find. The word fossil is derived from the Latin *fossus*, "dug up."

It is almost beyond our power to conceive how many of the mighty mountains came to be composed of organic remains, from base to summit. It is but the work of ages; layer after layer of sediment or mud, containing living creatures, was deposited by water, followed by upheaval; for the sea has not been lowered—that could not be.

"The Maker! ample in His bounty, spread
The various strata of earth's genial bed."

BROOKE.

Fossil shells which were once crawling on the bottom of the seas, lakes, and rivers, and of forms such as now abound in the same, are met with, far inland, both on the surface, at great depths below it, and at great heights above sea-level: in the Pyrenees at an elevation of 8000 feet, 10,000 feet in the Alps, 13,000 feet in the Andes, 14,000 feet in the Peuquenes ridge, on the Chilian side of the Cordillera, and 18,000 feet in the Himalayas.

This action is now going on. In the making of rocks no new matter is necessary: it is but the rearrangement of the material in existence.

What is deposited in one place is but the outcome of disintegration and denudation of other parts.

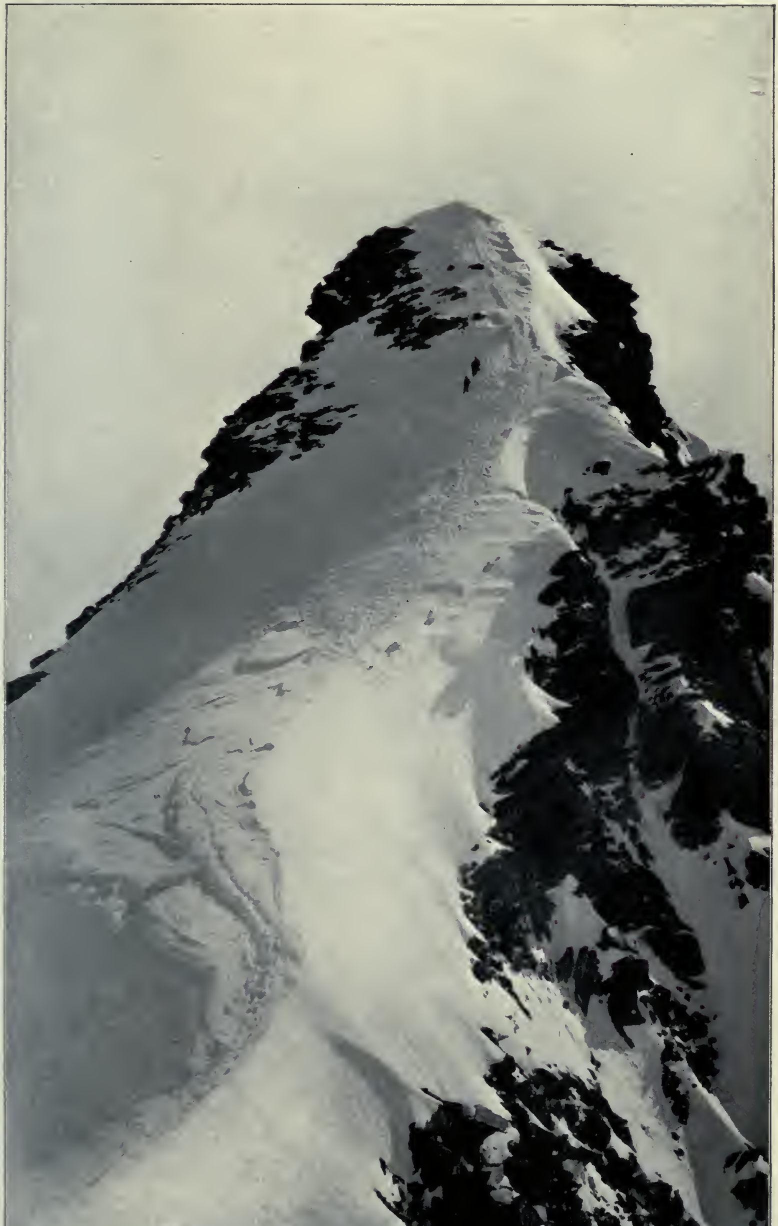
The slates which form the roofs of our houses provide a familiar instance of a water-formed rock, being but precipitated or deposited mud, turned first into clay, and compressed into rock by varying geological conditions. The chalk hills are but the accumulation of the shells of myriads of small creatures.

> "The endless kind of creatures which by name
> Thou canst not count, much less their natures aim."
>
> SPENSER.

But we will deal more fully with chalk in the next chapter.

"The earth is never at rest; it has had, and is undergoing, endless vicissitudes; even the matter that is seemingly unchangeable, is in reality in a state of ceaseless transformation. The mould of our garden is but the result of the disintegration of the apparently solid and stately rocks; even the stately Andes are wearing away, and every river which flows to the sea alters the configuration of the country, and does its little to lay the foundation of new lands, miles away" (Robert Brown).

The great mountain ranges were no doubt due to direct upward pressure from below, caused by the pressure of the earth's crust contracting as it cooled. Notwithstanding their enormous heights at the present time, Professor Ramsay proves that 29,000 feet have been removed from the Welsh mountains (Snowdon, now 3571 feet high, is but the stump of what was once a colossal eminence), and that



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MONTE ROSA.

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in Switzerland an amount equal to their present height has been removed from the mountains.

This must not be taken to mean that they were double their present height, as elevation and erosion must have gone on contemporaneously.

Our Welsh hills are far more ancient than their larger brethren. They had been mountains for ages and ages before the materials which now compose the Rigi or Pilatus were deposited at the bottom of the sea.

The Welsh mountains are older than the Vosges, the Vosges than the Pyrenees, the Pyrenees than the Alps, the Alps than the Andes, which last indeed are still rising.

"The Cambrian period was an epoch of vigorous volcanic action. The products of the volcanoes are seen in the Skiddaw slates of the Lake District, where about 12,000 feet of volcanic ash and Andesite lava, of Honister Crag and Seathwaite, mark the beginning of volcanic action which continued through the accumulation of the Borrowdale series of rocks" (Brend).

"Who can avoid wondering," writes Darwin, "at the force which has upheaved mountains, and even more so at the countless ages which it must have required to remove and level whole masses of them?"

As soon as a mountain range is raised, all nature conspires against it: sun, frost, heat, cold, air, water, ice, and snow; all plants, from lichen to oak; every animal, from worm to man.

Water, however, is the most powerful of all the agents of disintegration; autumn rain saturates every pore and cranny, and frost cracks and splits the hardest of rocks; spring comes, sun melts the snow, swelling the rivers, which carry off the debris to the plains.

Altitude of Mountains

"In bluish white the farthest mounts arise,
Steal from the eye, and melt into the skies."
HARTE.

By comparing Snowdon—which many of us have ascended—with some of the monsters of other countries, we shall get a more accurate idea of their immensity.

These heights, enormous as they are, are only in proportion to the enormous rivers to which they give birth, and the continents in which they are found.

Nature verily seems to work to a scale, and to maintain a uniformity in these mighty works as well as in the minutest form of creation.

	Height in feet.
Snowdon, Cambrian system	3,571
Ben Nevis, Inverness	4,400
Hermon, Syria	10,000
Maindetta, Pyrenees	11,500
Cook, New Zealand	12,000
Columbia, Rocky Mountains	14,000
Ras Dashan, Africa	15,100
Mont Blanc, Alps	15,732
Ararat, Armenia	17,000
Elburz, Caucasus	18,500
Demavena, Persia	19,400
Logan, Californian range	19,500
Kilimanjaro, Africa	19,600
Chimborazo, Ecuador, Andes	20,703
Aconcagua, Chilian Andes	23,910
Sorata, Andes	24,600
Everest, Himalaya	29,002

Influence of Mountains on Rain

The cold crests of mountains aid in the work of condensation; hence the enormous rainfall in mountain districts.

It is found that the amount of rain collected increases

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A MOUNTAIN SUMMIT, PIZ BERNINA.

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A HANGING GLACIER ON OBER GABELHORN.

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with the altitude, but only up to a moderate elevation; after which there is a reduction, due to the fact that the air is too cold to contain much vapour, and the amount of rain decreases accordingly. This height of maximum fall varies with the locality. At Cherra Punji, in the Khasia Hills, Assam, to which we have previously referred, the enormous annual rainfall recorded takes place at an altitude of about 4000 feet only.

Lofty mountain ranges also greatly influence the distribution of heat and moisture. The west winds from the Pacific, on reaching the coast ranges of California, are turned southwards and thus become north winds.

We have only to refer to the figures given under Rain and note the effect of our comparatively small mountains on the rainfall. From these we shall be able to form some idea of the influence of the mighty mountain ranges on the rainfall of any country, which yields a copious supply of water to the lakes nestling in the valleys below.

The deserts in Central Australia and Arabia are principally due to the absence of mountains, and the distance from the sea.

The Desert of Gobi, and many similar rainless regions, owe their aridity to the fact that they are shut off from the influence of moist winds by high chains of mountains, which arrest the clouds, and by condensation almost entirely exhaust them.

Volcanic Mountains

The building up of mountains by volcanic action is still going on. Many of them are but extinct volcanoes, and as the influence of mountains on atmospheric precipitation is great, they claim a place in our story.

It is assumed that, notwithstanding the enormous amount of denudation that is continually in progress, the total area of land above sea-level remains undiminished. "Running water," says Lyell, "and volcanic action are two antagonistic forces: one labouring continually to reduce the level of the land to the sea, the other to restore and maintain the inequalities of the crust, on which the very existence of islands and continents depends."

Ruskin says: "Having invented telescopes and photography, you are all stuck up on your hobby-horses, because you know how big the moon is, and can get pictures of the volcanoes on it! But you never can get any more than pictures of these, while in your own planet there are a thousand volcanoes which you may jump into if you have the mind to, and may one day perhaps be blown up sky-high by, whether you have the mind or not."

Von Humboldt gives the number of volcanoes as 323, but according to Keith Johnston 300 are recorded, some always active, but some only occasionally. Some of these are probably now extinct. On the eastern slope of Mount Loa (Mauna Loa), in Hawaii, which is 14,000 feet high, is the crater of Kilauea, which opens at 4400 feet above the sea. It is the largest active crater in the world, and has a diameter of over 2 miles and a circumference of about 9 miles; it is oval in shape, with vertical sides 1000 feet deep, and the bottom is covered with red boiling lava; the heat and light given out by this vast lake are intense.

Most of the mountains of Iceland have been volcanoes; at least twenty-five of them have been active within the last 1000 years. In 1766 Hecla threw out a column of ashes 16,000 feet into the air.

What mind can grasp the magnitude of the extinct volcano Askja, in the centre of Iceland, 4000 to 5000 feet high, its crater being 17 miles in circumference?

The famous Popocatepetl, or "smoking mountain," of Mexico, is an interesting study. It rises in the form of a snow-covered, regular cone to a height of 17,853 feet; the pine forests cease at 12,544, and the snow-line is 14,960. On the summit is an enormous crater 5000 feet in diameter, with a sheer depth of 2000 feet, which forms a cauldron of sulphur, which is worked by the Indians.

Fujisan, over 12,000 feet, crater 500 feet deep, is now apparently extinct: the last eruption took place in 1707.

Volcanic eruptions frequently occur under glaciers. On 11th May 1721, during the eruption of Katla (Iceland), an enormous mass of glacier ice was carried from its position, covering the sea to a distance of 3 miles from the coast, and the Myrdalssandur was flooded to a depth of 300 feet.

By the well-known eruption of Rotomahana, in New Zealand (to which reference has already been made), the whole surrounding country was covered in places to a depth of 200 feet by mud and scoriæ, over which nature, as if to cover her work of desolation, has caused the Scotch thistle, ferns, and other vegetation to grow and form a covering.

Many of these extinct volcanoes, that once belched forth fire, now stand peacefully capped with snow, and call to mind the lines—

"But soaring snow-clad through thy native sky,
In the wild pomp of mountain majesty."

Childe Harold.

Another example of mountains of this description is Mount Shasta in California. This mountain can be seen at a distance of 100 miles. It is 14,400 feet high; at its base the circumference is 75 miles; its crater is a mile in diameter and 1500 feet deep.

In the Andes we have many enormous volcanic mountains, both extinct and active. Among the active ones are Pichincha, 15,918 feet high, with a crater 2500 feet deep; also—

Tunguragua	16,685	feet high.
Sangay	17,460	,,
Cotopaxi	19,550	,,
Tolima	17,660	,,
Gualateiri	21,960	,,

The moon's surface is pitted all over with craters of enormous size, similar to those of the volcanoes on the earth. Many of them are 50 to 60 miles in diameter, some over 100 miles; small ones, up to 8 to 10 miles in diameter, exist by the thousand. They are nearly all circular, and surrounded by mountains up to about 20,000 feet high. In the centre of the craters is usually seen a peak or peaks, rising to the same altitude as the surrounding mountains. Many craters are filled to the brim, others are very deep.

Young, in his *Astronomy*, tells us that these are fossil formations, the result of true volcanic eruptions; for no evidence of existing volcanic activity has ever been found, all appears to be absolutely quiescent—"still as death."

Volcanic Eruptions

> "From the volcanoes gross eruptions rise,
> And curling sheets of smoke obscure the skies."
>
> GARTH.

It is a remarkable fact that out of 323 active volcanoes enumerated by Fuchs, all excepting two or three in Central Asia, and the same number in America, are near the ocean.

It is generally accepted that volcanic eruptions are more or less due to the action of water, which, percolating through the fissures in the surface, finds its way to the hot regions beneath, where it is formed into steam at high pressure, and forces a passage for itself through the crust of the globe, which is practically floating upon an internal nucleus of molten elements, and in an eruption these molten elements burst forth as liquid streams of lava.

The reader will probably wonder what use in the economy of nature the volcano and its attendant train of forces have. "The detritus," says Dr Buckland, "of the first dry lands, being drifted into the sea, and there spread out into extensive beds of mud and sand and gravel, would for ever have remained beneath the surface of the water, had not other forces been subsequently employed to raise them into dry land; these forces appear to have been the same expansive powers of heat and vapour which, having caused the elevation of the first-raised portions of the fundamental crystalline rocks, continued their energies through all succeeding geological epochs, and still exert them in producing the phenomena of active volcanoes, phenomena incomparably the most violent that now appear upon the surface of our planet.

"We therefore see that volcanic action is the principal force at work in the elevation of land from the ocean bed.

"Volcanic eruptions, therefore, are not only a means of destruction, but of reconstruction and renovation.

"The order that now reigns has resulted from causes which have generally been considered as capable only of defacing and devastating the earth's surface, but which we thus find strong grounds for suspecting were, in the primeval state of the globe, and perhaps are still, instrumental in its perpetual renovation.

"The great periods of upheaval, by volcanic and other disturbances, took place long before the creation of man, and may be looked upon as a series of mighty evolutions to fit our globe for life, both animal and vegetable."

Many theories are advanced as to the cause of volcanic eruptions, but all fail more or less to solve the problem to the satisfaction of those competent to judge of their accuracy.

Professor Milne finds some connection between this phenomenon and the periodic shifting of the earth's axis.

Professor Doelter attributes it to the variation of melting point with pressure.

"The lava of Vesuvius melts at a temperature of 1900° F. under ordinary atmospheric pressure, but the temperature at which fusion takes place is increased about one-twentieth of a degree for each atmosphere. This is not continuous; for the rise of melting point gradually reaches a maximum, after which any further increase of pressure leads to a lowering of the melting point.

"There must, therefore, be a level below which all rocks are in a state of fusion.

"Taking the mean rate of increase of 1° F. for each 60 feet, the underground temperature would overtake the rising melting point at, say, 70 miles, while the maximum melting point would not be reached under a depth of 100 to 200 miles.

"These conditions, combined with water and gases, given off as solidification ensues, or, as some assert, which have gained access by percolation and capillary attraction, cause an increase of pressure which, becoming great enough to overcome the resistance, leads to an eruption, and the molten *magma* of the earth's interior is belched forth."

It is concluded that the source of activity of Vesuvius is at a depth of about 12½ miles, and the temperature at that depth would be about 2550° F.

As this volcano has recently been in a state of eruption, the following particulars from the *Daily Telegraph* of 10th April 1906 may be of interest:—

"Vesuvius is a comparatively recent mountain raised in Tertiary times. For several centuries the Romans regarded it as a force which was spent. In the second Servile war Spartacus and his followers encamped within the crater. The first eruption of which we have any record took place in A.D. 63, when Pompeii suffered seriously. Its citizens were still rebuilding or repairing their shattered homes when they were overwhelmed by the great eruption of A.D. 79, which blotted out the city. Including the inhabitants of Pompeii and Herculaneum, 200,000 persons are supposed to have perished. Then ensued another era of repose.

"It was six centuries later before another serious eruption occurred, that of 1631, in which, it is reported, 18,000 persons perished. Thereafter the intervals grew shorter, and since 1701 the great volcano has been chronically perturbed. In the eighteenth century twenty-six considerable outbursts were recorded; and in the nineteenth century twenty-seven. The most disastrous of these occurred in 1767, 1794, 1822, 1867–8. The latest noteworthy displays were in 1872, 1879, 1885, 1892, 1897, 1900–1."

During the eruption of Imbaburu, Ecuador, in 1691, floods of mud were emitted in which were an immense number of dead fish, the stench of which caused a pestilence in Huera. This points to the breaking in of the sea, and its coming into contact with the internal heat. The steam ejected by one of the parasitic cones of Etna, during an eruption of 100 days, is estimated to have been equal to 460,000,000 gallons of water.

In the year 1883 Krakatoa poured forth a vast volume of steam which escaped from an opening 30 yards wide. This was followed by the greatest volcanic eruption ever known: the atmospheric vibrations encircled the globe, and the dust from this eruption was suspended in the air for about two years, causing beautiful sunsets all over the world.

Lord Byron, in *The Corsair*, gives us a beautiful description of a glorious sunset:—

> "Slow sinks, more lovely ere his race be run,
> Along Morea's hills the setting sun:
> Not as in Northern climes, obscurely bright,
> But one unclouded blaze of living light!
> O'er the hushed deep the yellow beam he throws,
> Gilds the green wave, that trembles as it glows."

These eruptions give us an idea of the power of the elements when they break their bounds and fire and water meet.

The volcano Antuco, in Chili, sent stones flying 36 miles. Cotopaxi is said to have hurled a 200-ton block of stone 9 miles.

The heat of a volcano is intense. The lava emitted from Vesuvius melted copper wire when thrust into it. This requires a heat of 2000° F., which is the fusing point of copper.

Mauna Loa, an active volcano, already mentioned, has a terminal crater 8000 feet in diameter, with nearly vertical walls, inside, 600 feet high. In 1843 there issued from this three streams of lava 5 or 6 miles wide, 20 to 30 miles long; in 1859 a stream, which continued to flow for two months, was 50 miles long, 1 to 5 miles wide, from 10 to hundreds of feet thick, reaching the sea-coast in eight days; again, in 1885, there was a flow of 70 miles long, 7 miles wide.

The lava stream ejected from Skaptar-Jokul, in Iceland, in 1783, was 50 miles long, with a depth of 500 feet. Tomboro, a volcano on the Island of Sumbara, in 1851 cost more lives than fell in Waterloo; and 30,000 to 40,000 people perished at Krakatoa.

During modern times the greatest eruption was on Coseguina, where for 25 miles the ground was covered with 16 feet of muddy water, and clouds of dust and ashes extended 20° to the west.

Volcanic eruptions have been known to influence greatly the fall of rain. Darwin tells us that almost unprecedented rain, which fell in Central America at a time of year most unusual for it, was entirely due to the eruption of Coseguina, and suggests that there is some intimate connection between the atmosphere and subterranean regions.

In the earlier stages of the earth's history the flows of lava were such as absolutely to eclipse any modern example. The Deccan basalts of India, for instance, attain a thickness of 4000 feet, and cover an area of 200,000 square miles.

Earthquakes

Earthquakes, like volcanic eruptions, are generally supposed to have their centres of disturbance under or near the sea, and they are attributed to the filtration of water down to igneous matter.

"A bad earthquake," says Darwin, "at once destroys our oldest associations. The earth, the very emblem of solidity, has moved beneath our feet like a thin crust over a fluid; one second of time has created in the mind a strange idea of insecurity, which hours of reflection would not have produced."

Sir Archibald Geikie, in the *Encyclopædia Britannica*, says: "We must conceive a vast reservoir of melted rock, impregnated with superheated steam, and impelled upward by the elastic force of the vapour. It is the pressure of the imprisoned vapour and its struggles to get free which produce the subterranean earthquakes and explosions and outpourings of lava. Mallet took this view. An earthquake, he said, is an incomplete attempt to form a volcano. In Mexico the cone of the burning mountain Jorullo was thrown up in a single night, on 29th September 1759, after months of subterranean rumblings; a small volcano there doubtless took the place of an earthquake, or a series of shocks. Mallet supposed that under Montemurro a cavity in the earth had filled with steam, and that at the computed depth there would be a temperature of 884° F., which would give a pressure of 684 atmospheres, or 10,260 lbs. per square inch. He reckoned the walls of this cavity as equal to 27 square miles, and so arrived at a total pressure of at least 640,258 millions of tons. The force with which volcanoes like Etna and Vesuvius can throw up masses of rock 10,000 feet and 20,000 feet, furnishes some indication of their subterranean energy. But these outbursts are probably feeble compared with the powers that cause such earthquakes as those of Lima in 1746; Lisbon in 1755; Calabria in 1783; Riobamba, in Ecuador, in 1797; and Peru and Ecuador in 1868. Professor John Milne says: 'The Riobamba earthquake, which projected bodies with an initial velocity of 80 feet per second, appears to have been the most violent earthquake, so far as impulsive effect is concerned, of which we have any record. It occurred among the Andes, where there are volcanoes from 16,000 feet to 21,000 feet high.' The town of Riobamba was annihilated, and 30,000 persons perished."

On 26th October 1891 an earthquake devastated Central Japan, causing a loss of 10,000 lives.

Earthquakes are mentioned in Japan as early as 286 B.C., when, according to ancient legends, Mount Fuji rose and the Biwa Lake was formed. The earliest authentic record is A.D. 416.

Earthquakes have caused lakes to become dry and land to be depressed, forming sites for lakes.

They are also prolific in the formation, by upheaval, of geological "faults," and they have in many ways helped to make this world a fit place in which to live; and although at times awful from the damage they cause, and from the number of the lives that are sacrificed by their fury, they are not only forces of destruction.

Volcanic Islands

Submarine volcanoes are no doubt caused by the infiltration of sea-water. They are of frequent occurrence, and many new islands have arisen through volcanic action.

"There be lands also," writes Holland, "that put forth after another manner, and all at once in some sea; as if nature cryed quittance with herselfe, and made even, paying, one for another, by giving againe that in one place which those chawmes and gaping gulfes took away in another."

Early in July 1831, Graham Island, in the Mediterranean, arose out of the sea. In the following August it attained a circumference of 3 miles, and a height of 200 feet. In less than three months, the sea again claimed it and lowered it to sea-level, and shortly afterwards reduced it to a dangerous shoal. It disappeared in 1864.

In the year 1795, on the coast of Alaska, an island (Bagosloff) rose out of the sea 42 miles from the land. In four years it was a cone 3000 feet high, 2 or 3 miles in circumference; two years later it was still too hot to walk on, and has since then again been in a state of eruption.

On the 19th October 1885 a volcanic island arose in the Pacific near the island of Tonga; and it has been recorded that a year after some of these submarine eruptions, the sea has been so hot as to melt the pitch off the hull of a vessel passing the vicinity of the eruption.

In May 1883, when Krakatoa, in the Sunda Straits, was in eruption, an immense wave swept over the shores of the neighbouring islands, and two new islands appeared where the morning before there had been from 30 to 40 fathoms of water.

On 15th December 1906 a new island suddenly appeared to the north of the Cheduba Island, on the Arakan coast of Burma. When visited on 30th December by the officers of the Marine Survey of India, it was found to be composed of mud and still very warm; 3 feet below the surface the temperature was 148° F. This island was a quarter of a mile long, the main crater being 20 feet above high water.

CHAPTER XVI

CHALK

"He brought water out of the stony rock, so that it gushed out like the rivers."—Psalm lxxvii. 17.

CHALK has been selected for fuller description as a typical example of aqueous rock, and, as such, frequent reference has of necessity been made to it.

Chalk is the rock which forms the higher part of a series or group of strata, comprising rocks of various kinds, and termed the Cretaceous system.

It forms our beautiful Downs, Chiltern Hills, Salisbury Plain, Beachy Head, and the white cliffs of the English coast.

> "Already British coasts appear to rise,
> And chalky cliffs salute their longing eyes."
>
> FALCONER.

Its composition varies, but it has been found to consist of 96 per cent. carbonate of lime, the remaining 4 per cent. being silica, clay, etc.

It is estimated that the enormous masses of carbonate of lime are equal to about one-eighth part of the entire mass that forms the superficial crust of the globe.

Formation

"Chalk was probably formed by the decomposition of sea-water; then, holding lime and silica in solution, the carbonate of lime and silica fell to the bottom together, forming chalk and flints. The silica was especially attracted by the organic remains lying on or beneath the beds, and collected around the same, forming the familiar flint" (Phillips). Frequently fossil sponges, Echinoderms, and other Cretaceous organisms are completely turned into flint, as well as being embedded in it.

"In a similar manner the Oolitic matter has collected around shells, the Lias limestone round ammonites, the carbonate of iron round ferns, etc." (Phillips).

Flint is found in the Upper Chalk in horizontal layers; in the Middle Chalk, however, it is only found in scattered, irregular-shaped pieces of all sizes; it is rarely met with in the Lower Chalk, but I have occasionally had to pierce hard masses of it in this part of the formation.

It was from this product of the work of water, by which this hard siliceous stone was formed, that our ancestors made their first implements of peace and warfare; the flint axe, with which they hollowed out their rude boats and of which they made their arrow and lance heads, knives and wedges, similar to those still used by some of the savage tribes. Truly, the slaughter of animal and man with such weapons must have been a gruesome operation.

It was this same rock, pulverised and put through certain processes, that formed the original material from which the glass called flint-glass was made. This was formerly used largely for the object-glasses of telescopes and microscopes, etc., but it is now more or less supplanted.

The varied uses to which chalk is put in the form of lime, cement, etc., are too well known to need mention here.

The carbonate of lime is composed almost entirely of shells. A microscopical examination of a piece of chalk will show thousands of perfect shells in a cubic inch, and that it consists largely of parts of bodies of minute animals.

"Every stratum was the burial-ground of its time."—Lyell.

"It is surprising," says Dr Buckland, "to consider that the walls of our houses are sometimes composed of little else than comminuted shells that were once the domicile of other animals at the bottom of the ancient seas and lakes." Vast areas of the bed of the Atlantic Ocean are said to be covered with calcareous mud, which consists principally of living Foraminifera, engaged in secreting lime from the water and forming their shells.

These minute marine animals, which are diffused abundantly in all but the Polar seas, collect by imbibition the carbonate of lime, etc., held in solution (not solid particles in suspension) by the sea-water, building it into their structures. In this manner they have formed and are still forming limestone and chalk, which are composed almost entirely of these little creatures, chiefly of the genus Globigerina.

Minute animals similar to those forming the chalk hills of our country are found in the "Levant mud," the white, chalk-like deposit on the bottom of shallow seas. This mud, when dried, corresponds in every particular with the chalk.

Over a large portion of the Atlantic basin is an abundance of minute Foraminifera, the accumulation of whose shells and disintegrated remains forms a calcareous deposit of unknown thickness, which also corresponds in all essential particulars with chalk. We have here chalk beds in the course of construction, and can see nature carrying on the process of building up rocks.

One writer, referring to these minute and apparently useless creatures, states:—

> "For all are equally
> A link of nature's chain,
> Formed by the hand that formed me,
> Which formeth naught in vain."

Although we can safely assume that chalk is formed in this manner, it still remains a mystery from whence the sea obtained such enormous supplies of this substance as to have formed and still be forming rocks of this description; for carbonate of lime, unlike sand, clays, etc., is not the result of disintegration: "The only remaining hypothesis," says Dr Buckland, "being that lime was continuously introduced into the lakes and seas by water that had percolated rocks through which calcareous earth was disseminated."

Thickness of Chalk

The thickness of the chalk in England is seldom less than 500 feet, and rarely so much as 1000 feet. In the Isle of Wight, however, the section at Culver Cliff gives from 1200 to 1300 feet. It is also about 1200 feet thick in Dorset and Hampshire.

The maximum thickness of the chalk found in England is said to be 1700 feet. A deposit of this depth would require 2,000,000 years for its formation, for it has been estimated that 1 inch only of chalk is deposited in 100 years.

Flint and Gravel in Chalk

Flint, gravels, and clay are formed by the destruction of the chalk, thus providing the natural soil of the chalk districts. This is solely the work of water, and is a very slow process; it is estimated that the chalk rocks are worn away at the same rate at which they are formed, viz. 1 inch in 100 years.

In a similar manner, in districts in which granite or any other rock forms the surface rock, the soil is formed by the disintegration of the same. In the granite districts the apparently indestructible formation is found to have been subjected [illegible]vages of chemical action to a depth of 30 to 40 feet in [illegible]ces.

Disintegration

When we consider these periods of formation and destruction of chalk rocks only, it requires but little stretch of the imagination to grasp Lord Avebury's statement: "We can hardly estimate at less than 100,000,000 years the time which must have elapsed since the commencement of life on our planet. Out of this the Tertiary Period might occupy, say, 5,000,000 years, the Glacial Period may have commenced about 200,000 years ago, and lasted down to within about, say, 50,000 years of the present time."

"How long ago?" is a question often asked of geologists. As a rule no answer can be given. A unit of time is still wanted. Mr E. A. Martin, F.G.S., attempts a general reply in the *Geological Magazine* for August 1907. He observes that Professor Huxley's willingness to confine himself to 100 million years is not now altogether approved, since the discovery of the energy lying dormant in radioactive bodies has shown the possibility of the far greater age of the sun than the physicists would formerly allow. "I am justified from many points of view," he writes, "in assuming that a solid crust had formed about 250 million years ago, that strata had formed at an average rate of 1 foot in 700 years, and that the older the rocks the more the strata have been compressed into thinner layers." On this basis Mr Martin computes that "the Coal Age came to a close over 70 million years ago, and the Chalk Age 31,680,000 years ago; and that the winged reptiles of Jurassic times took 21,875,000 years for their evolution."

The author gives good reason for these computations, and there is no more antecedent motive for cutting down time than limiting space. We should be inclined to think, with Professor Sollas, that the rate of deposition, 1 foot in 700 years, is on the average too slow (*Daily Telegraph*).

The chalk escarpment usually forms the highest ground; this is the case in the Weald of Kent; and at Blue Bell Hill, in the neighbourhood of Chatham, it reaches an altitude of 600 feet.

Chalk as a Natural Filter-Bed

Where rivers obtain their supply direct from the rainfall, they only flow in rainy seasons and cease to run in dry weather.

Where supplied by rain indirectly, as through the intermediate agency of springs fed by Chalk formation, they continue to flow in dry weather, the undergound sources supplementing and continuing the direct supply, as the Chalk formation maintains the summer flow of the Thames. This formation was tested for this purpose in 1859, when the river Wandle was found to continue its yield of water (from the chalk springs) at least eighteen months after it had practically ceased to receive a supply from the surface, so great is the amount absorbed by the chalk.

The chalk springs at Chadwell, near Ware, the source of the New River (opened in 1613), alone yield 4½ million gallons a day.

The Chalk formation is one of the best natural filter-beds for water; it absorbs a large quantity and yields it up again in the form of springs, as we have already seen. The chalk practically forms a reservoir, preserving the water pure and at an even temperature of about 50° F., cool and refreshing in summer and far from freezing in winter.

Water contained in Chalk

The specific gravity of chalk is 2·315; a cubic foot weighs 145 lbs. and will hold 2 gallons of water; a cubic yard will hold 54 gallons, and 1 acre 1 yard thick will hold 261,360 gallons; a square mile the same thickness holds 167,270,000 gallons. These figures give some idea of the water contained in the chalk.

All rocks absorb water in proportion to their degree of porosity.

		Per cent. of water by weight.
Granite	will absorb . . .	0·1 to 0·4
Gypsum	„ . . .	0·5 „ 1·5
Slate	„ . . .	2·0 „ 10·0
Sandstone	„ . . .	3·0 „ 8·0
Limestone	„ . . .	5·0 „ 8·0
Chalk	„ . . .	15·0 „ 20·0
Plastic clay	„ . . .	19·0 „ 24·0
Marl and loam	„ . . .	30·0 „ 50·0

In the *Geographical Journal*, 1902, it is stated by W. G. Cox, C.E., that chalk of the Cretaceous formation of the London Basin has, by careful research, been found to contain for each square mile 1 yard thick 3½ million gallons of water. The same quantity of rock is capable of absorbing, if saturated, 200 million gallons.

In England this formation has a surface area of 3794 square miles, upon which falls as rain 4000 million gallons daily, a quantity equal to five times the summer flow of the Thames.

Water experiences little difficulty in obtaining ingress to chalk but considerable resistance to its egress, as the capillarity of chalk appears to accelerate the inflow of water and to impede its discharge.

Professor Boyd Dawkins evaporated 2·542 gallons of water from a cubic foot of chalk, but on resoaking found it to absorb only 2·437 gallons, or 95·86 per cent. of that previously evaporated; this loss was no doubt due to the obstructive action of the air in the pores of the chalk.

Referring to this subject, Mr Charles Bird, F.G.S., says: "If a cubic foot of sand will bear the addition of 3 gallons of water, it is apparent that there is only a little over half the solid capacity of sand, 6¼ gallons being equal to 1 cubic foot. This does not follow that 3 gallons of water could be obtained as the yield from every foot of sand, or 18 pints for every cubic foot of chalk, for in the latter case it would retain by imbibition 10 pints, yielding only 8 pints.

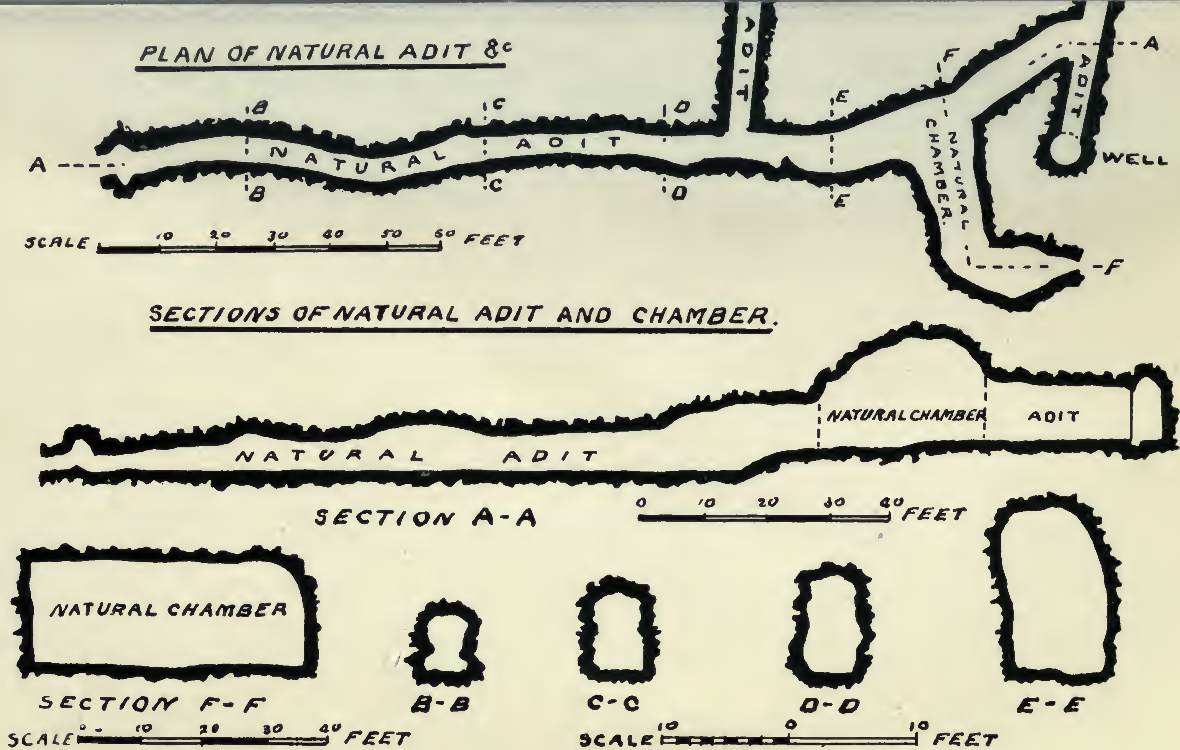
"A cubic foot of chalk below the water level will contain 18 pints of water (35 per cent. of its own bulk of water of saturation); above this level it will be found to contain 10 pints to the cubic foot (19 per cent. of its bulk): this is called 'water of imbibition,' or 'quarry water.'

"The force which causes this phenomenon is called 'capillary attraction,' and as moisture is removed from the top by evaporation fresh supplies rise by 'capillary attraction' from the saturated portion below. The interstices of the chalk which are not filled with water—making the difference between 35 per cent. and 19 per cent. above stated—are filled with air, the explanation being that some of the cavities are too large to retain water by capillary attraction."

Natural Chambers

A considerable amount of water is stored in the joints and fissures in the chalk, which are sometimes of enormous size. The natural adit at the Strood waterworks, the property of the city of Rochester, is well known to the writer, and a short description may be of general interest.

By kind permission of the engineer, Mr William Banks,



From the original by William Banks, C.E.

STROOD WATERWORKS, KENT—NATURAL CHAMBER AND ADIT IN THE CHALK.

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I am enabled to reproduce plan, sections, and photographs of this remarkable adit or natural passage.

As will be seen by the sections, there is a large natural chamber, over 17 feet high, of considerable width and length, and from this chamber there is a natural adit, through which a person can walk for about 60 feet; after this it gradually gets smaller, but a considerable distance further can be seen.

The whole of the water for the supply of Strood, Kent, flows through this adit and chamber. The adit is a sight not easily forgotten; here, at a depth of 120 feet below the surface, flows a small stream of clear, sparkling water through enormous cavities not made by hand.

To enable the photographs to be taken, the water was pumped out. This necessitated long, continuous pumping to overcome the inflow of the water from the springs, by which all these adits and the chamber are quickly filled, as they are almost entirely below the line of saturation.

Professor Prestwich states that in sinking a well in the chalk near the edge of the escarpment at Knockholt, the workmen discovered, at a depth of 270 feet, a cave of 30 feet long, 12 feet broad, 18 feet high, of irregular shape, at the bottom of which ran a stream of water.

Another curious natural opening in the chalk was found by the writer during the extension of some adits; this natural opening was cut completely through.

It was large enough for a man to stand up in, and after going a few feet, a pipe or branch passage turned sharply upwards in a spiral form towards the surface; the end was hidden from view, but a distance of over 30 feet upward could be seen, as shown in the section.

This, like many similar spaces in the chalk, appeared to have been at one time partly filled with a brown, soapy, laminated clay.

Some authorities are of opinion that the soapy clay so often found in these seams and adits is now being deposited by water which percolates through them and fills up the various cavities, but it is more probable that these deposits were formed long since, for the seams cut in the upper chalk above the line of saturation, where there is no running (or free) water, are also frequently found full of the same material.

This cavity or fissure, like many others, was yielding but a *small* supply of water at D, out of all proportion to the size of the opening, but no water was running down the vertical adit C C.

These large natural watercourses are a part of nature's system of drainage, and under prehistoric conditions, when the rain and melting of the ice (which helped to form these dry valleys) were at the most active period of operation, they carried off the water in greater quantities than we can well imagine, delivering it, probably as submarine springs, into the rivers and sea.

Water-worn fissures, now dry, are frequently seen high above the present rest-level of the water, proving that the variable line of saturation was much higher in remote ages than to-day.

Another interesting cavity was found by the writer in sinking a deep boring. At the commencement of the lower chalk, 250 feet from the surface, the boring tool met with practically no resistance through 40 feet of descent. No debris was brought to the surface during that distance; what little was cut at places disappeared down a fissure.

Some time was spent in ascertaining whether there was water in this cavity. A little ingenuity was necessary here, for the boring commenced from the bottom of a well 150 feet deep, containing about 80 feet of water. This upper water was kept from entering the boring by means of

THE NATURAL CHAMBER, STROOD WATERWORKS, KENT.

Muskett and Sills.

THE NATURAL ADIT, STROOD WATERWORKS, KENT.

[*To face p.* 370.

tubes driven through the bottom of the well. A tubular pump was lowered into the boring and set to work, and the fissure, 100 feet below an immense body of water, was tested, and there was found to be no yield.

The Lower Chalk rarely yields any quantity of water, the most favourable conditions for water being where the Upper Chalk is below the line of saturation; here a considerable quantity may generally be obtained if there is a corresponding watershed behind it.

Percolation in the Chalk

"The salts with curious percolation strain,
And kindly through the porous strata drain."

BROOKE.

From a report of the Royal Commission when the Dover and St Margaret's area was tested, a drainage basin of 12 square miles yielded 5½ to 6 million gallons per day. On a basis of 5 millions we get 10 inches of percolation on the square mile of chalk; at Croydon 11 inches were found to percolate. Other trials have shown that 10·6 out of a rainfall of 25 to 27 inches find their way through the chalk.

The Royal Commission (Balfour) on London water supply reported that not more than 3½ inches of percolation in the chalk north and south of London could be relied on.

The average rainfall for the Chatham district is about 26 inches. Allowing, say, 8 inches for the annual percolation, the difference, 18 inches, would represent the loss by evaporation and absorption by vegetation.

Adits in the Chalk

We have seen what enormous quantities of water are held in the pores of the chalk, but it is not wise to rely on all this quantity as being available for consumption, for it will yield only 8 parts and retain 10 parts, as we have seen; but rather the free water in the seams, joints, and cavities, that has percolated from the surface and is passing on to its original outlet resembling an underground stream similar to the natural chambers and adits already described.

The writer has frequently found, after driving a large adit many hundreds of feet into the chalk at a depth of about 100 feet below the rest-level, that the chalk does not yield even a trickle of water. When approaching within a distance of, say, 4 or 5 feet of a large spring, the only indication would be a kind of sweating. Beads of water would be seen, hardly sufficient to trickle down the sides of the adit; a few feet further, and a blow with a pick would necessitate a quick withdrawal for safety. This proves how tenaciously the saturated chalk clings to the water it absorbs. It does, of course, contain 2 gallons per cubic foot, and it holds very tightly to it.

Description of Adits

It is only at certain periods, when works are being carried out during the course of which it is necessary to keep down the water by pumping, that it is possible to visit these underground reservoirs, both natural and artificial. There is always a certain amount of risk in penetrating the water-bearing strata, and permission to do so is not readily granted.

Familiarity breeds contempt, and one who has spent many hours daily in these subterranean passages forgets about risk, and takes it as a matter of course.

It is a fascinating experience. On reaching the bottom of the well, say, 250 feet deep, you alight on a stage: the water is rushing under your feet on its way to the pumps.

By permission of Mr William Banks, C.E.

AN ARTIFICIAL ADIT IN THE CHALK FORMATION, WITH BRANCHES RUNNING IN ALL DIRECTIONS TO INTERCEPT THE WATER-BEARING FISSURES.

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Artificial adits are usually at least 9 to 10 feet high and nearly as wide, cut in the pure white chalk, and for scientific reasons they are generally parabolic in section. Branching out in all directions are other passages and crevices, down which the separate streams from the various springs are conducted to the pumps. You will have been provided with Sou'wester, oil-skins, and top-boots, and are standing perhaps 100 feet below the level to which the water will rise when the pumps stop. You will then wade perhaps 1800 or 2000 feet up one of these passages, through 18 inches of pure bright water, by the light of lamps or dozens of candles fixed on the sides of the adit to illuminate it. At last you come to a spring, spurting out of the chalk in front, overhead, and on either hand, also bubbling up under your feet, as may be seen in the picture.

This spurting and bubbling is at once suggestive of great force: at times it will bowl along large pieces of chalk, or easily knock down a man. The reason is not far to seek. We have already stated that you are now standing 100 feet below the rest-level of the water, which means that all around you the rock is charged with water to a height of 100 feet; and the water is rushing to the point at which you stand, naturally escaping at its lowest vent. A pressure of 43 lbs. per square inch would be required to hold back the water (100 feet × ·43 lbs.).

Here you see, beneath the parched surface of a dry chalk valley, cool, sparkling waters welling forth:

> "How without guile thy bosom, all transparent
> As the pure crystal, lets the curious eye
> Thy secrets scan."
>
> LONGFELLOW (*from the Spanish*).

On retracing your steps you may find that the water will overflow the tops of your boots. To reach the surface again you either use a seat like a swing, called a boatswain's chair, or, standing with others round the rim of a large bucket, you are hauled up by a windlass, and you go home without hose, unless you have provided a spare pair for such emergencies, thinking of bounteous nature and her wonders, how you have been deep into her bosom and have seen the manner in which she provides water for our use, as is so beautifully expressed by the Psalmist in the words quoted at the head of this chapter.

By permission of Mr William Banks, C.E.

AT THE BOTTOM OF THE WELL.
(The bucket ascending with the excavated chalk.)

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CHAPTER XVII

DENUDATION

The Forces at Work

"There was a period when the mountains we now see were hewn or worn by forces for the most part differing both in mode and violence from any now in operation."—RUSKIN.

DENUDATION, or the wearing and washing away of the surface of the earth by the elements, began as soon as land appeared above the surface of the water, and this work of destruction and reconstruction has never ceased.

This is the greatest of the works performed by water, and its name, which means "to strip, or make naked," is most appropriate, for the action continually exposes the hard surface of the rocks, that they may be riven asunder by cold and heat.

The principal forces which carry on this operation are water, change of temperature, chemical action, and growth of vegetation; but water is the principal agent.

Subaerial denudation is the destruction, or, more correctly, the disintegration, of the rocks by the forces of the atmosphere—sun (heat), ice (cold), wind, rain, lightning, and all mechanical and chemical forces above the surface of the sea.

Marine denudation is the work of waves and tides, and *submarine* denudation the work of the sea and ocean currents, at depths beyond our immediate observation, but nevertheless work in direct proportion to their own immensity.

No doubt in ages gone by the whole of the forces referred to acted with far greater violence than at present; the heat, torrential rains, deluges of heated waters, and, in a later epoch, intense cold, added their powers to the denudation, thus assisting to destroy the surface of the earth.

Mr Croll concludes that the whole terrestrial surface is lowered one foot in 6000 years by subaerial denudation.

The tops of the mightiest mountains have by these means travelled downward, fertilising the plains and ministering to the wants of the animal and vegetable kingdoms; but their ultimate destination is the great ocean, where again, after ages of repose, they accumulate and form massive beds, and will be raised once more above the waters, and repeat the cycle of changes.

"Here then," says Sir Archibald Geikie, "is a vast system of circulation ceaselessly renewed. And in that system there is not a drop of water which is not busy with its allotted task of changing the face of the earth. When the vapour ascends into the air, it is almost chemically pure. But when, after being condensed into visible form and working its way over or under the land, it once more enters the sea, it is no longer pure, but more or less loaded with material taken by it out of the air, or from rocks or soils through which it has travelled. Day by day the process is advancing. So far as we can tell, it has never ceased since the first shower fell upon the earth. We may well believe, therefore, that it must have worked marvels upon the surface of our planet in past time, and that it may effect a vast transformation in the future."

Denudation by Change of Temperature

We have seen that the direct rays of the sun raise the temperature of the earth about four times as much as that of the water, the effect being to heat the surface of rocks by day, causing expansion, as the temperature falls quickly by radiation at night. This infinitesimal expansion and contraction, however, splits and disintegrates the rock, giving freer access to the rain, which accelerates the work of destruction, to which we shall refer on a later page.

The wind in a similar degree also assists this work, for it is found that the amount of sand in the great deserts is increasing; clouds of sharp, hard grit or dust, carried by the wind, beat against the exposed surfaces of the rocks, and cut into them.

It is stated that in Kerguelen Island, situated in the Roaring Forties—the stormy belt of the ocean between 40° and 50° S., where strong west winds prevail all the year round—all the exposed rocks are grooved in this manner from west to east.

Denudation by the Atmosphere

The amount of destruction wrought by the chemical action of the acids contained both in the atmosphere and rain on rock surfaces is enormous, producing changes known as weathering.

Here again water and vapour show their handiwork. The gases in the atmosphere, that is, the oxygen and the carbonic acid, are continually attacking the rocks, so affecting the exposed surface as to render it capable of being acted upon by the rain and its co-partner in the work of denudation, that is, frost.

Referring to this weathering of the rocks, Tyndall writes:

"Detached spears and pillars of rock stood like a kind of defaced statuary along the ridge."

Denudation by the atmosphere is not so apparent; the process is slow, but nevertheless sure.

The great Sahara Desert, $3\frac{1}{2}$ million square miles in area, is not, as is generally supposed, a great level desert and the dried-up bed of a former inland sea; on the contrary, its configuration disproves that theory.

Its surface level ranges from sea-level to 8000 feet above it, and it is but the result of the disintegration of the Sandstone formation by atmospheric influence. In like manner the principal agents of destruction of the large stone buildings, cathedrals, etc., in our great cities are the rain and the atmosphere, and the gases contained in them.

Professor Phillips refers to the subject as follows: "The wasting effects of the atmosphere are those initial or preparatory processes by which the earthy materials are provided for rivers and the sea to transport and deposit in new situations. The crumbled granite of Muncaster Fell, Cumberland, is surrounded by heaps of its disintegrated ingredients."

In many parts of the earth portions of sculptures broken from old ruins and buried in the ground are in good preservation, but all traces of workmanship have been obliterated from such parts as have remained exposed to the air.

Denudation by Rain

So slowly does the work of destruction by frost and rain proceed, that in the short span of a life but little effect is noticed on the rocks under observation. It is, nevertheless, an undoubted fact that this work never ceases. Ruskin says: "The forms of rocks in this manner are so softly modified that eyes can scarcely trace, or memory measure, the work of time."

Mrs Aubrey Le Blond.

A GENDARME, NEAR THE ORTLER.

To illustrate the action of the atmosphere on rocks.

[*To face p.* 378.

The manner in which rain becomes charged with carbonic acid has already been explained, as has also the manner in which it absorbs and holds in solution, by a chemical process, certain matter with which it comes into contact; little remains to be said on this point.

"The chemical properties of water," says Dr Mill, "and its effects as a solvent, are brought into action by sun-heat, which separates it from the salts of the sea, shakes it with the gases of the atmosphere, and pours this powerfully solvent and oxidising solution over the rocks."

Presuming that one-third of the rain which falls on the land is evaporated, the remaining two-thirds, whether they flow into rivers or sink into the earth, are at nature's disposal for use in the work of denudation either chemically or mechanically or both.

It has been stated that the acid-laden rain of the town will remove one-third of an inch from the surface of a marble monument in a century. This seems of little importance, but with nature's work a century is but a span long.

This reference to monuments calls to mind a carved figure which the writer has periodically watched for some six years. The stone saint stands on an elaborate truss, formed on one side of a church door; there is a stone canopy over the head, so carved that channels cut in it conduct the few drops of rain that fall on to it directly on to the nose of the figure. This nose is now all but a thing of the past, which shows that designers of churches should give their saints larger canopies or shorter noses.

The following quaint lines also refer to the rapid destruction of carvings in stone by rain:—

> "Or find some figures, half obliterate,
> In rain-beat marble, near to the church gate."
>
> BISHOP HALL.

The carbonic acid in the air is derived from the decay of organic matter, the breathing of animals, the combustion of coal, and many other sources. It is partly taken up by the rain in falling, as well as any other soluble constituents of the air. In its passage through the soil it accumulates a still further quantity, and is thus enabled to bring about the changes which we shall describe, changes which could not be effected by water free from carbonic acid.

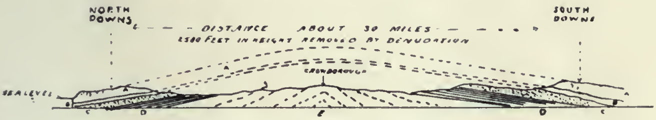
The apparently indestructible granite and harder crystalline rocks are not proof against this action of rain; no known rock can entirely withstand the chemical action of the carbonic, sulphurous, and other acids in the air.

Under the action of rain and air the chalk hills are slowly being dissolved away, the soil and flints that cover the surface being the undissolved parts which remain. These form about 4 per cent. of the rock, the remaining 96 per cent. being pure carbonate of lime, which is readily dissolved by the rain.

In many quarries in Cornwall the rock has been found to be disintegrated to a depth of 30 to 40 feet, in China even to 200 feet. This is due to the felspar, the alkaline salts of soda and potash being decomposed by the carbonic acid, leaving the silicate of alumina, the mica, and the quartz.

Thus we see all underground water—springs, thermal waters, geysers, mineral springs—is aiding the work of denudation. Vegetation also assists disintegration: the roots of plants insinuate themselves into the crevices, grow and expand, and so help to break up the rocks; one often sees rocks and strong walls cracked, lifted, and ever thrown down by the roots of trees.

SECTION OF THE WEALD OF KENT.



A, Chalk. B, Gault and Upper Greensand. C, Lower Greensand.
D, Weald clay. E, Hastings beds.

C. Spencelayh.

OLD WELL-HEAD, SNODHURST FARM, KENT.

[*To face p.* 380.

Denudation by Rivers and Streams

We have seen how the rivers carry the disintegrated matter into the lakes and seas, also the amount of solid matter contained in the water of the various rivers.

"As we watch some tiny rivulet, swelling into a little brook, joined by others from time to time, grow into a larger and larger torrent, then to a stream, finally into a great river, it is impossible to resist the conclusion, gradually forced upon us, that, incredible as it must at first sight appear, even the great river valleys and plains, and the general configuration of the land, though their origin may be due to the initial form of the surface, are due mainly to the action of rain and rivers" (Lord Avebury).

The transporting power of water depends on its velocity, and it increases as the sixth power of that velocity; or, if the velocity be doubled, the motive power becomes 64 times as great; if trebled, 729 times.

The Ganges transports in the four rainy months, to a distance of 500 miles from its mouth, 577 cubic feet of solid matter per second. Its annual discharge is computed at 6,368,000,000 cubic feet, which is equal to raising the whole of the surface of Ireland 1 foot in 144 years.

Looking nearer home, we find an interesting example of denudation and transportation.

The Weald of Kent

In the Weald of Kent, between the North and South Downs, the whole of the Upper Cretaceous formation has been removed. The Geological section shows the four principal divisions, Chalk, Greensand, Weald clay, and Hastings beds. The axis of elevation runs from Winchester by Petersfield, Horsham, and Winchelsea to

Boulogne. On each side of this axis are two ridges or escarpments of Chalk and Greensand.

At one time the greensand and chalk formed one mighty dome across the Weald, joining together the North and South Downs. In the centre of this district, say at Crowborough Beacon, where the Hastings beds appear on the surface, some 2500 feet must have been removed by denudation.

Here again, as with mountain ranges, it does not of necessity mean that the altitude of this mighty dome of chalk was 2500 feet above the present level, as denudation and elevation no doubt proceeded together.

It is certain, however, that this 2500 feet of the Upper Cretaceous formation has been removed by the action of the elements and transported to sea by the rivers.

Thus the rivers chemically and mechanically destroy, wear away, and transport to the sea the aqueous rocks which, as the name implies, owe their origin in the first instance to water, and are constantly re-forming stratified deposits.

The word "chemically" here refers to the matter carried away by solution, that is, dissolved. As a typical instance of this we have the water of the glacier-fed Rhone, which in January contains 33 parts of dissolved matter per 100,000, diminishing to 10 parts in July and August; in this manner 750,000 tons of dissolved matter are carried into the Lake of Geneva every year by the Rhone, and 400,000 tons by other streams. This will enable us to form some vague idea of the amount of erosion by solution.

The word "mechanically" signifies the carrying away and depositing elsewhere of the solid matter held in suspension.

The delta of the Po has increased in the last six centuries by 198 square miles, adding that area to Italy, or a

J. N. Bryan.

A MOUNTAIN STREAM.

[To face p. 382.

gain of $\frac{1}{600}$ of its previous area. This is a typical instance of the work water is doing in building up new lands.

These deposits will again be solidified into rock in the ages to come, and will again be raised above the surface of the waters, forming new lands, which will in their turn suffer destruction.

> "This let me further add, that nature knows
> No stedfast station, but or ebbs or flows;
> Ever in motion, she destroys her old,
> And casts new figures in another mould."
>
> DRYDEN.

When we consider that flints form only a fractional proportion of the whole of the Chalk formation, and note the immense beds of flint, gravel, and shingle in the Thames valley, along our south coast, and elsewhere, we can get a faint idea of the enormous amount of chalk that has been removed.

The flint was formed in the upper bed of the Chalk formation, in which it occurs as a series of concretions, the silica in sponges and other marine animals which lived on the sea-floor while the chalk was being deposited, being attracted into nodules.

"The calcareous and siliceous dun," says Lyell, "of which whole hills are composed, has not only been once alive, but almost every particle—albeit invisible to the naked eye—still retains the organic structure which, at periods of time incalculably remote, was impressed upon it by the powers of life."

The English Channel

The commencement of a second dome of chalk occupies the southern half of the Isle of Wight, and rises so abruptly that at Scratchells Bay, near the Needles, the layer of flints can be traced distinctly; at the base it is absolutely vertical, and it curves over in a grand arch which was obviously once continued over where the Channel now is.

We must again go back to the time when the greensand and chalk were continued across the Weald. The rivers ran down the slope of the dome, and gradually weathered back, a process still in operation, carrying the chalk in suspension and solution into the sea.

The English Channel is only a valley 130 feet deep at Dover Strait, but it widens and deepens to 500 feet towards the Atlantic. It seems probable that the anticlinal axis of the Weald extended across the Channel and marked the old watershed from which the rivers at one time ran to the Atlantic on the one side and to the North Sea on the other, when the southern rivers of England, with those of Northern France, ran down the great valley, now the English Channel, into the Atlantic. The Thames joined the Rhine, and subsequently the Humber ran northward into the Arctic Ocean. Along the banks of these rivers roamed the bear, lion, bison, elk, rhinoceros, hippopotamus, and elephant, whose remains are abundant in the North Sea and river valley.

Animal Remains

The writer has on several occasions seen large pieces of mammoth teeth among the gravel dredged from the bed of the river Thames, proving that these monsters existed there in great numbers. The teeth of smaller animals are also frequently found, and tend to prove that they reached these districts before this country was severed from the continent and became an island as we now find it, for the Channel proper was but a river channel which has since been widened by the action of the waves.

Referring to this severance of England from the Continent, the quotation by Waller is worth repeating:—

> "Whether this portion of the world were rent,
> By the rude ocean, from the continent,
> Or thus created it was sure design'd
> To be the sacred refuge of mankind."

In previous chapters we have dealt shortly with the work of rivers in the transportation of matter, formation of deltas, filling of lakes, etc.

Denudation by Landslips

Landslips are also due to the action of water, the excessive saturation of the soil by rain causing the slipping or sliding of the land from a higher to a lower level, thus assisting the work of denudation. A typical instance of this is Goldau, a valley of Rossberg Mountain behind the Rigi in Switzerland, where on 2nd September 1806 a portion of the Rossberg, 3 miles long, 1000 feet broad, and 100 feet thick, fell into the valley, burying villages with over 800 inhabitants.

Denudation by Glaciers

When water solidifies, the resulting ice is greater in volume than the water of which it is formed.

The irresistible power of ice, which forms in the fissures of the rocks, literally bursts them in pieces, and in time will disintegrate the hardest rocks, reducing them to powder.

"The Alps are crumbling and being washed away, and if no fresh elevation takes place, the time will come when they will be no loftier than their rivals in point of age, Snowdon and Helvellyn.

"From the summit of Mont Blanc 10,000 to 12,000 feet of strata have already been removed. The conglomerates of Central Switzerland, the gravels and sand of the Rhine and the Rhone, the Danube, and the Po, the Plains of Dobrudscha, of Lombardy, of South France, of Belgium and Holland, once formed the summits of Swiss mountains" (Lord Avebury).

It has been calculated that at the present rate of denudation the Andes will have disappeared in 9,000,000 million years; another estimate is 156,000,000 million years. This period is, however, more difficult to realise than it was to calculate; in fact, it cannot really be brought home to the mind, the vast duration of time indicated; if it but leaves a vague impression, these figures will have served their purpose well. In Europe we have the huge granite mountain mass of the Pennine Chain of the Alps, which includes among its summits Mont Blanc; in this district, from an area of about 30 miles long by 10 miles wide, issue about thirty glaciers, including Des Bossons, Argentière, and Mer de Glace.

Here we have an instance of the work of glaciers: thirty glaciers alone (without taking into consideration the atmospheric changes, etc.) are at work, slowly grinding and wearing away this mountain mass. The process is very slow, but it certainly is very sure.

As these and all other glaciers recede, either periodically or continuously, and expose their channels at the lower end, we are able to see the results of the work of denudation and destruction. On each side are mounds of debris, the lateral moraines, and, in some cases, medial moraines as well. We also find the various terminal moraines, marking the respective stages of retreat.

"In large tracts of Norway and Sweden," says Lyell, "where there have been no glaciers in historical times, the signs of ice-action have been traced as high as 6000 feet above the level of the sea."

Mrs Aubrey Le Blond.

THE BIETSCHHORN—TO ILLUSTRATE THE TYPE OF SCENERY PRODUCED BY THE ACTION OF ICE ON MOUNTAIN SUMMITS.

[*To face p.* 386.

It is stated that the Isortek River, in Greenland, which flows from under a glacier, carries away as sediment 4,000,000 tons of eroded matter every year.

All this disintegrated matter is in course of transport by water slowly but continuously, from the scene of its destruction.

Formation of Plains, etc.

Rivers also form plains and broads by denudation, and by the deposit of silt, gravel, etc.

The Norfolk Broads, which rest on drift and alluvium in some places 150 feet deep, were no doubt formed by bars being thrown by the sea across the outlets of the valleys in which they lie, and the consequent silting up of the main channels by the sediment brought down by the rivers.

All our beautiful valleys were also formed in this manner; and the present configuration of our globe is but the work of disintegration, denudation, transportation, and reconstruction.

The chalk cliffs, promontories, bays, channels, even the shingle and the sandy beaches on which the children love to play, are the handiwork of water.

River Terraces

It is generally agreed that, where river terraces exist, they represent the shore-lines of ancient rivers and lakes.

They show us the different levels at which a river flowed in the ages gone by, under conditions no doubt very different from anything we can imagine.

Nothing short of a deluge of water must at one time have assisted in forming these terraces. The enormous width between the topmost shore-lines compared with the present diminutive beds seems to point to the above conclusion.

To obtain an accurate conception of the magnitude of the work of denudation effected by rivers, let us take two examples:—The valley of the Ticino, which is 12,000 feet below the highest river terrace; and, coming nearer home, though on a smaller scale, the parallel roads of Glenroy, a narrow valley in Inverness-shire, where we have three natural terraces at corresponding altitudes on opposite sides of the valley. The lowest of these is 862 feet, and the highest 1155 feet above the present valley. These were no doubt the respective levels of ancient lakes, the three levels representing three stages of the recession, at long intervals, of the ancient glacier dams at the extremity of the valley.

Denudation by the Sea

> "So swelling surges, with a thundering roar,
> Driven on each other's backs, insult the shore;
> Bound o'er the rocks, incroach upon the land,
> And far upon the beach eject the sand."
>
> DRYDEN.

We have seen how rain, rivers, waterfalls, and water generally carry on this great work. We have but touched the fringe of the subject, for all previous instances sink into insignificance beside the mighty sea, a giant among his brethren at the work of denudation that is going on all over the world.

"Where has the great destroyer not been—the devourer of continents, the blue, foaming dragon, whose vocation is to eat up the land? His ice-floes have alike furrowed the flat steppes of Siberia and the rocky flanks of Schiehallion (in Perthshire), and fish lie embedded in great stones of the Pyramids, hewn in the times of the Pharaohs, and in the rocky folds of Lebanon, still untouched by the tool.

Mrs Aubrey Le Blond.

THE BIRTHPLACE OF GLACIERS—VIEW FROM MONTE ROSA.

[*To face p.* 388.

"As long as the ocean exists there must be disintegration, dilapidation, change; and should the time ever arrive when the elevatory agencies, motionless and chill, shall sleep within their profound depths to awake no more, and should the sea still continue to impel its currents and to roll its waves, every continent and island would at length disappear, and again, as of old, when 'the fountains of the great deep were broken up,'

"'A shoreless ocean tumble round the globe.'"

HUGH MILLER.

Longfellow, in *The Lighthouse,* gives us a vivid picture of denudation by the sea:

"It sees the ocean to its bosom clasp
The rocks and sea-sand with the kiss of peace,
It sees the wild winds lift it in their grasp,
And hold it up and shake it like a fleece.
The startled waves leap over it, the storm
Smite it with all the scourges of the rain,
And steadily against its solid form
Press the great shoulders of the hurricane."

Dr Hutton observes: "The billows of the ocean agitate the loose material on the shore, wearing away the coast with endless repetitions of this act of power and imparted force; the solid portion of our earth, thus sapped to its foundations, is carried away into the deep, and sunk again at the bottom of the sea, whence it had originated, and from which, sooner or later, it will again make its appearance."

We are thus led to see a cycle of destruction and renewal in the matter of which the globe is formed, and a system of beautiful economy in the works of nature.

Referring to coast erosion, Mr Clement Reid, F.R.S., in a paper on the changes on the coasts of the British Islands, says: "Our present coasts have not always been where they are now. About 4000 years ago there set in a rapid but intermittent subsidence of the land or a rise of the sea. The rise of the sea-level was probably completed about 3500 years ago, and then commenced the coast erosion, which we now see. Then our present shingle beaches and sand dunes began to form, and these constitute our best protection against further inroads. Some compensation for the loss on the coast we have in the great gain of alluvial land in sheltered estuaries, though against this must be set the silting up of harbours."

In the discussion of the paper, Mr E. R. Matthews stated that no less than 115 square miles of land had been lost by sea erosion in Holderness.

On 10th January 1905, between St Margaret's Bay and Dover, a strip of rock about a quarter mile long and estimated to weigh about 250,000 tons, fell into the sea; and in January 1906 an enormous mass of Shakespeare Cliff, between Dover and Folkestone, was claimed by the ocean.

All along our coast there is a more or less continuous loss of land from the action of the sea. In some parts, as on the coast of Yorkshire, from Bridlington to Spurn, some 36 miles, the waves erode 2¼ yards annually. In parts of the coast of Norfolk and Suffolk, 14 feet a year is claimed by the sea.

This loss must amount to many square miles in the course of 100 years; and though the material is deposited in other parts, this does not counterbalance the loss which is apparent, for the formation of new land is so slow that it is hardly appreciable.

According to some authorities, our east coast especially is getting smaller, wasting away. The author of the story of *Lost England* asserts that "in the last hundred years a fragment of our kingdom as large as the county of London has been buried beneath the sea. In Yorkshire alone there are no fewer than twelve buried towns and villages. In Suffolk there are at least four. Some eminent geologists who have examined this problem believe that quite as much new land is created as is lost by the sea's erosion; but the farmer at Withernsea, or Cromer, or Southwold, who loses part of a field, may not be consoled to learn that in Pegwell Bay, or at Pevensey, new land is being formed, and that hundreds of thousands of sheep graze on marshes at Romney, where in Roman times there was sea. The land-owners of Norfolk and Suffolk are justified in approaching the Government to ask that something shall be done to save 'this England' from the waves. There is reason to believe that a large area might every year be saved from the sea by some such plan as Rennie proposed for the Wash. At present mere defensive measures, which prove insufficient, are costing some of the local authorities large sums. Cromer has spent £36,000 in protective works, Lowestoft £57,000 Sheringham £19,950, Southwold £13,582, and Felixstowe £16,602."

If the sea is playing such havoc under our very eyes and in parts where there are attempts to stay its encroachment, what is it doing on the coasts of the mighty continents? It is indeed a question which we cannot answer, but can only vaguely guess.

Dickens, in the *Christmas Carol*, says: "The thundering of water, as it rolled and roared, and raged among the dreadful caverns it has worn, fiercely tried to undermine the earth."

Denudation by Tides

"As surely as the pale moon draws,
By nature's fix'd, unerring laws,
The refluent tide of ocean's stream
By magnet power in its cold beam."

ANON.

The tides are the rising and falling of the water of the sea, which occur periodically (12 hours 24 minutes, on an average, elapse from one high tide to another), and are caused by the attraction of the sun and moon. The great tidal wave takes its rise in the Antarctic Ocean. Here only is there a free water-ring completely encircling the globe, unbroken by land, and the water is not raised more than a few feet; but in other places, where the natural order of things is interfered with by obstacles in the form of continents, groups of islands, coast-lines, etc., the rise is from 12 to 70 feet, and the navigation is dangerous. At the mouth of the Wye it is about 40 feet; Bristol Channel, 36 feet; the Wash, 24 feet; Cromer, 16 feet; Lowestoft, 7 feet; Wexford, 4½ feet. Were the whole earth covered with water to an equal depth, the tide would flow regularly from east to west and everywhere attain the same height under the same latitude.

In the Mediterranean there is no perceptible tide. Byron, in the *Siege of Corinth*, says:

> "There shrinks no ebb in that tideless sea
> Which changeless rolls eternally."

The cause of the existing variation is beyond the scope of our story. We may, however, state that the oceanic tides do not vary more than from 2 to 3 feet in height; it is when the masses of water from the ocean approach the shore, or roll over shallows, or through channels or gulfs that the above variation in depth occurs.

In our tidal rivers we have a typical instance of power practically running to waste. It has been calculated that if the waters of the Severn were dammed up in the Bristol Channel, an available power of 240,000 electrical h.p. could be obtained. This is but a trifling example of the tidal power that is wasted in rivers only.

Tides form an important factor in the work of denudation and transportation, carrying sand and solid matter, as the rivers do, from one place to another, forming flats, marshes, sands, etc., which in the course of time will rise above the sea and create new lands.

> "As the spring tides with heavy splash,
> From the cliffs, invading, dash
> Huge fragments, sapped by ceaseless flow,
> Till white and thundering down they go."
>
> BYRON.

We have now shortly described the manner in which the mountains are being gradually carried into the ocean, swept by tides, and deposited over a large area of its bed. Were this process alone in progress, in the course of time (time is here used in the geological sense, meaning, of course, millions of years) the whole earth would eventually disappear, and the waters, as "in the beginning," would roll unobstructed round the globe, and the world would consist of one universal sheet of water only.

Here we see clearly the absolute necessity of the elevating forces about which we so much concern ourselves, earthquakes, volcanoes, subterranean disturbances, and upheavals, and the less apparent but slow and sure upheaval of continents and ocean beds by the gradual cooling and contraction of the earth's crust; thus nature counteracts her work of denudation, that it may not amount eventually to complete destruction.

We cannot do better than conclude these remarks on denudation by quoting Sir Robert S. Ball, who says: "Change is the order of nature; many changes, no doubt, take place rapidly, but the great changes by which the system has been wrought into its present form, those profound changes which have produced results of the greatest magnificence in celestial architecture, are extremely slow. We should make a huge mistake if we imagined that changes—even immense changes—are not in progress, merely because our brief day is too short a period wherein to perceive them."

I would suggest that the reader substitute for the words "celestial architecture" the words *the configuration of our globe,* and it will be found to be as true and forcible as when applied to our solar system, to which the celebrated astronomer referred.

Of these immense changes that are still going on, so slowly as to be noticed but by the keen observer, Tennyson writes:—

"There rolls the Deep where grew the tree.
O Earth, what changes hast thou seen!
There, where the long street roars, hath been
The stillness of the central Sea.
The hills are shadows, and they flow
From form to form, and nothing stands;
They melt like mists the solid lands,
Like clouds they shape themselves and go."

CHAPTER XVIII

WATER, HOW OBTAINED

"Drink waters out of thine own cistern, and running waters out of thine own well. Let thy fountains be dispersed abroad, and rivers of waters in the streets."—Proverbs v. 15, 16.

We have seen in the foregoing chapters that all sources of water supply have but one common origin, viz. rain, snow, etc., from the clouds, and that it ultimately either evaporates and returns invisibly to the atmosphere, is absorbed by vegetation, percolates into the earth, or, as a stream or spring, eventually joins the mighty ocean, whence it returns, by evaporation, to the clouds.

The importance of a supply of pure water cannot be exaggerated.

The Rivers Pollution Commission states that: "In respect of freedom from the most objectionable of impurities, organic matter (organic carbon and organic nitrogen), waters range themselves in the following order:—

1. Spring water,
2. Deep-well water,
3. Rain water,
4. Upland surface water,

the last being much inferior to the first three."

In respect to wholesomeness, palatability, and general fitness for drinking and cooking, the waters derived from various sources may be classed in the following order:—

Wholesome { 1. Spring water.
2. Deep-well water.

Suspicious { 3. Upland surface water.
4. Stored rain water.

Dangerous { 5. Surface water from cultivated land.
6. River water to which sewage gains access.
7. Shallow well water.

Shallow Wells

We are all familiar with the common shallow well, from which water is drawn by a hand-winch and rope with bucket attached, such as is usually seen in villages and in parts where there is no proper water supply. In Eastern countries we find still more crude methods of raising water.

Water from this source is usually of the worst description, and is classed as dangerous.

It is surprising how people cling to the fallacy that their wells contain pure water simply because it looks clear; the fact that a cesspool may exist within a few feet is of no importance to them.

Badly fitting covers allow all kinds of vermin to fall into the water; defective drains also frequently pollute it. The writer knew of an instance where, in rainy seasons, the farmyard pond overflowed into the well, and yet, miraculously, the folks survived and were apparently little worse for the contamination.

It is at times amusing, when a shallow well containing impure water is condemned by the sanitary authorities, to listen to the heated discussion that arises. The occupier recalls in anger the various ages of his ancestors who drank this water, the general trend of the remarks being that some secret collusion exists between the medical officer and the water authorities who have supplanted this beautiful well, and insist on being paid for a far inferior water. These shallow wells, supplying only a cottage or two, hardly deserve the name, as they are in most cases supplied by a little local percolation. Where-ever the geological conditions are favourable, a considerable amount of water can be obtained from shallow wells.

Even in parts of the Sahara Desert the water falling on the mountains makes its way long distances underground, and breaks out as artesian springs, or is obtained by shallow wells sunk into the sand, in which the water is held as in a sponge.

Deep wells are found in the Egyptian Soudan, where, in the Province of Kordofan, in the rainy season the water quickly percolates through the sand, and what does not disappear in this way evaporates quickly, leaving the surface parched.

"The downward progress of the water is, however, stopped by a bed of mica-schist, and the water lies in the hollows of the same formation. Wells are sunk down to these depressions and water is met with in more or less abundance, according to the position in which the well is sunk; here there are about 900 wells, in depth varying from a few feet to 200 feet. But for these wells life in Kordofan would not be possible."

In Yucatan, however, different geological conditions exist; here the inhabitants have to obtain water from cave springs 1000 feet below the surface.

We have also the larger, and generally deeper, wells for farm and village use, from which water is obtained by the help of a horse harnessed to a pole; by walking in a circle the rope or cable is wound on to a drum and so the water is brought to the surface. There is also the common hand well-pump, and pumps actuated by the wind, which are too well known to require description.

"Shallow" and "deep" here refer rather to the depth of water in the well than to the depth from the surface to the water, for some shallow wells, or wells in which there is only sufficient water to enable the bucket to fill, are at a great depth from the surface, but the bottom is only a few feet below the line of saturation, and as a rule only just below the line of variable saturation, for wells of this description are quickly pumped dry. The writer has frequently had to increase the depth of these wells, in order to continue their supply, owing to the underground extensions of adits, etc., at the adjoining pumping station.

Deep Wells

If water is required in large quantities, wells penetrating far below the line of saturation must be sunk deep into the chalk and other porous rocks.

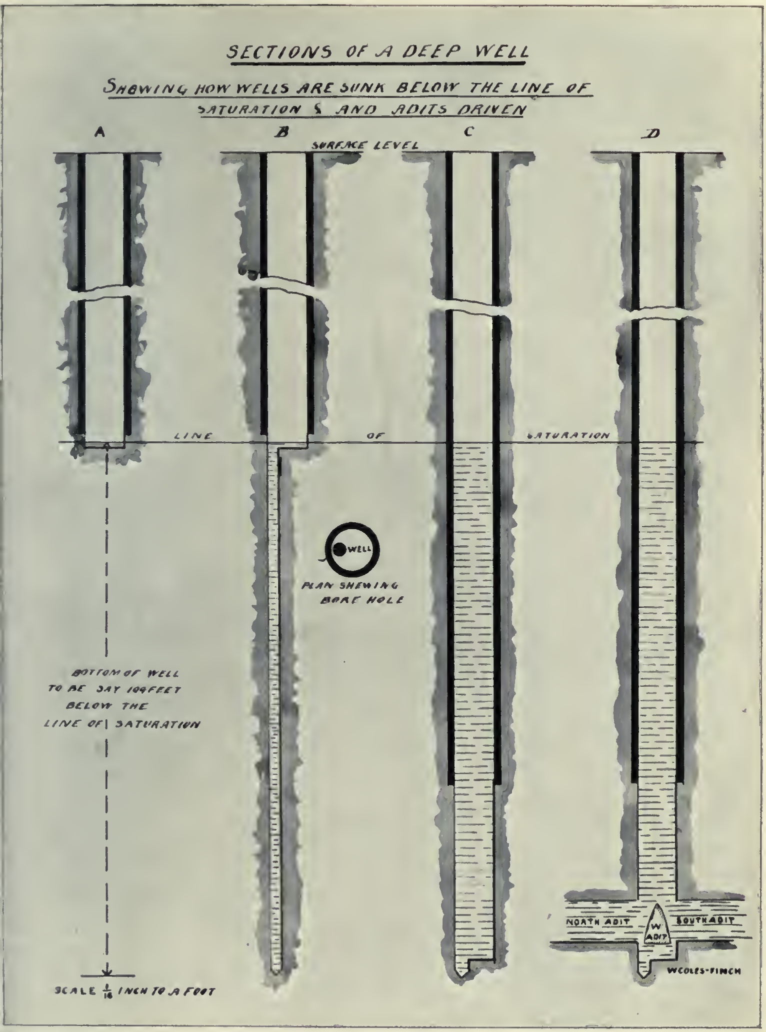
A short description of the manner in which deep wells are sunk may be of interest.

Some persons, when requiring a supply of water, send for a diviner, with his rod, to point out the most likely spot. This rod is indeed a source of wonder to many.

In a book before me I find the rod and its use most carefully described as follows: "A rod, usually of hazel, with two forked branches, used by persons who profess to discover minerals or water underground. The rod, which is carried slowly along by the forked ends, dips and points downward, it is affirmed, when brought over the spot where the concealed mineral or water is to be found."

We will presume that the site for the deep well has been selected in such a locality, where, judging by the geological position and not by any hazel-twig manœuvring, there is likely to be a considerable amount of free water in the chalk, passing on to the sea.

Here a strong structure of timber or iron, called a gantry,


SECTIONS OF A DEEP WELL
SHEWING HOW WELLS ARE SUNK BELOW THE LINE OF SATURATION & AND ADITS DRIVEN
A
B
C
D
SURFACE LEVEL
LINE OF SATURATION
WELL
PLAN SHEWING BORE HOLE
BOTTOM OF WELL TO BE SAY 109 FEET BELOW THE LINE OF SATURATION
NORTH ADIT
SOUTH ADIT
W ADIT
W. COLES-FINCH
SCALE 1/16 INCH TO A FOOT

[*To face p.* 398.

is erected similar to that shown in the illustration. A boiler for generating steam and a steam-winch are fixed, and the work of sinking the well (usually 8 to 10 feet diameter) is carried on in the usual way, *i.e.* by digging down to water, or to the line of saturation.

This sounds fairly simple: in some cases it may be so, but generally there is some trouble to contend with, either faulty rocks, large seams of slippery clay, which may at any moment cause a few tons of material to slip in and crush the men, rubbly chalk which will not stand alone, infiltration of water, impure air, and the ever-present liability of a small piece of rock falling from the bucket; such a fragment, when falling from a height, acquires the velocity of a bullet, and it is not an unusual experience for a piece to come whizzing by one, and embed itself in the bottom of the well. These and similar contingencies have to be provided for and overcome.

Unsound ground is usually remedied by inserting rings of masonry as the work proceeds, carefully underpinning each ring as the sinking proceeds, but this method is not practicable if there is much water to deal with. Resort is then had to iron cylinders, which are bolted together in sections, and so the well is practically one long iron tube, all objectionable matter being shut out.

This part of the work will bring us to the bottom of the "sunk well," perhaps 150 feet below the surface, at the line of saturation and water. (*See* section, fig. A.)

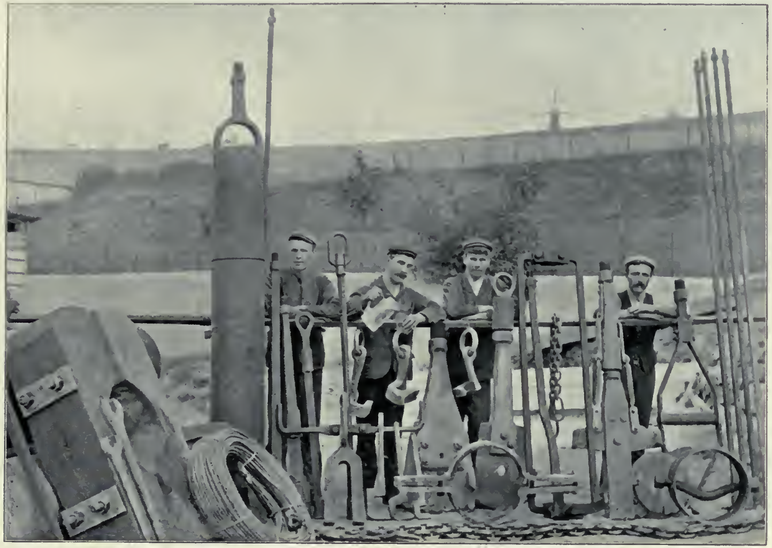
When this point has been reached, boring tools of required size (up to 5 or 6 feet diameter) are brought into use. A large hole is bored from the bottom of the sunk well to a further depth of, say, 100 feet, as fig. B. The usual method of sinking cannot be adopted here, as we are piercing the fully charged rocks, below the line of saturation.

Well-boring is not generally dangerous, but it is a laborious task, and I know of no single employment so drearily monotonous. In boring on the percussion system a hardened steel chisel of a width equal to the diameter of the borehole is attached by rods and a punching chain to the revolving drum of a steam-winch, which raises the tool a few feet and drops it with a thud. This process is termed "punching"; men control the chisel as it falls, slightly turning it at each fall or stroke. In this manner a truly cylindrical hole is bored, or, more correctly, jumped or cut. When some distance has been cut in this manner, a cylindrical bucket made of steel, called a shell, with a hinged door opening upwards, in the bottom, is lowered into the debris and water, which fills it; it is then drawn to the surface and emptied.

There is a system of boring in which this process of "shelling out" is not necessary, hollow rods being used, down which water is forced, which escapes at the extremity of the chisel, through holes provided for the purpose; this keeps the debris in a liquid condition, and it overflows continually at the surface in the form of a thin "slurry": where conditions are favourable this is a most economical and expeditious method.

This process is continued day by day: each day the chisel works deeper, rods being added, until at last, after, maybe, weeks, months, and in some cases years, the required depth is reached (fig. B). But now we have a well, say, 8 or 10 feet in diameter down to the water, and only a bore-hole 5 or 6 feet in diameter through the water-bearing rock. We must have the 8 or 10 feet well all the way; how shall we do it?

We must now, either in a temporary or permanent manner, fix a powerful pumping engine, then, length by length, ton after ton, the suction rose and working barrels, rising mains, valves, rods, plungers, and other



MEN AND TOOLS EMPLOYED ON THE ARTESIAN BORING,
LUTON, CHATHAM.

THE AUTHOR AND MEN BORING WITH A
60-INCH CHISEL.

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necessary machinery, are lowered into the sunk well and bore-hole, to the extremity of the latter, say, 300 feet below the surface (fig. B).

The engine is then started, the pumps conducting water from the 100 feet of bore-hole to the surface, keep the water pumped down, so that the well may be sunk at its full diameter to the bottom of the boring, as shown in fig. C.

When we begin sinking through the fully saturated rock the work proceeds with greater difficulty, for as we get lower the pressure against us increases, water spurts, froths, and bubbles everywhere, rushing to the pump; everybody employed is more or less wet continually; masonry and steel lining-cylinders are put in if necessary. At last we reach the depth required; the engine is stopped and the men come to the surface; the well fills with water and preparation is made to test the yield of the deep-seated spring.

The capacity of the pumps is known, and the number of strokes is recorded. From these data the amount of water is calculated.

Adits

If sufficient water has not been met with at this stage, adits are driven from the bottom of the well in all directions, as shown in fig. D, the pumps still keeping the water down.

Adits are tunnels cut in the chalk. A light, temporary tram-line is laid down at the bottom of the well and is extended as the work proceeds, a trolley running to and fro bringing the excavated chalk to the foot of the shaft, whence it is drawn up to the surface by the steam-winch in large buckets.

These adits are driven a considerable distance until some fissures or natural pipes are cut and the water rushes into the adit.

In the photograph we see a typical adit in the water-bearing chalk 150 feet below the surface, with branches running in all directions.

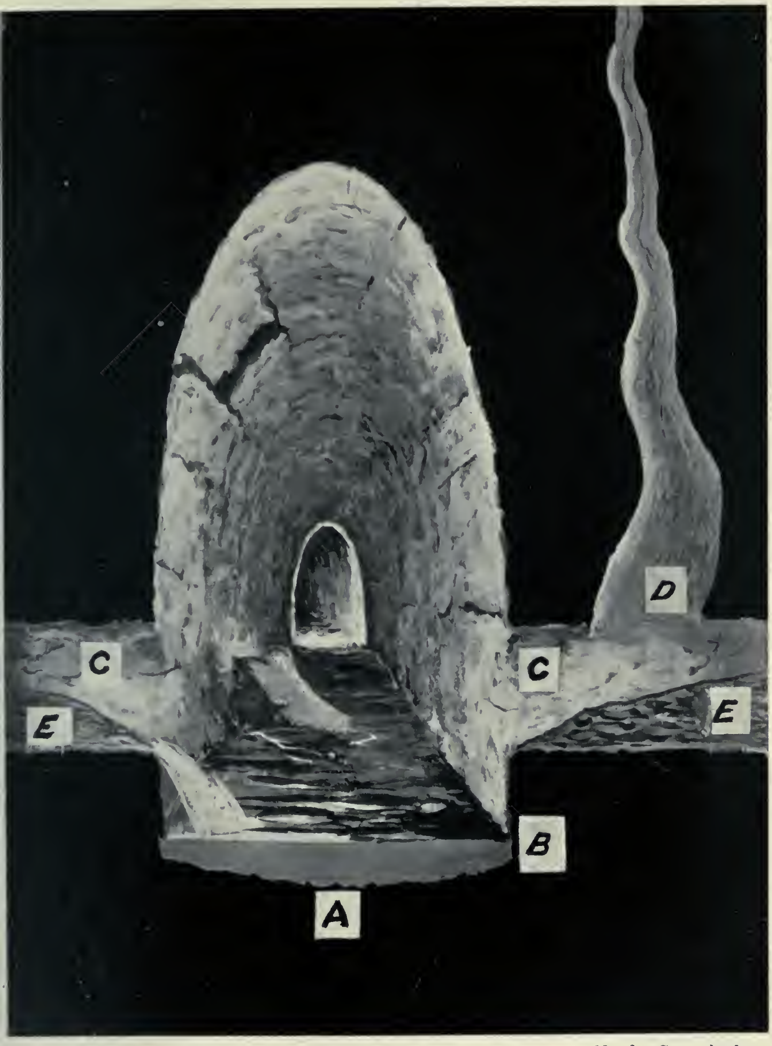
If any considerable length has to be cut, or if the depth be great, fresh air must be forced down the well and carried along the adits to where the men are at work, for if the air contain more than 30 parts of carbonic acid in 10,000, it becomes poisonous and will cause death, as in the open country only 3 parts per 10,000 are found.

One great difficulty, which the reader will appreciate, is to carry out these underground excavations and at the same time to maintain the supply of clear water for the community, for the water coming from the adits in which the men are at work is of course soiled.

The writer has found it of great utility, and a source of great economy, where there are several wells, adits, and engines (all adits and wells being connected on the bottom level), to provide these separate adits with dams of clay or concrete, fitted with valves and pipes, so that the water from the various springs may be kept more or less under control.

If this be done, and men are working in the adits and soiling the water, the soiled water can then be isolated and caused to flow to one pump; the clear water flowing down the other adits can be led to other pumps that are keeping up the supply.

In this way the underground water can be controlled within certain limits, and where the supply of pure clean water has to be maintained while the extension of the underground works is in progress, these means are of great assistance.



Charles Spencelayh.

AN ARTIFICIAL ADIT IN THE CHALK.

A, bottom of artificial adit 150 feet below surface.
B, water flowing to pumps.
C C, natural horizontal fissure crossing adit.
D, natural spiral vertical fissure.
E E, laminated clay.

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In some cases it has been found very convenient and economical to lay mains at this depth and carry the clean water in pipes for some distance *through* the soiled water, in order that the two waters shall reach their respective pumps (see plan).

When a sufficient supply has been obtained, the temporary dams and pipes are removed and all the water flows clear and clean.

This work is surrounded by difficulties, and it is at times attended by dangers from various sources. If the pumps break down we must run for life, impeded by heavy water-boots, etc., wading through water to reach the well, before the water rises, for we are 250 feet below the surface of the ground and 100 feet below the rest-level of the water, and it is trickling or spurting through the seams; unsuspected huge pieces of rock may slip in, notwithstanding every care we have used, for this frequently occurs. We often hear of accidents, and loss of life by drowning is not uncommon in carrying out the work of searching for water in the bowels of the earth. This should make us more careful than we generally are to avoid wasting this most precious of nature's gifts.

If great demand is made on the source of supply, in a few years the water-bearing rock becomes so depleted that the adits must either be extended or deepened. The latter course is frequently adopted: periodically a few feet are removed from the bottom, thus increasing the depth. These tunnels measure as much as 30 feet from crown to bottom, having been deepened by degrees, say, 20 feet.

In these cases, unless piers of masonry be inserted at intervals, the rock would slip in; timber is used as a temporary precaution, as will be seen in the illustration.

Horizontal Wells and Upward Borings

This heading will probably puzzle some readers, but boring in this direction is actually adopted. There is an instance of a well "sunk" in this manner at Folkestone, where the necessary geological conditions exist which make it possible.

There, as will be seen by the section, an adit is driven almost horizontally into the face of the North Downs, in that part of the Chalk formation called the marl, which is almost impervious, and above which the Middle and Upper Chalk strata lie. This adit or tunnel is extended for a considerable distance, when branches are driven from the main adit at right angles to the original direction.

In these adits a number of small borings are made in an upward direction, piercing the water-bearing chalk above, and the water passes down through these borings into the adit, flowing by gravitation into the reservoirs.

In percolating through the chalk the soft rain, which has an average hardness of only 0·62°, becomes hardened to an average of 27°; in other respects it is, as a rule, absolutely pure and needs no filtration or treatment of any kind.

Cause of Accidents in Wells

The engineer in charge of well-sinking or adit-driving operations must be careful to ascertain if there are any old wells, adits, or disused workings in the vicinity of proposed new works, especially at a waterworks where large supplies are used, and the normal level of the water lowered many feet by heavy pumping. He must also see that the accuracy of any plans relating to old workings is verified as far as possible.

D. C. Graham.

AN ARTIFICIAL ADIT IN THE CHALK FORMATION.

To illustrate how an adit some 150 feet below the surface, being at first only 8 feet high, becomes 30 feet high, and frequently, at last, abandoned and new ones formed at greater depths owing to what is termed frequent "bottoming out," that is, the repeated lowering of the bottom, to follow the continued lowering of the rest level brought about by excessive pumping; that is, pumping continuously more than the amount of percolation, thus drawing on the reserve water stored up in the chalk.

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The water in existing workings, when near to new ones, must also be kept at the same level in the old as in the new works. The neglect of these precautions has, to the writer's knowledge, been the cause of disaster and death on more than one occasion.

At a certain waterworks in Kent, the line of the old adits was said to be 15 feet from a point where it was proposed to sink a new shaft. Presuming this to be correct, the water in the old workings was allowed to rise 60 feet above the bottom of the new shaft. The work was almost completed when the accumulated water in the old system burst suddenly through the side of the well and two men out of the three who were working on the bottom of the new shaft or well were drowned.

The distance between the new shaft and the old adit was proved to be, not 15 feet, as stated, but only 13 inches. No indication was given by the strata, which was chalk, that the old workings were so near, until a piece of the side, about 18 inches square, blew out. The water rose almost instantly to the level of the water in the old system, 60 feet above the bottom of the new well, submerging the two men as described.

In sinking shafts for coal at Dover, the water was allowed to accumulate to a depth of several hundred feet in a shaft sunk to the Lower Greensand formation. Another shaft was then sunk in close proximity to the first, and on nearing the same formation the bottom burst upwards, resulting in the loss of several lives. This was brought about by the water not being kept balanced in the two shafts, the great force exerted by the weight of water in No. 1 causing the bottom of No. 2 to give way, when, as the sinking proceeded, it became too weak to resist the pressure.

In some parts of the world there are very deep wells: in the state of Jaisalmer, in Rajputana, where water is scarce, there are some nearly 500 feet deep.

In deep wells the noxious gases in the air are a source of danger, and frequently cause loss of life.

The well-known precaution of lowering a candle should always be resorted to; if it will not burn, it is certain that the percentage of oxygen in the air is less than is necessary for the support of life.

Artesian Wells

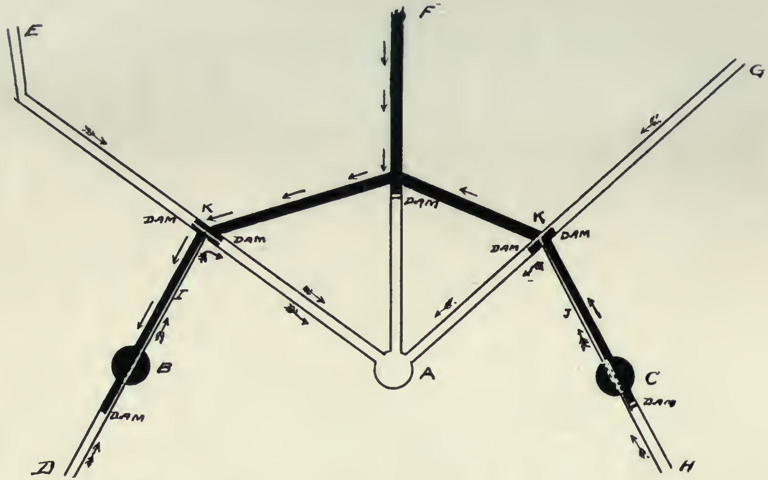
We will now turn our attention to the sinking or boring of artesian wells, so called from the French province of Artois, where they were first sunk on an extensive scale. They are perpendicular borings, through which the water rises to its rest-level, not necessarily the surface, producing a constant flow of water.

The force by which the water is enabled to rise is derived from the natural hydrostatic pressure, when the overlying impermeable strata are pierced; there must, of course, be no natural flaw in either the upper or lower confining layers of impermeable strata, by which the water might escape and disappear into another formation or stratum.

Where the water-bearing stratum lies at a great depth below the surface, this method of boring for water is usually adopted in preference to the more expensive well-sinking.

We are naturally, especially in this country, liable to associate artesian borings exclusively with a domestic supply of water for our towns and villages; in other countries, however, they are also used for purposes of irrigation. Water for these purposes is usually obtained from rivers, but where this is not available the under-

THE AUTHOR'S METHOD OF CONTROLLING UNDERGROUND WATER DURING EXTENSION OF ADITS.



A, well to which clean water gravitates from adits D, E, G, H.
B, well to which soiled water gravitates from adit F.
C, draw-well to which excavated debris is taken and hauled to surface.
D, E, G, H, adits down which clean water is flowing to pump A.
F, adit down which soiled water is passing from workings at F.
I, main laid on side of adit to conduct clean water *via* E, A from D.
J, ,, ,, ,, G, A ,, H.
K, K, clean water mains at junctions of adits are placed level with the surface of bottom of adit so as not to obstruct work.
→ direction of soiled water.
➳ ,, clean water.

Not drawn to scale.

[*To face p.* 406.

ground supplies have been tapped, as in many places in India, Algeria, and America.

It is stated by W. G. Cox, C.E. (*Geographical Journal*, 1902), that in the Madras Presidency alone millions of acres are irrigated from artesian wells. In Central Asia and Persia 200,000,000 persons depend solely for their food upon areas irrigated by water drawn from underground sources in the form of wells, springs, etc.

In Algeria, principally in the Sahara, over 329,000 square miles have been brought under cultivation by means of artesian wells. Here 15,000 borings have been made into the underground water of the arid deserts.

Artesian wells can be numbered by thousands in U.S.A. with results exceeding those in any other country.

In Queensland 532 borings are yielding over 350,000,000 gallons per day. Other borings in Australia yield, by pumping, enormous quantities; one, for instance, at Coongoola, 6,000,000 gallons per day.

The preliminary arrangements for making an artesian well are very similar to those necessary for sinking deep wells; but here the boring is continued from the bottom of the well until no further progress can be made, owing to the sides of the borings falling in, which usually occurs if a bed of clay or running sand has to be passed through.

At this period of the work tubes are lowered into the boring, a steel shoe having been screwed on the end, to assist in cutting off any obstruction in the passage of the tubes through the rock, etc.

These tubes prevent the falling in of the sides or the choking of the bore-hole with debris, and boring may be resumed, the tool being lowered inside the tubes; a few feet are bored and the debris removed, and the tubes are lowered, or, if necessary, forced down, still further.

This process is continued until the friction on the exterior of the tube is so great that the tubes cannot be forced further into the earth.

A smaller set of tubes is then inserted through those already in position; these have also a steel shoe similar to the larger ones. The work again proceeds, until at last the water-bearing stratum is pierced, and the water rises in the tube. Perforated pipes are then forced down and protrude into the water-bearing stratum. The holes allow the water to enter the tube, but prevent the sand or rock from choking the pipe.

There are various methods of carrying out this work, necessitating the use of different tools.

Should the boring be through hard rock, rows of Brazilian black diamonds, on which the rock has but little effect, are embedded in the edges of the tools, projecting so as to cut through the rocks. This system of rotary boring with diamonds is the invention of a Swiss engineer, Leschot.

The diamond rock drill is now more or less supplanted by the shot drill. In this the principle is somewhat similar to the former, but instead of using expensive diamonds, hard steel shot run loose, underneath the crown of the drill; the pressure on them by the weight above as they revolve crushes and cuts the rock, leaving a solid core, which is brought to the surface, the finer debris or slurry being washed to the surface as described in percussion boring.

In the Sahara Desert, on the borders of Algeria, artificial oases have been created by means of artesian wells, from which water, generally of good quality, is obtained, though sometimes it is slightly saline, so that by these means "He maketh the wilderness a standing water, and water-springs of a dry ground."

Artesian borings seem to have been used here by the Arabs in bygone days.

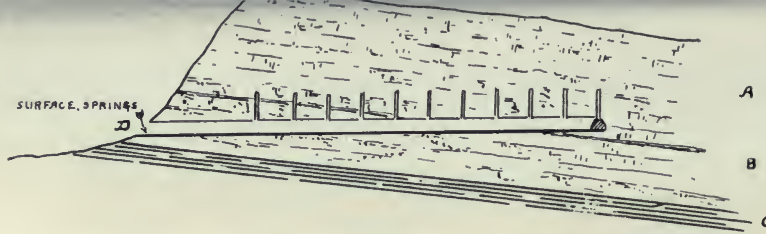
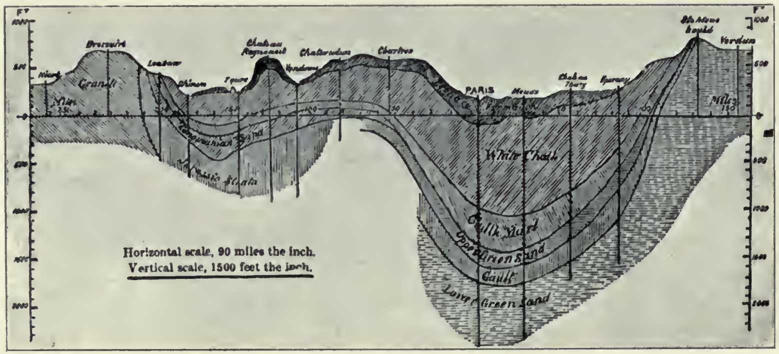


DIAGRAM SHOWING ADIT DRIVEN INTO THE ESCARPMENT OF THE NORTH DOWNS. FOLKESTONE, KENT.

A, upper and middle chalk (water-bearing). B chalk marl (almost impervious). C, gault clay. D, adit with upward borings.
Not drawn to scale.

GEOLOGICAL SECTION THROUGH THE PARIS BASIN (FROM NIORT TO VERDUN).



SECTION SHOWING THE CAUSE OF THE RISE OF WATER (FROM THE LOWER GREENSAND) IN ARTESIAN WELLS IN THE PARIS BASIN.

[*To face p.* 408.

Traces of more ancient bored springs are also found in Lombardy, Asia Minor, China, and Egypt.

In Chicago there is a boring only 5 inches in diameter which yields 800,000 gallons per day. In St Louis (Missouri) a well 3147 feet deep yields brine. In Louisville (Kentucky), one 2086 feet deep, though only 3 inches in diameter, yields nearly as much as Grenelle, which has a delivery of about 800,000 gallons per day.

In Budapesth there is an artesian well 3182 feet deep, and at St Louis, U.S.A., one 3843 feet deep; one of the deepest wells near us, at Grenelle, Paris, is only 1798 feet deep.

The Passy and other Borings

The "Passy" boring, in Paris, is a notable example. The geological section of the Paris basin shows distinctly that the water falling on the Lower Greensand at Verdun keeps the formation charged. (*See* Geological Section.)

The average depth of the water-bearing strata around Paris is six times that of the chalk-beds underlying London.

The Passy boring, which pierces the same water-bearing strata as the Grenelle, was started on 15th September 1855; it is 1923 feet deep, and has at the bottom a diameter of 2 feet 4 inches. It throws a continuous stream of water, 54 feet above ground, at the rate of 5½ million gallons per day.

This formation, bearing an enormous supply of water, is 1798 feet below the surface of Paris. It is imprisoned by the Gault clay overlying it, above which are the Upper Greensand and Chalk, and finally the Tertiary formation.

When these strata have been pierced, the water rushes quickly upwards through them, until it finds its rest-level.

The water from the Grenelle boring, when confined in pipes, rises to 128 feet above the surface.

The operation of sinking this boring extended from 1834 to 1841. During the progress of the work (May 1837), when a depth of 1254 feet had been reached, the boring rods broke, and they were only recovered after fifteen months' incessant labour.

At a depth of 1798 feet the subterranean water-bearing stratum was reached, and water with a temperature of 82° F. spouted up at the rate of 600 gallons per minute, corresponding with the amount of the rainfall, which percolates through the permeable strata of Champagne, 100 miles distant.

Another gigantic boring 5 feet in diameter was sunk into the Paris basin at La Chapelle in January 1886; another, 6½ feet in diameter, is at Butte aux Cailles; and there are many others of small dimensions.

At Aire, in the province of Artois, is a well of this description from which the water has spouted steadily and continuously 11 feet above ground for more than a century; another, in the old Carthusian convent at Lillers, dates from the twelfth century, and is still flowing.

At Sperenberg, Berlin, there is a boring 4194 feet deep through rock salt, which produces brine. This is one of the deepest borings in the world.

At Schladebach, near Leipzig, in Germany, there is a boring, though not for water, 5631 feet deep; at the bottom the diameter is no larger than one's little finger.

The increase in temperature recorded in the Sperenberg boring as the work progressed was as follows:—

At a depth of 1000 feet . .	1° F. for each 42 feet.
" " 2000 " . .	1° F. " 57 "
" " 3000 to 4000 feet .	1° F. " 95 "

At Kissingen, Bavaria, there is a salt spring which

A TYPICAL ARTESIAN BORING.

(Showing the water overflowing from the top of the tube which conducts it from the water-bearing strata below to the surface.)

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throws up a column of water 58 feet high, from a depth of 1878½ feet.

The projecting force here is not hydrostatic pressure, but carbonic acid gas, generated at the junction of the gypsum with the magnesium limestone at a depth of about 1680 feet.

The following are the temperatures of the water from several renowned borings, and they show an average increase of temperature, due to the earth's internal heat, of 1° F. for a descent of from 40 to 55 feet:—

Grenelle	same	82° F.	St. Louis,	73·4° F.
Passy	source,	82° F.	Louisville,	76·5° F.
Kissingen		66° F.	Charlestown,	87·0° F.

As far as England is concerned, some of the most prolific borings are in Lincolnshire.

Recently a boring was made at Bourn for supplying Spalding with water; and here, at a distance of 66 feet from the surface, chalybeate water was met with: this was excluded by inserting tubes 13 inches in diameter.

At a depth of 78½ feet springs were tapped in the Lincolnshire Oolitic Limestone, but water rose slowly, taking twenty-four hours to overflow at the surface.

At a depth of 100 feet the yield increased to 1,872,000 gallons per day. Boring was continued to a depth of 134 feet, the yield at that point being 5,011,000 gallons in twenty-four hours. This is one of the most prolific borings in England.

At Scunthorpe, Lincolnshire, a boring was sunk to a depth of 1767 feet into the New Red Sandstone. An abundant supply was obtained, free from organic impurities; but, to the great disappointment of all concerned, it was found that mineral impurities were present in excessive quantities, viz. 388·5 grains per gallon, due, no doubt, to the presence of calciferous beds in the lower sandstones, making the water unfit for use.

Lincolnshire has also the distinction of possessing the deepest boring (for water) in the United Kingdom, the first 400 feet being a sunk well 12 feet in diameter, the next 1102 feet being reduced to 9 feet in diameter, followed by a boring 33 inches in diameter 59½ feet deep = 1561½ feet. "A contract for sinking this boring at Boultham, Lincoln," says Professor Hull, "was entered into in 1901. On Sunday, 10th June 1906, the top bed of the New Red Sandstone was reached, at a depth of 1561½ feet. The rush of the water when the formation was pierced could be heard distinctly above ground, the water eventually reaching and overflowing at the surface.

"This boring passed through Lower Lias clay 641 feet; Rhætic beds 52 feet; red marl and sandstone (Keuper) 868 feet into the New Red Sandstone conglomerate; which formation reaches the surface in a broad tableland at an altitude of 300 to 400 feet above sea-level to the north of Nottingham, and constitutes the source of supply for that town, and a large district ranging into Yorkshire. Its nearest border is about 20 miles from Lincoln.

"Owing to its extreme porosity, its absolute continuity in the direction of the dip of the beds (there being no faults between), and the constantly increasing hydrostatic pressure of the water in the direction of Lincoln, there are all the conditions for a successful artesian water supply."

Future developments, however, proved that these sanguine expectations would not be realised. After allowing the water to overflow at the surface, and pumping it to waste for several months, with the hope of improving the quality, it was found that the water would not be fit for a public supply.

EXPLODING A CARTRIDGE IN A DEEP BORING TO INCREASE THE YIELD OF WATER.

[*To face p.* 412.

It was then decided to continue the boring to a depth of 2200 feet. This was done; the quality of the water, however, becoming slightly worse.

Let any who think lightly of the duties of those responsible for maintaining a pure water supply for a community, digest these few facts, as an instance of disaster which could not be foreseen, when, after about seven years' (1901–8) patient, difficult, and anxious work, and the spending of about £30,000, the result could only be—abandonment!

There are innumerable artesian borings all over the country. At Croydon there are two, yielding, it is said, 1,000,000 gallons per day. Also at Brighton the yield from similar wells is about 1,000,000 gallons per day.

Sometimes, with a view of increasing the yield of a boring, a powerful explosive cartridge is lowered, and ignited by electricity. The result at the surface can be seen in the picture: here the boring is 400 feet deep in hard rock, and 7¼ inches in diameter. This method of shattering and opening the crevices and fissures frequently has a marvellous result, greatly increasing the supply from these deep-seated sources.

Borings in the Medway Valley

Many borings of artesian wells exist in the valley of the Medway, Kent, and though for yield they are eclipsed by those of Lincolnshire, some are worth consideration.

The deepest in this district is at Chattenden Barracks. It is sunk 1162 feet deep into the Lower Greensand, and water rises to within 100 feet of the surface.

The next of importance, at Chatham Dockyard, was sunk in 1868.

This boring passes through 12 feet of alluvial mud, gravel, etc., 684½ feet of chalk, and 191½ feet of gault.

The rock at the base of the Gault was pierced, and the Lower Greensand entered at a depth of 903½ feet.

Owing to the several reductions in the sizes of the tubes as the work proceeded, at completion the tube entering the water-bearing stratum was only 4 inches in external diameter. The water overflowed at the rate of 115,000 gallons per day, and reached a height of 19 feet above the surface. The temperature of this water is 65°, that of the Upper Chalk in the adjoining well being 54°.

In order to obtain a larger supply a larger boring was sunk in 1880, the result of which was at least disappointing.

Pumps were inserted in the boring, and water was pumped from a depth of 122 feet below its rest-level, and the yield was only 300,000 gallons per day.

This boring was then, for experimental purposes, carried down to a depth of 965 feet, into the Oxford clay. This water showed a rise of temperature of 1° F. for every 57½ feet.

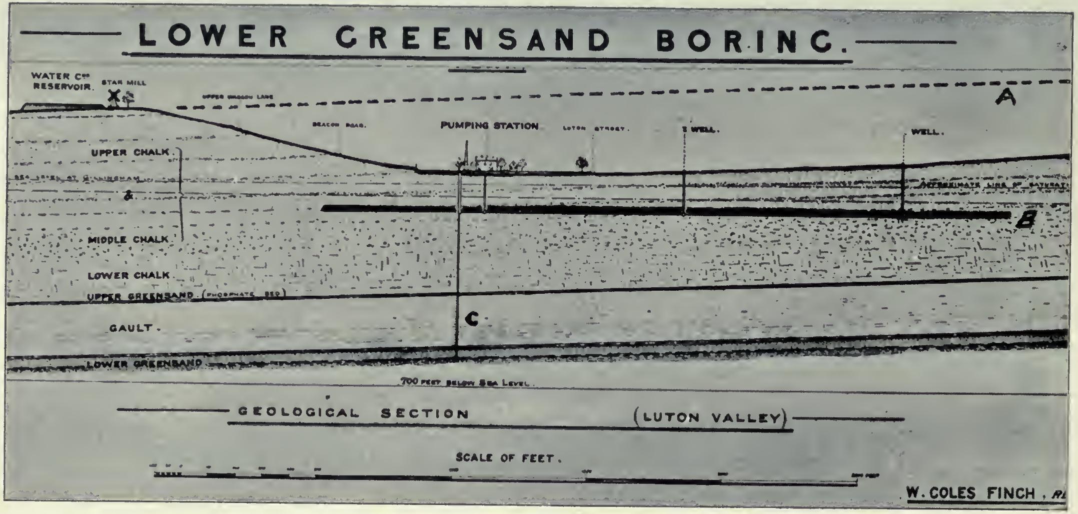
One other boring only will be mentioned, that at the pumping station at Luton, Chatham, which was carried out under the supervision of the writer.

This boring was commenced in one of the many chalk wells at the station, in which there is a depth of about 80 feet of water from the chalk.

To avoid soiling this water, 20-inch tubes were driven into the chalk bottom of the well, and through these tubes the work of sinking the artesian well was carried out.

Like the dockyard boring this was carried through the Chalk, Gault, and rock into the Lower Greensand at a depth of 664 feet.

Here, fortunately, only one reduction in the size of the tube was made. The 18-inch tubes were carried through



GEOLOGICAL SECTION ILLUSTRATING HOW WATER IS OBTAINED FROM BOTH THE UPPER AND LOWER CRETACEOUS FORMATIONS AT CHATHAM, KENT.

A, the dotted line represents the surface of the chalk removed by denudation, forming the dry chalk valley.
B, adits driven in the chalk to intercept the water-bearing fissures and to convey the water to the numerous wells.
C, the deep artesian boring (see enlarged section).

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and driven on to the rock overlying the water-bearing stratum.

The rock was then pierced, and perforated tubes 14½ inches in diameter were inserted.

Water rose to its rest-level, which was found to be 75 feet above sea-level. It had a temperature of 65° F., whereas the chalk water in the same well was 53° F.

This boring was a complete success, yielding about 200,000 gallons per day; but the quantity can be increased from time to time as required.

This is done by the removal of a tube or tubes from the top, allowing the water to deliver at a lower level, and so reducing the hydrostatic pressure on the delivery, increasing the flow proportionately.

These conditions are unique, the same well yielding both water with 20° of hardness, and soft water having only ·78° of hardness; the latter welling up through the tubes inserted in the bottom of the well.

We must not attempt a description of the various fossils brought to the surface; but there is food for thought in one little find that came up in almost the last shell, which was being emptied when the writer saw a glittering, irregular piece of matter roll out. It sparkled in the sunlight as if closely set with diamonds. Upon examination it proved to be a piece of fossilised wood, probably oak. The silver streaks and grain can be seen distinctly, the sparkling stars embedded in it being iron pyrites or marcasite. Here, 664 feet below the Chalk, Upper Greensand, Gault clay, rock and Lower Greensand, the product of ancient forests was found, and brought once more into the light of day. If we add the 200 feet removed by denudation, we get a total depth of 864 feet, and, presuming that this formation was laid down at the rate of 1 inch a century, we get over one million years.

Then a considerable number of millions of years must be added for the time that has elapsed since the Upper Cretaceous formation was laid down. Surely this is a most ancient piece of wood!

Rest-Level and Area of Exhaustion

The rest-level in a well or boring is that level to which the water rises upon cessation of pumping; this is fairly constant if the amount extracted is not in excess of the percolation. The rest-level and pumping-level vary in different formations and according to local circumstances. The writer has known cases where there has been a difference of over 100 feet; that is, the level is reduced over 100 feet by pumping.

Where these conditions exist, a special kind of pump is necessary, for here there would be over 70 feet of water above the pumps; and should they require repairing or the valves have to be changed, grave difficulties might arise; so pumps are used that can be controlled, repaired, or changed from the surface, with the well full of water.

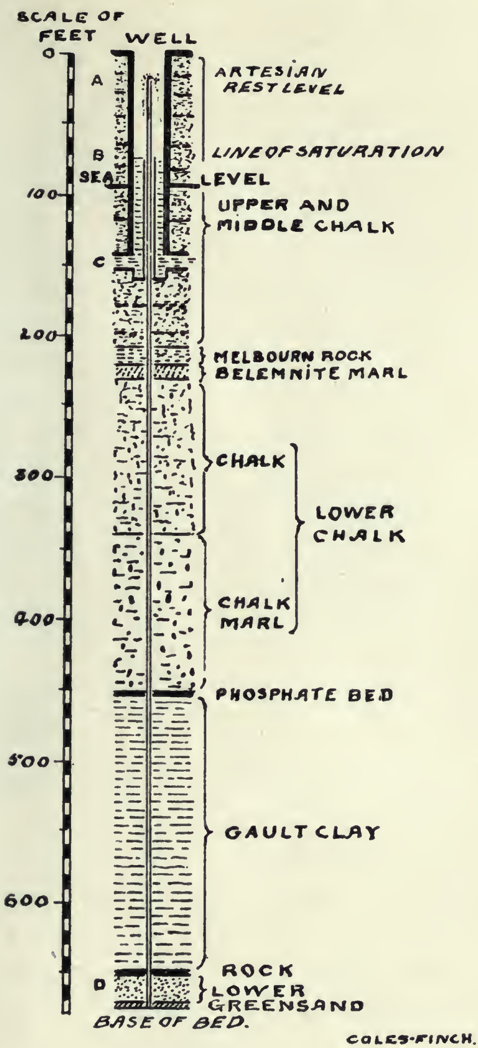
If extensive pumping is carried out, it will be found that the water-level, or line of saturation, will vary, being governed by the amount of rainfall absorbed.

If it has been lowered locally by these means, the original level will be restored on the cessation of the pumping, if sufficient time be allowed, and provided the volume abstracted annually is not more than is absorbed annually from the rainfall.

When the demand increases and more water is required, either the pumps have to be placed at a lower level, the well having been sunk deeper and fresh adits driven also at a lower level, or the existing adits must be extended

ENLARGED SECTION OF THE ARTESIAN BORING, LUTON, CHATHAM, KENT.

(Passing through the Upper Cretaceous formation into the Lower Greensand.)



REFERENCE.

A, top of tube conducting the soft water from the Lower Greensand, 665 feet deep, from which it flows by hydrostatic pressure.

B, surface of water (hard) from the Upper and Middle Chalk, into which the softer water falls and mixes with as shown.

C, adits conveying chalk water to the well.

D, the formation that yields the soft water.

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and more water-bearing fissures cut, thus increasing the area of exhaustion around the well.

In some formations the area of exhaustion resembles an inverted cone, the apex of which is formed by the point at which the water is abstracted, but from experience and systematic experiment this is found not to apply to wells in the chalk. The amount of water that can be obtained in this formation is proportionate to the amount of rainfall, the capability of absorption, and the area of the watershed in which the operation is being carried out. The amount actually obtained, however, depends upon the number and size of the water-bearing courses or fissures intercepted.

The height to which the water rises in artesian borings is called the artesian rest-level.

Pumping will reduce the level, as in ordinary wells, and this reduced level is called the artesian pumping-level.

An instance of this is seen in the artesian wells in the chalk under London. Where formerly the water rose above the surface in the lower-lying portions of the Thames valley, now, through the multiplication of artesian wells, the amount of water obtained has increased to such an extent that the level has been greatly reduced, until it now stands about 100 feet below the Thames, the percolation of the rainfall on the outcrop being less than the quantity of water pumped.

Reference to the geological section will help to explain the position of the Chalk formation under London, from which source all the artesian borings are supplied; here it is over 300 feet down to the chalk, which formation is 650 feet thick.

The Thames basin has been riddled with borings; many of the large London breweries, railways, prisons, asylums, as well as the Bank of England, the Mint, and the fountains in Trafalgar Square, derive the water from the chalk by means of artesian wells.

Should these conditions continue, the supply will eventually decrease so much that the amount will be limited to that of the annual percolation; the accumulation of ages, stored away in the formation which now supplements the supply, will then have been used up, leaving the rainfall only.

The water from the artesian wells sunk into the Lower Greensand is stored in the interstices between grains of sand, just as water is stored when poured into a pail previously filled with shingle.

Great care has to be used in pumping water from these borings in the sand, for if it be taken too freely the sand is carried with it, which either ruins or breaks the pumps or chokes the tubes, and so shuts out the water.

Should this occur, special tools are employed for the removal of the sand, and the water is again enabled to flow up the tubes.

The manner in which this water, of a distinctly different character from that found nearer the surface, bubbles up from depths of hundreds of feet, is not generally understood.

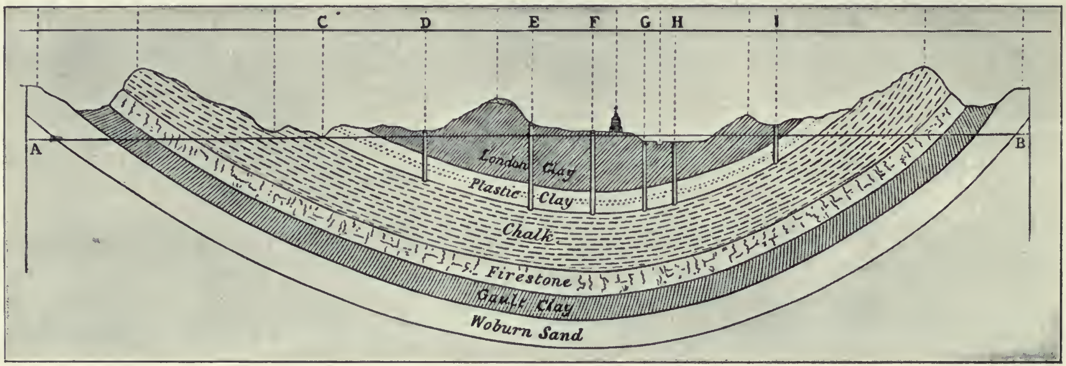
A short time devoted to the study of this phenomenon will prove its simplicity so far as the work of nature is concerned. The work of sinking deep borings is, however, beset with difficulties. The wells consist of a shaft, sunk or bored through impermeable strata into a permeable or water-bearing stratum.

The water obtained from this source is derived from the rain falling at the outcrop of the permeable stratum, generally many miles from the spot where the well is being sunk, and percolating into the formation.

This water is confined, and unable to rise to the level it

GEOLOGICAL SECTION THROUGH THE LONDON BASIN—LEIGHTON BUZZARD TO SEVENOAKS.

Leighton Buzzard. Dunstable. St Albans. Hampstead. London. R. Thames. Sydenham. Knockholt. Sevenoaks.



SECTION SHOWING THE CAUSE OF THE RISE OF WATER (FROM THE CHALK) IN ARTESIAN WELLS IN THE LONDON BASIN.

A, B, line at which water overflows as springs at C.
D, E, F, G, H, I, artesian wells sunk into the chalk.

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otherwise would reach, by the impermeable strata overlying it. When these have been pierced the water is forced up the artesian tube by the hydrostatic pressure, due to the level at which the water (as rain) was received. (*See* Geological Section.)

Water from Lakes and Rivers

"Streams never flow in vain; where streams abound,
How laughs the land, with various plenty crown'd!"
COWPER.

A very large proportion of our supply of water is derived from the lakes and rivers.

Some lakes are preserved exclusively for this purpose. The natural Loch Katrine, in Scotland, for example, is used as a reservoir for the supply of water to Glasgow; it has an area of 3000 acres, and a capacity of about 5,600,000,000 gallons.

Some natural lakes have their water-level artificially raised by dams, so that a greatly increased amount of water is made available, as in the case of Thirlmere, from which Manchester derives its water. Where these conditions prevail, the impervious stratum of the watershed or gathering ground is of clay or rock.

The amount of water obtained from lakes and rivers, as in the case of wells, is in proportion to the area and the rainfall, less, of course, the amount of annual evaporation, etc. Here, in the rainy seasons, the water rapidly finds its way back to the sea in the form of rivers, unless it be impounded.

It is estimated that, on the Scotch and Welsh hills, 60 inches out of the rainfall of 70 inches is available, evaporation claiming only 10 to 12 inches per annum.

Many large towns obtain their water from these sources. Unlike the well and spring waters, which are generally of a high standard of purity, the streams, rivers, and lakes contain more or less matter in suspension, gathered up, as we have seen, by the water in its journey over the rocks; hence its lower place in the scale of purity of waters.

This impurity must be removed before the water is used for supply; for this purpose it is passed over filter-beds, and if the work be efficiently carried out, all objectionable matter should be removed.

These upland waters differ considerably in their chemical composition, according to the rock on which they fall and the soil by which the rock is covered: vegetation and many other things tend to give each its own peculiarity.

Water from the Elan Valley, from Lake Vyrnwy, etc.

The manner in which artificial lakes are formed by impounding the waters of streams or rivers may be described briefly as follows:—

If water flowing from a spring or a stream be taken by any water authority, compensation can be claimed by those who previously had the use of the same.

Hence the term "compensation water," which is the amount of water given or passed down the stream to enable manufacturers and others to continue their respective works as before the waters were impounded. In this way they do not suffer any loss, for when the dam is completed, the flood water that originally ran to waste is stored, and the working power of the stream is increased. Thus all benefit: a town is supplied with water, the mill-owners get a regular and efficient supply in times of drought, when otherwise there would be but little water in the stream, and the damage from floods arising from heavy rainfall, or melting of the snow, is averted.

By permission of G. F. Deacon, C.E.

No. 1. THE VYRNWY DAM—EXCAVATING THE TRENCH ACROSS THE VALLEY OF THE RIVER VYRNWY.

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In underground water, however, it is different. If a well be sunk in any locality, and pumping operations deprive a community of its water, there is no redress, there being no legal title to underground water.

A typical instance of a supply for a large community from these sources is found in the city of Birmingham, which now obtains its water from the rivers Elan and Claerwen, tributaries of the Wye.

This watershed has an area of over 70 square miles, the average rainfall being 63 inches per annum, and the storage will be sufficient to provide 75,000,000 gallons a day for 200 days, in addition to 27,000,000 gallons a day for compensation water, or the amount of water allowed to flow continually down the valley for the requirements of those who were users of water before dams were constructed across the valleys.

Strong dams of masonry were built to impound the water. The bed of the river at the lowest dam (Caban Coch) is 700 feet above mean sea-level, the top water-level being 822 feet above the sea. The Peny-Gareg Dam is 945 feet, and the Craig-yr Allt-Gosh Dam 1040 feet above sea-level.

Thus a vast body of water is accumulated, turning the once peaceful valley into a series of artificial lakes.

When this scheme is fully completed there will be six artificial lakes retained by six massive dams of masonry varying in height from 98 to 125 feet, and in length from 500 to 900 feet. The first four only of these reservoirs have a combined top-water area of 1000 acres, and contain 12,700,000,000 gallons.

The water is conducted from the reservoirs, by means of large iron pipes, to Birmingham, a distance of 80 miles. The complete scheme will cost about £6,000,000.

Liverpool obtains its water from a similarly constructed artificial lake, Lake Vyrnwy, in Montgomeryshire.

One of our illustrations of the Vyrnwy reservoir shows the excavation of the trench for the massive dam in progress. In the centre of the valley the depth down to the solid rock was 60 feet, the width of the trench at this point being 124 feet.

This splendid example of waterworks engineering is more or less typical of all dams of this kind; it has a top length of 1350 feet and a width of 20 feet, and has to sustain a body of water 70½ feet deep. The total height of the masonry, in the centre of the river valley, from the rock to top water-level, is about 140 feet.

This artificial lake has a surface area of 1100 acres, and will supply 40 million gallons per day to Liverpool, a distance of 68 miles, the aqueducts passing through the bed of the river Weaver, and under the bed of the river Mersey.

The surface level of this lake is about 550 feet above the reservoirs at Prescot, into which the water is delivered.

Manchester, in like manner, also derives its supply of water from Thirlmere, which is a natural lake in the Lake District, but its level has been artificially raised 20 feet, to a height of 554 feet above sea-level.

When this lake has been raised to its full extent, it will be 584 feet above sea-level, over 3½ miles long, and 793 acres in area, containing 8,135,000,000 gallons, which will provide 50 million gallons a day for 160 days, even if no rain should fall. The reader has seen how remote these chances are in the Lake District.

From Thirlmere to Manchester is 95 miles, and provision is made to convey 50,000,000 gallons a day this distance.

When we consider these distances over which water has to be conducted, and the great pressure some of the pipes must be capable of withstanding, and then see the old wooden pipes through which the water passed to supply

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No. 2. THE VYRNWY DAM NEARING COMPLETION.

This dam impounds the waters of the Welsh mountains, forming an artificial lake of considerable extent which provides the supply of water for Liverpool, some sixty-eight miles distant.

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our ancestors in the great Metropolis and other places, we can realise the stride that has been made in this branch of engineering. The first attempt to supply London with water by mechanical methods was in 1581, the conduits fed by springs being no longer sufficient for the increasing population.

The Corporation of London granted a lease to Peter Morrys, of Dutch nationality, who erected a water-wheel under the first arch of London Bridge; this was actuated by the tide, and drove the pumps which forced the water through the pipes in the streets.

This first mechanical supply of water to the Metropolis only extended to Gracechurch Street. In the presence of the Lord Mayor, as the result of his invention, Peter squirted a fine jet of water over St Magnus Church steeple. "This performance," says G. P. Bevan, F.S.S., "so pleased the city fathers, that they granted the Dutchman a lease of the Thames water for 500 years, including the ground on which his forcier stood, and one of the arches of the bridge, wherein to erect more works. All this was granted at the very moderate rental of ten shillings a year, and it is quite certain that no inventor ever got such good terms out of the city either before or afterwards.

"Two years later the knowing Peter obtained another arch, also for 500 years.

"When in 1601 the New River scheme was first proposed, Peter sold his right to Richard Soane for the sum of £38,000. Soane then applied to the city, and obtained a lease of one more arch."

We must not, however, be led into a further description of this ancient supply, interesting as it may be. It is, however, stated by the same writer that "far-seeing citizens, who had acquired property in the lanes on the riverside, laid claim to a wayleave, which was such a disagreeable form of water-rate that a popular commotion took place in the time of Edward III., with the result that the above was remedied."

He concludes that it was no doubt this sharp practice of "the brigands of the lanes" extorting revenue in this manner from the citizens, that set Peter Morrys's ingenious brain to work.

The water pipes of this period were merely trunks of trees roughly trimmed to shape, bored out, pointed, and recessed to fit each other.

Aqueducts

"It is entertaining to observe how little springs and rills, that break out of the sides of the mountain, are gleaned up, and conveyed through little covered channels, into the main hollow of the aqueduct."

ADDISON (Italy, near Rome).

In ancient times, before the introduction of iron pipes for the conveyance of water to a distance from the reservoir, aqueducts were built for this purpose.

These were used extensively by the Romans, and were in some instances works of considerable magnitude, as will be seen in the pictures. They consist of tiers of arcades; the upper tier, upon which is formed the water channel, is more clearly defined in the second picture.

Many aqueducts remain in various parts of the continent of Europe; generally as ruins, but some are still in use.

The Aqua Marcia, 56 miles long, which was constructed 146 B.C. and restored in 1869, now brings a supply of water to Rome from the Sabine Mountains.

In Rome we have also the Porta Maggiore, commenced A.D. 38, which was completed in ten years. This has a double water channel, one above the other. One was constructed to bring water from a distance of 45 miles,

ROMAN AQUEDUCT AT SEGOVIA, SPAIN.

Mrs Aubrey Le Blond.

AN ENLARGED PORTION OF THE SAME.

(This aqueduct is still in use.)

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the other 62 miles; the arches at one place being 109 feet high.

There are twelve others that assisted in supplying water to the city of Rome, but space will not admit of a description.

The Pont du Gard, of which we give an illustration, in the south of France, 14 miles from Nismes, consists of three rows of arches, striding across the valley of the river Gardon. It is built of large stone blocks, and has a total height of 180 feet, the upper arcade, which contains the water passage, being 882 feet long. It is indeed a grand monument of the Roman occupation of France, and is said to have no rival for lightness, boldness, and beauty of design.

At Segovia, in Spain, another example is to be seen. This was also built by the Romans. In places it has two tiers of arcades, reaching the height of 102 feet. Its length is nearly 3000 feet, and it is considered to be one of the finest works of antiquity.

We have also illustrations of the Roman aqueducts at Merida and Terragona in Spain, the latter being 876 feet long and 83 feet high.

Swinburne, in his *Travels in Spain*, writes: "This aqueduct is not only an admirable monument of antiquity for its solidity and good mason's work, which have withstood the violence of so many barbarians, and the inclemencies of the seasons during so many ages, but also wonderfully beautiful and light in its design."

Another similar witness of Roman occupation is to be found at Mayence. Here the ruined aqueduct is 16,000 feet long. Other ruins exist in Dacia, Africa, Greece, and many other parts.

There are, however, aqueducts of more modern construction now in use in many countries, but they are now constructed principally in connection with canals, though some of them are used for the purpose of waterworks supplies; one, which conveys the water to New York, may be seen at Croton, U.S.A. It is one of the most magnificent works of this kind, but we dare not attempt a description for want of space.

The Coolgardie Water Supply

Before closing this chapter, a few particulars of this kind of work in a foreign country will be of interest, and we will take the water supply of the Coolgardie Goldfields, Western Australia, as an example.

These great groups of mines at Kalgoorlie and Coolgardie are some 363 miles in a direct line from Port Fremantle. The area is practically waterless, the rainfall being 7·14 inches, and the evaporation is equal to 82·6 inches, with a temperature often over 100° F. in the summer.

Gold was discovered here in paying quantities in 1892, near the present town of Coolgardie. When the great rush of 1893 set in, the want of water caused indescribable suffering, and many men died from typhoid fever.

Here inferior water, hardly fit for human consumption, was worth 2s. 6d. per gallon, and even at this price the supply was very limited.

As the mines developed, salt water containing 30 oz. of saline matter to the gallon was found in the lower levels. This was condensed and sold at 70s. per 1000 gallons, and typhoid fever still raged for want of an adequate supply of pure water.

In 1894 the railway was extended to the goldfields (Southern Cross to Coolgardie, 130 miles), and the cost of the water for the railway alone amounted to £1000 per day in the summer. It was then decided to obtain water

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RUINS OF A ROMAN AQUEDUCT AT MERIDA, SPAIN.

Mrs Aubrey Le Blond.

PUENTE DEL DIABLO, TARRAGONA, SPAIN.

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from the Helena River, near Mundaring, in the Darling ranges, 30 miles from Perth. A gigantic dam of concrete was built across the river, closing up the valley. This dam is 760 feet long and 100 feet high, and the foundations were carried down nearly 100 feet below the level of the river.

The thickness of the dam varies from 85 to 120 feet, tapering to 15 feet at the top. In this way an artificial lake was formed, 8 miles long, with a capacity of 4,600,000,000 gallons of water, the watershed area being 850,000 acres, chiefly granite hills, the water being exceptionally good.

The next consideration was to pump these 5,600,000 gallons per day, a distance of 330 miles, against a pressure equal to a head of 2700 feet, at the rate of 2 feet per second, through a main having a diameter of 30 inches.

This main consists of 60,000 pipes, each 28 feet long, $\frac{5}{16}$ to $\frac{1}{4}$ inch thick, weighing about $1\frac{1}{4}$ ton. They are tested to a pressure of 400 lbs. per square inch, and about 76,000 tons of steel plate were used in their manufacture.

To do this work twenty pumping stations were erected along the route of 330 miles. These will consume, in the course of twelve months, if working continuously, 30,000 tons of coal.

We in England have many obstacles to overcome in obtaining and distributing a supply of water, but they fade to insignificance compared with the scheme referred to.

The manufacture of the machinery alone, the packing and transport of the same by rail, ship, etc., the delivery of 5000 cases each at its respective pumping station, along these dreary 330 miles of granite ranges and sandy, parched plains, with the loss of only one small hydraulic valve, is a tribute to the splendid management of those who undertook and carried out such a task in the short period of twenty-seven months.

We should also remember that all these stations are many miles from any place where the men could obtain food or lodging, and that there was a perpetual scarcity of water.

Before deciding on this colossal undertaking, boring was tried, a depth of 3300 feet being reached through granite, in hopes of obtaining water, but the attempt was then given up.

Where, on account of local conditions, it is impossible to impound the water in the manner described, as in the case of the Thames, a certain portion only of the water is drawn from the river. There is probably no catchment basin so richly endowed with springs of pure drinking water as the valley of the Thames. The manner in which the great Metropolis is supplied with water, its different sources, the geological and historical facts concerning it, are of great interest, but we dare not start on such a subject for want of space.

The following extract in reference to the river Thames will, however, be of interest:—

"The Thames basin includes within its area," says De Rance:

"170	square miles of	Lias.
931	,,	Oolites.
5	,,	Hastings sand.
13	,,	Weald clay.
453	,,	Greensand and Gault.
2096	,,	Chalk.
945	,,	Tertiary deposits.

"The Chalk above Kingston occupies 1047 square miles, and the deep-seated springs in this formation maintain the dry-weather flow of the rivers, which amounts to at least 350,000,000 gallons per day. About one-third of this amount is taken for supply (after filtration)."

The amount obtained from this formation is enormous.

Mrs Aubrey Le Blond.

A ROMAN AQUEDUCT, PONT DU GARD.

Mrs Aubrey Le Blond.

THE WATER CHANNEL, PONT DU GARD.

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The largest water board in the world, the Metropolitan, supply 6½ million persons with water principally derived from the Chalk.

The amount consumed by this vast population each day during the month of March 1904 was nearly 200,000,000 gallons; this was derived from—

River Thames . . .	107,219,000	gallons
River Lea, etc. . .	51,041,000	,,
Wells and springs . .	39,962,000	,,
	198,222,000	,,

Here we see that the supply from the river is augmented from wells and borings sunk into the chalk, water from this source being free from organic impurity. Is it not wonderful that the sediment of the ancient seas, raised to its present position, should fulfil such marvellous duties, absorbing any amount of rain that may fall in the wet seasons, and dispensing it more or less regularly in dry weather, when otherwise no water would be available?

Reservoir Dams

The construction of these dams for impounding the waters of rivers and forming artificial lakes varies according to the geological conditions; some are perfectly straight, as at Lake Vyrnwy; some, like the dam across the Eifel valley, are constructed in the form of a curve. This gives additional strength, where the valley is narrow, and the height of the water to be impounded proportionately great. In this case the dam is 180 feet high, the depth of water being 150 feet. It is stated that this reservoir will be 7 miles long. Not only will this artificial lake prevent serious floods, which have occurred owing to the destruction of forests, but the waters will also provide the electric light to the district of Aix-la-Chapelle.

The most difficult part of the work, in constructing these dams, consists in the controlling of the water while the excavation for the foundations is in progress.

The stream must either be diverted to some other channel for the time being, or, if a small one, carried in a temporary aqueduct, clear of the works, until the excavation is carried down to the rock and the masonry is raised up to the level of the river-bed. The large valves and pipes are then built in, some few feet of masonry added, and the stream is then allowed to follow its own course, through the pipes which have been inserted. In larger schemes other methods are adopted; for instance, temporary dams are made, excluding the water from certain portions of the river-beds, which are then pumped dry, and thus, section by section, the dam is raised above the water-level.

The foundations for these works are most important. After the solid rock is reached, across the valley and up the flanks of the hills on either side (to top water-level) every little piece of loose rock is picked off, the mass scraped and cleansed, so that the rock and dam shall form one homogeneous mass. This seems a simple matter, but it is difficult indeed; in some cases, as in that of the Nile dam at Assuan, under pressure of the water the fissures in the rock became so many little springs, each of which had to be dealt with separately and controlled, and the water pumped away while the foundations were being put in.

It is in these first works, that part unseen, the foundation, that the chief engineering problems arise, and on them the stability of the dam depends. The contour of the surface rocks has to be traced, however irregular it may be, down to the solid, even, as in the case of the Helena dam, to a depth of 100 feet below the river-bed.

No crevice, crack, or fault may be overlooked, or all your after efforts will be in vain, and the water, under pressure of a full reservoir, will escape. We can hardly appreciate the difficulties of the task, or the anxiety that must fill the minds of those responsible, when these dams are for the first time subjected to the full pressure they have to withstand. From this point the work of fixing valves and overflows, building water-towers, and all the other engineering contrivances necessary to the distribution and control of the water, is more or less familiar to every reader, and a detailed description of them cannot be attempted here.

There is no set method or design in the construction of a reservoir: every dam differs in some way from others, local conditions requiring a special design in every instance; no doubt exists, however, as to the beneficial effects that accrue from these and similar works of man's ingenuity.

Filtration

When the dam is completed and the valves closed, the water fills the lake: here the bulk of the suspended matter is deposited. Much finer matter, however, has to be removed mechanically, as no objectionable matter must be allowed to reach the consumer; therefore, on leaving the lake or river, the water is passed on to filter-beds, which consist of large concrete tanks, about 7 or 8 feet deep, the floors of which are covered with brick, laid so as to form a network of channels all over the bottom of the "bed." On the top of these bricks is placed 6 inches of coarse stone (say from $\frac{3}{4}$ to 2 inches in size). This is followed by 3 inches of finer material ($\frac{3}{4}$ to $\frac{3}{8}$ inch), 6 inches of still finer gravel ($\frac{3}{8}$ to $\frac{1}{8}$ inch), then about 15 inches of sand; on top of this a final layer of 6 inches of fine sand, 10 per cent. of which would pass through a screen having 4900 holes to the square inch. According to Mr C. H. Priestley, a bed thus constructed, 200 feet by 75 feet in area and 7¼ feet deep, would filter 1,000,000 gallons in twenty-four hours, allowing 2·78 gallons per superficial foot of filtering area per hour.

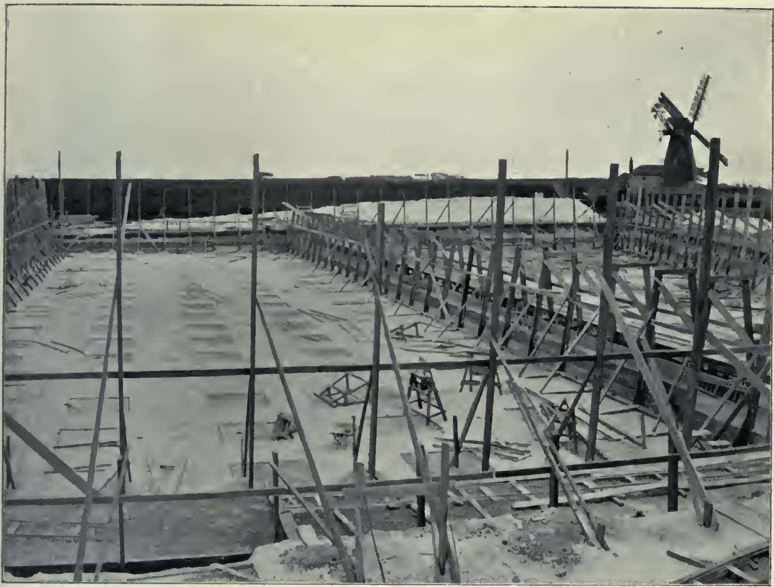
By percolation through these beds the remainder of the suspended matter is removed from the water and is retained in the sand, but we must remember that only the substances mechanically suspended are removed; matter in solution, or dissolved substances, are not removed by filtration, for these can only be eliminated by other methods.

From these beds the water passes on to the consumer, either by gravitation or, where the natural fall is not sufficient, by means of pumps.

When the filter-beds become foul from use, the water percolates more slowly and filtration is less perfect; the material of the bed is then thoroughly washed in machines constructed for the purpose, and when thoroughly cleansed it is used over again.

Covered Reservoirs

Although hard spring water and that from deep wells may be, and generally is, bright and clear, when exposed to the direct rays of sunlight it becomes covered with *confervoid* growth, which has a most objectionable appearance. That the sunlight is the chief offender is patent, for open reservoirs in winter will keep fairly free in this respect for many weeks; in summer, however, this growth will attain considerable prominence in a fortnight. It is to prevent this that "covered service reservoirs" are constructed; they are usually placed on elevated ground, and the pumps deliver the water into them; it then flows by gravitation all over the district to be supplied. These reservoirs are usually constructed to contain enough water for from seven to fourteen days' consumption.



A COVERED SERVICE RESERVOIR, 5,000,000 GALLONS CAPACITY, IN COURSE OF CONSTRUCTION.

THE IRON COLUMNS AND GIRDERS THAT SUPPORT THE ROOF, WITH THE CENTERING TO FORM THE ARCHES.

[*To face p.* 432.

The first work in the construction of a "covered service reservoir" is to remove the vegetable soil, and the ground is then excavated to the desired depth, and a solid bottom reached; the whole area is covered with concrete. The necessary timbering is erected to enable the massive walls to be carried up; heavy iron columns are then placed in rows, to secure the girders that are to carry the roof; wooden "centering" (in the form of arches) is then fixed between the girders and covered with concrete; the whole of the reservoir is then carefully coated with neat cement worked to a smooth surface, and made perfectly water-tight. The arches forming the roof also receive a similar coat on the outside to ensure that no water shall penetrate from above. The excavated earth is embanked round the sides. The vegetable soil previously referred to is spread on the top and sown with grass, thus protecting the water from changes of temperature. These reservoirs are, of course, fitted with necessary supply valves, washouts, overflows, etc., which it is not possible to describe in detail; also usually an electric water-level transmitter, which sends down to the pumping station either *positive* or *negative* currents to the electric receiver actuating an electric recorder, which registers on a roll of paper every variation in the depth of water, as it *rises* or *falls*, during the twenty-four hours.

Space will not admit of a description of the various kinds of artificial reservoirs constructed for the storing of water. But whether it be the ordinary open service reservoir, or the more expensive but more wholesome covered reservoir, or the large impounding reservoir, occupying an enormous valley, with powerful masonry dams for holding up the water, great engineering skill is necessary for their construction. Particular mention of the obstacles to be overcome and the various circumstances to be considered and the forces to be controlled would take too much of our space.

Badly constructed reservoirs have many times caused death and destruction through the waters breaking loose. We all know the old proverb, "Water is a good servant, but a bad master," as was proved in 1889, when Conemaugh Lake and reservoir (Pennsylvania, U.S.A.) burst. Johnstown and district was laid waste, and 9000 people perished.

Artificial Distribution of Water

This branch of engineering requires much skill and foresight, and applies exclusively to the manner in which the water is conducted from the reservoir to the consumers, some near, others many miles away, in valleys or on tops of hills, those requiring only a domestic supply, and those using water for factories, breweries, and works of all descriptions. The different sizes of mains must be calculated exactly so that all may be efficiently supplied, and with an eye to the probable increase in the demand in various parts of the district; in fact, for this work one should be blessed with second sight, so that he can foretell the quantity likely to be required at any time from thirty to fifty years ahead, for the first great expense of distribution must be planned with a view to its meeting the demand for many years to come.

This is difficult, for the unexpected usually happens; the district supposed to offer the best chances of development stands still, and a locality not expected to make rapid strides increases and flourishes beyond all anticipation. Thus "the best laid schemes o' mice and men gang aft agley." Shortly, the artificial distribution of water may be compared to the circulation of our blood; our throbbing, beating heart is the pumping engine, which sends the fluid through the larger arteries or trunk mains, at every point sending off branches to nourish or supply separate parts, to the extreme limits of the district, which may be compared to our fingers and toes, the limits of our anatomy. How all these things run in parallels, is strange; there is hardly anything in nature which does not point to some similarity in our very selves; indeed, we are fearfully and wonderfully made.

The first mention of an engine is supposed to refer to a heat engine, made in 130 B.C., by Hero of Alexandria, but no real progress was made until the sixteenth century.

The first mechanical contrivance possessing any ingenuity whatever, for raising water, was the Archimedean screw, named after its inventor Archimedes, a Greek physicist and geometrician, about the year 287 B.C.

Denis Papin produced a vacuum by condensation, under the piston of an engine, in 1690. Slavy patented a water-raising engine in 1698. Newcomen's engine for pumping water from mines was introduced in 1711.

James Watt, an instrument-maker of Glasgow, when repairing one of Newcomen's engines in 1763, was struck by the waste of fuel, and introduced the steam jacket, which is a means of keeping the cylinder warm by live steam. He was also the inventor of the modern condensing engine.

From this date improvements and fresh adaptations of the steam engine followed, the first railway engine, named the Rocket, being constructed by George Stephenson, in 1829.

The year 1802 saw the first steamboat being tried on the Firth of Clyde.

These improvements all culminate in the powerful Parsons turbine, which is now adopted for driving warships, liners, etc., and bids fair to supplant the reciprocating engine. But we must resume our story.

A full description of the various kinds of pumps used for raising water would be out of place in the present volume. Briefly, however, we have the suction pump (the common household pump), which only removes the atmospheric air or pressure from above the column of water in the pipe. If a perfect vacuum be created, the water will rise only to the height of about 32 or 33 feet, according to the height of the barometer: but the water rises only to a height in proportion to the power of the pump to create a vacuum. The efficiency of the suction pump, therefore, is limited.

The force-pump, however, will, as its name implies, force water to any distance and height, provided sufficient power is available.

The method by which we ascertain the amount of power required to raise a given amount of water from a well of certain depth in a given time, and pump it to a reservoir at a certain height situate at a certain distance, forms but one of the everyday problems that come before a water engineer, but a description of the calculations involved would hardly be of interest to the general reader.

In addition to the foregoing there are also centrifugal pumps, pulsometer pumps, and the air-lift pump. The last of these has no valve whatever, the water being raised to the surface by compressed air alone.

CHAPTER XIX

USE, ABUSE, AND WASTE

The Use of Water

"Flowing waters have not only power to wash out material stains, but they also clear away the cobwebs of the brain—the result of incessant work—and restore us to health and strength."—LORD AVEBURY.

IN the previous chapters we have closely followed water in its various forms: from its invisible flight from the surface of the ocean into atmosphere, its condensation, and the many forms in which it is returned for our benefit. In this chapter we will endeavour to trace a few of the important duties it fulfils.

The everyday domestic uses to which this marvellous and necessary fluid is put we will not discuss: its indispensability in this direction is patent to all. Its circulation through, and the amount of it contained in, the tissues of animals is also a matter of general knowledge; and that in one way or another, if we wish to keep in good health, we must consume about one twenty-fifth of our own weight of water per day, is sufficient proof of what a short time we could exist without this precious gift of water.

Some of my readers, however, may not be aware of the fact that men and animals generally can subsist for a longer period without food than without water.

There are, so far as I am aware, few exceptions to this rule.

The camel is, as we well know, designed by nature to do an enormous amount of work in arid deserts, covering many miles of parched sands under a heavy burden, with but little inconvenience from want of water. A camel has been known to travel 510 miles in forty days and only drink 6½ gallons of water on the journey, drinking 3 gallons on the thirty-second day and 3½ gallons on the fortieth day.

It has been stated that a camel has existed for two months without water.

The manner in which the vegetable kingdom relies almost exclusively on water for its life and propagation may also be passed over.

No doubt irrigation forms the most important work of water, and to its work in this manner we will devote some serious attention.

Irrigation

"The rivers of God are full of water; thou preparest their corn, for so thou providest for the earth."

Irrigation is the art of increasing the productiveness of soils by the artificial supply of water to them.

Here in England there are but few districts that do not receive an ample supply of water in the form of rain, and a serious drought is of rare occurrence.

Famine is usually associated with drought, or failure of crops from want of rain. One of the greatest famines of history occurred when the overflow of the Nile failed for seven successive years. This was about the year 1060. Two provinces of Egypt were wholly depopulated, and in another, half the inhabitants perished.

It is, however, stated that "the worst famines or periods of great scarcity recorded in Britain were in the years 272, 306 (Scotland), 310, 739, 823, 954 (lasting four years), 1087, 1193, 1251, 1315, 1335, 1353, 1438, 1565, 1748, 1795, 1801. Some of these were occasioned not by drought but by excess of rain."

Excess of rain has also contributed to the list of these disasters. Torrential rains destroy seeds and crops, and cause rivers and lakes to overflow their banks, which are not able to retain the abnormal quantity of water.

Water, again, in the form of hail, does incalculable harm to crops; but fortunately hailstorms are only local in their effects, rarely exceeding an area of 60 miles long by 6 miles in width, and usually of much smaller area.

Many parts of the world are not so blest; some periodically experience long droughts, and but for some system of irrigation, large tracts of land would become useless and go out of cultivation, which is in itself a great loss to mankind, as well as the famine and death which follow in the wake of such a catastrophe.

Darwin mentions the "gran seco" or the great drought at Buenos Ayres in 1827–1830, where at the lowest estimate a million head of cattle perished, and dust accumulated to such an extent as to obliterate all boundaries and landmarks, and people could not tell the limits of their estates.

It is in such regions as these that resort is had to irrigation, or the artificial means of watering the land by storing, diverting, and distributing the flood water of a river or rivers.

The primary conditions for successful irrigation are, therefore, a sufficient supply of water, and that at such an elevation as to admit of its being stored up in flood time, preparatory to being drawn off into the irrigation canal formed for this purpose.

The practice of irrigation has existed for many ages, both in India and in Egypt, where the remains of ancient systems have been discovered.

In Australia especially irrigation is greatly needed: the dreaded drought and loss of cattle and crops from want of water is only too well known.

"It is estimated," says a correspondent of the *Daily Telegraph* (24th April 1906), "by the U.S.A. Reclamation Service, that in the West some 50,000,000 acres could be won from the desert by irrigation. Of this area, about the size of England and Scotland together, 10,000,000 acres have already been rendered productive, at a cost of £18,000,000. This reclaimed area now yields every year harvest valued at £30,000,000, and supports a population of 2,000,000 souls. That would seem to be a fair investment. The difficulties of the problem in Australia are not greater than they seemed in the Far West. The crying want of the Southern Continent is water. Cannot the Australian people do something better with the waters of the Darling, the Lachlan, and the Murray, than pour them into the Southern Ocean?"

An article in the *Geographical Journal*, by Captain C. H. Buck, illustrates strikingly what may be done in tropical lands by irrigation. This contribution relates especially to the Punjab, where the rivers Chenab, Jhelam, Ravi, Beas, and Sutlej have all been tapped, and deserts turned into productive country. The Chenab irrigation canal serves 3,000,000 acres, and yields a net profit to the State of £450,000—a return of 23 per cent. on the capital cost. The crops raised are worth £4,000,000 sterling. The other works are similarly profitable. Some idea of the magnitude of these undertakings may be formed from the fact that the main line of the Chenab Canal is 250 feet wide, carries nearly 11 feet of water, and discharges 10,800 cubic feet per second—about fourteen times the quantity ordinarily discharged by the Thames at Richmond. The Ravi River sometimes runs short of water, whereas the Chenab has a surplus, and a work is designed which will feed the Ravi from the Chenab. By means of these schemes a large and prosperous population has been settled on what used to be waste lands, and famine in the Punjab is practically a thing of the past.

The Nile and the Assuan Dam

Egypt has been the scene of vast works of this description.

In 1843 French engineers commenced a great dam or barrage across the river Nile at Cairo, but the work was not completed.

Since the country came under British influence, this work has been completed, and so efficiently, that the summer flow is actually all drunk up by the land, and none goes on to the sea, the level of the river below Cairo being only the same as in the Mediterranean.

The White Nile rises in the great lakes of Central Africa (3800 feet above the sea, and about 2000 miles south of Cairo), viz. Victoria Nyanza, Albert Nyanza, and Albert Edward Nyanza. It is fed on its way northwards by the Gazelle and Sobat rivers, and joins at Khartoum the Blue Nile, which rises in Lake Dembea and the Abyssinian mountains. The river is then known as the Nile. At 200 miles north of Khartoum it is joined by its only tributary, the Atbara. The Nile enters Egypt at Assuan, 1125 miles north of Khartoum and 750 miles from the Mediterranean.

The water begins to rise about the end of May. In August and September it is in full flood, being charged with rich, fertilising mud, which the Atbara and the Blue Nile bring down from the Abyssinian hills, while the White Nile carries the decayed vegetation from the swamps of Fashoda.

The discharge of the river during this period rises from 14,000 cubic feet to 353,000 cubic feet per second.

The mud deposited by the Nile has been proved by analysis to consist of—

Water	·11
Carbon	·09
Oxide of iron	·06
Silica	·04
Carbonate of magnesia	·04
Carbonate of lime	·18
Alumina	·48
	1·00

The White Nile does not attain its maximum until a month later than the other two rivers.

There are two systems of irrigation in Egypt, basin irrigation and perennial irrigation. In the former case the Nile when in flood is turned on to the land, where the mud is deposited; the water covers the land to a depth of 5 feet for about forty days, and is then turned into the river again, and under this system one crop per year is obtained.

With the perennial system the land is irrigated all the year round, and two crops are obtained every year from this portion of the ground.

The Assuan Dam extends across the valley, as shown in the illustration. The waterway, when in flood, is 1530 yards wide, with a maximum depth of 56 feet, when the top water-level will be 348 feet above sea-level.

The storage capacity of this enormous reservoir is estimated at 37,612,000,000 cubic feet.

THE ASSUAN DAM ACROSS THE VALLEY OF THE NILE.

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To control this enormous amount of water and to empty the reservoir there are provided 180 large sluices fixed at four different levels.

The full length of this dam is 6400 feet. It is built principally of granite and cement, for which purpose 75,000 tons of the latter, made from the Chalk formation, to which such frequent reference has been made, were sent from England.

The excavations for the foundations of this dam had in places to be carried down five times deeper than was anticipated. This work was carried out in a most trying climate, the summer temperature (for three months) being from 108° F. to 115° F. in the shade, and at times as high a temperature as 120° F. was recorded, the mean temperature at night being 85° F.; and sometimes it did not fall below 100° F. at night.

On some days in June the thermometer in the sun registered 160° F., and no day during the month less than 140° F. There is, therefore, little wonder that cases of sunstroke, some fatal, were of daily occurrence among the men employed.

The work occupied 3½ years, and cost £2,450,000, or about £10 per million gallons of water impounded.

The benefit to the vast population consequent upon the construction of this dam has already been most apparent.

In the year 1907 the Nile was the lowest on record. This would have involved the death of thousands, for in past times a low Nile meant not only famine, but all the diseases that go hand in hand with starvation and unwholesome food: but this work of man's construction has changed all, and a low Nile now, if not producing plenty, at any rate no longer brings in its train misery, suffering, and starvation.

The Temple of Philæ

At first the dam was to have been of such height that the Temple of Philæ, situated on an island in the middle of the river, about 1 mile above the dam, would have been submerged, but under the existing scheme the water only rises to the floor of the temple.

A considerable amount of time, ingenuity, and money was expended in underpinning and strengthening the foundations of this temple, so that the submerging of the base should not cause its destruction.

It has, however, now been decided to raise the height of the dam by 7 metres, or about 22 feet. The raising of the existing dam was the only possible plan. No other suitable place for a dam could be found, which would give such enormous storage, although an exhaustive survey of the Nile valley from Wady-Halfa to Khartoum was made.

The quantity of water stored by the new dam will be 2¼ times greater than is impounded at present.

This additional water will irrigate about one million acres of land, at present untilled and unproductive, and it is estimated that the increase in the value of the cotton crop, made possible by this heightened dam, will be between £3,500,000 and £4,000,000 sterling annually.

The cost of adding these 22 feet to the dam will be £1,500,000, which figure includes the compensation to the inhabitants of Nubia whose lands will be submerged. The work will occupy six years.

The raising of this dam will further submerge the Philæ Temple, and it is with regret that we hear that it will be covered for about five months annually. Many opinions are given as to the effect of this submersion: it probably means eventual destruction.

Irrigation works are also contemplated, and will no doubt shortly be carried out, whereby the waters of the Gash will be utilised to enrich the plains in the neighbourhood of Kassala.

Extensive irrigation works have also been carried out in India. In Sinde 80 per cent., and in the North-West Provinces 32 per cent., of the cultivated area is irrigated.

The Ganges and Jumna Canal, opened in 1854, alone irrigates 3,000,000 acres. It has a main artery 525 miles long.

The Ganges, 200 miles from its mouth, spreads out, forming a mighty delta which, during the annual inundation, has the appearance of an immense sea: here hundreds of miles of rice-fields are submerged, the ears of grain only appearing on the surface.

For the irrigation of the Lombard Plain, 762,000 cubic feet of water per minute are drawn off by canals.

The water not only supplies moisture, but furnishes mineral constituents, etc., that it gathers on its journey from its source, and so manures as well as irrigates.

The river Orinoco, in South America, in the rainy season inundates vast plains, forming a large expanse of water as far as the eye can reach.

Referring to these and similar works of man, Hartwig says: "By planting or destroying woods, he is able to compel nature to a more equitable distribution of her gifts. In marshy and low countries he may remove the superfluous water by drainage, and increase the productiveness of arid plains by judicious irrigation. Thus man is the lord and master of the earth, but hitherto he has done but little to reap all the advantages he might have obtained from his dominion."

Canals

Canals are really artificial waterways, and form generally short routes for the passage of ships and barges bearing passengers or merchandise.

The most important of these is the Suez Canal, which connects the Mediterranean with the Red Sea, a distance of about 100 miles. It was begun in 1859 and finished in 1869. It has no locks. It is of great importance, and shortens the journey from London to Bombay by 4800 miles, for before it was constructed all vessels had to sail round the Cape of Good Hope.

Canals existed in Egypt before the Christian era. They are mentioned by Aristotle, Pliny, and others.

The Mahmoudieh, in Lower Egypt, connecting Alexandria with the Rosetta branch of the Nile, was dug under Mehemet Ali, and is 50 miles long by 100 feet broad: 12,000 labourers died in ten months while the work was in progress; this estimate of the reckless disregard of human life is, unfortunately, well known to be accurate.

The largest canal in the United States is 363 miles long, from Buffalo to Albany, connecting the Hudson with Lake Erie. It has seventy-two locks, and is carried over several large streams on stone aqueducts; it was opened in 1825, and cost £2,000,000.

There are also in America the St Lawrence Canal, which was made to avoid the rapids on the river of that name, 70 miles long; the Welland Canal, to avoid the Niagara Falls, 27 miles long; and St Mary's Canal, to complete the navigation of the St Lawrence to Lake Superior.

In Holland, where canals were constructed as early as the twelfth century, we have the great Ship Canal, connecting Amsterdam with the North Sea; also innumerable smaller canals.

The Imperial Canal, China, commenced in the thirteenth century, is said to pass over 2000 miles and to 41 cities.

In France there are 3000 miles of canals. In Germany the North Sea and Baltic Canal (Kiel), costing £8,000,000. The Ganges Canal, North India, already referred to, for irrigation and navigation, from Hardwar to Cawnpore, cost about £2,800,000.

In this country we have the Caledonian Canal, a waterway from Moray Firth to Loch Eil and the sea, passing through the great glen of Scotland, the whole length, including Lochs Ness, Oich, and Lochy, being 60 miles. There are twenty-seven locks, the highest of which is 95 feet above the sea. There is also the Manchester Ship Canal, which cost £15,000,000. In the British Isles there is a total length of canals of 3800 miles, the earliest being the Bridgewater Canal (1761–65), 38 miles long.

Locks enable canals to be made where geological conditions prevent the construction of a level waterway. Boats are transferred from one level to another by the opening, emptying, and filling of the locks, raising and lowering the water in them. Locks (on canals) were not invented until the fifteenth century.

Merchandise can be sent by water for the same amount of money at least fifteen to twenty times as far as by land.

What an interesting sight it is to see the ships ploughing their way, laden with the necessaries of life, to and from our shores. The tramp steamer, the worker of the busy hive (it has been called the "shuttle in the empire's loom"), coming and going year in and year out. The mighty modern ocean liner, exquisitely fitted, and arranged more like a palace than a ship. Mail-boats, with their thousands of sacks of correspondence, mostly letters of love and hope to friends abroad; linking together nations by bonds stronger than iron; by their speed practically bringing all corners of the earth close together, running with such regularity, seeming to defy the very elements, that their movements are timed and marked with great accuracy; considering the distance, more accurately than some railway trains.

Even in this age of steam we see here and there the tall, straight mast of some sailing vessel, whose sails and innumerable ropes remind us of the pre-steam period, when the oceans were dotted and our rivers crowded with these graceful but fast disappearing vessels.

May the time be far distant when they will have disappeared absolutely, for little do we realise what we owe to them in the past; 'twas in such vessels as these that the British sailor, by hardships, exposure, and hard work, became possessed of the mettle which made the nation what it is.

History repeats itself. What if the future should see these "white-winged clippers" again hold their own against steam, in the days when the world has learnt the price it pays for hurry, bustle, tear, and drive, and a slower pace in all is adopted for our national good.

Here we see the uses of water: borne on its bosom are the fruit, vegetables, meat, cattle, corn, timber, gold; but who could attempt to complete the list of what comes to us in this manner, or who could find words to express what we owe to the oceans and rivers for the comforts around us?

Power of Falling Water

"The work done against gravity in raising water-vapour to the height at which it condenses to the liquid state, as rain, is converted into potential energy, like a clock wound up before it has run down. The height to which a quantity of water is raised by the sun's heat is a measure of the dynamic power which the water can exert in its descent."—Dr H. R. Mill.

That part of mechanical science which has to do with the various means of raising, conducting, confining or applying water as a mechanical power is called hydraulics.

The word power may be used in a variety of senses: it is used here as defining a capacity for work. Wind and water were, without doubt, the first mechanical powers used, followed by heat derived from the combustion of wood, coal, oil, and gas, steam, and electricity.

Man's control of water is of great and ever-increasing importance; great strides in this branch of engineering have been made since our ancestors erected the crude watermill as a means of replacing animal and manual labour.

The idea of converting the whole of the power of falling water into motive power was first suggested to a solicitor while fishing near an old watermill in Dent Dale in Yorkshire, where the amount of power wasted in this manner attracted his attention, and in it he found a matter worthy of study. He made a series of experiments, and in 1845 he gave a lecture at Newcastle-on-Tyne on "The employment of a column of water as a motive power for propelling machinery."

This solicitor was no other than the renowned Lord Armstrong, of the famous gun-works at Elswick, and his experiments resulted in the invention of the hydraulic crane and other machinery whose motive power is derived directly from water.

Speaking generally, the power of waterfalls is universally wasted, though of recent years a considerable increase in the employment of this force has taken place, chiefly in connection with the production of electrical energy. The reason for this is plain: many of the most powerful sources of this description are hundreds of miles from the locality where the energy could be utilised, but distance presents few difficulties to the transfer of the electric current; theoretically there is no limit to the distance to which it may be transmitted.

Tramways are being worked at Oakland in California by power developed 140 miles away.

The Californian Gas and Electric Company are also supplying current at a distance of 350 miles. This is the greatest distance yet traversed; here the voltage is 100,000.

On 19th November 1906 electrical energy equal to 40,000 h.p., generated at Niagara, was delivered at Toronto, the distance being 80 miles.

A far greater undertaking, however, is in course of construction, whereby the energy of the Victoria Falls on the Zambesi shall be transmitted electrically to the goldfields of the Witwatersrand, 600 miles away, by which means a saving in the cost of working the mines of about a million pounds annually will be effected. The voltage will probably approach 150,000, transmitted by cables suspended from steel towers 1000 feet apart.

The force exerted by falling water depends upon two factors, the quantity falling and the height of the fall or "head." The effective energy equals the number of gallons per minute flowing over the fall, × 10, which gives the number of pounds of water per minute; multiply this by the vertical height of the fall in feet, and we have the energy in foot-lbs.; this, divided by 33,000, will be the horse-power of the waterfall.

One horse-power is equal to 33,000 foot-lbs. per minute. This factor was first used by James Watt as a means of comparing the power of his various engines, viz. 33,000 lbs. raised 1 foot per minute, or 1 lb. raised 33,000 feet per minute, or 1000 lbs. raised 33 feet in one minute, or any number of pounds raised any number of feet, the two numbers multiplied together equalling 33,000 per minute. If the calculation be per second, we must divide 33,000 by 60 = 550 foot-lbs. per second per horse-power.

There are several methods of calculating the available horse-power of a waterfall.

If the amount of water be given in cubic feet per minute, this must be reduced to pounds by multiplying it by 62·28, the weight of a cubic foot; for example, if 5000 cubic feet are falling per minute over a fall of 150 feet high, the power would be computed in the following manner:—

$$\frac{\overset{\text{Cubic feet}}{5000} \times \overset{\text{lbs.}}{62{\cdot}28} \times \overset{\text{feet.}}{150}}{33{\cdot}000} = 1415 \text{ H.P.}$$

Some, however, adopt the following simple formula (cubic feet per minute × height of fall × ·001887):—

$$\overset{\text{Cubic feet.}}{5000} \times 150 \times {\cdot}001887 = 1415 \text{ H.P.}$$

Thus we find that Niagara is at present wasting an available energy of over 9,000,000 h.p., and the Victoria Falls 35,000,000 h.p.

It may be more easily remembered if we state that 530 cubic feet per minute gives 1 h.p. per foot of fall.

The practical available energy is, however, considered to be 80 per cent. of the theoretical amount. A good turbine will develop this, whereas a steam engine only gives us about 25 per cent. return in actual work; this proves falling water to be by far the cheapest source of power known.

It is stated that the cost of the power generated at Niagara Falls is only 0·24d. (pence) per horse-power hour.

As far as the Niagara Falls are concerned, charters have been granted recently to various companies for the development of about 900,000 additional h.p. The average water-power of this fall is said to be equal to 5,000,000 h.p., with a minimum of 4,000,000 h.p. It is also calculated that when all existing and contemplated works are in full operation, 41 per cent. of the minimum discharge of the river will be utilized. Here we have 1,000,000 tons of water per hour falling 160 feet, so the present and projected plants should produce a total of 1,000,000 h.p. It is contemplated that no visible effect on the beautiful fall will be apparent.

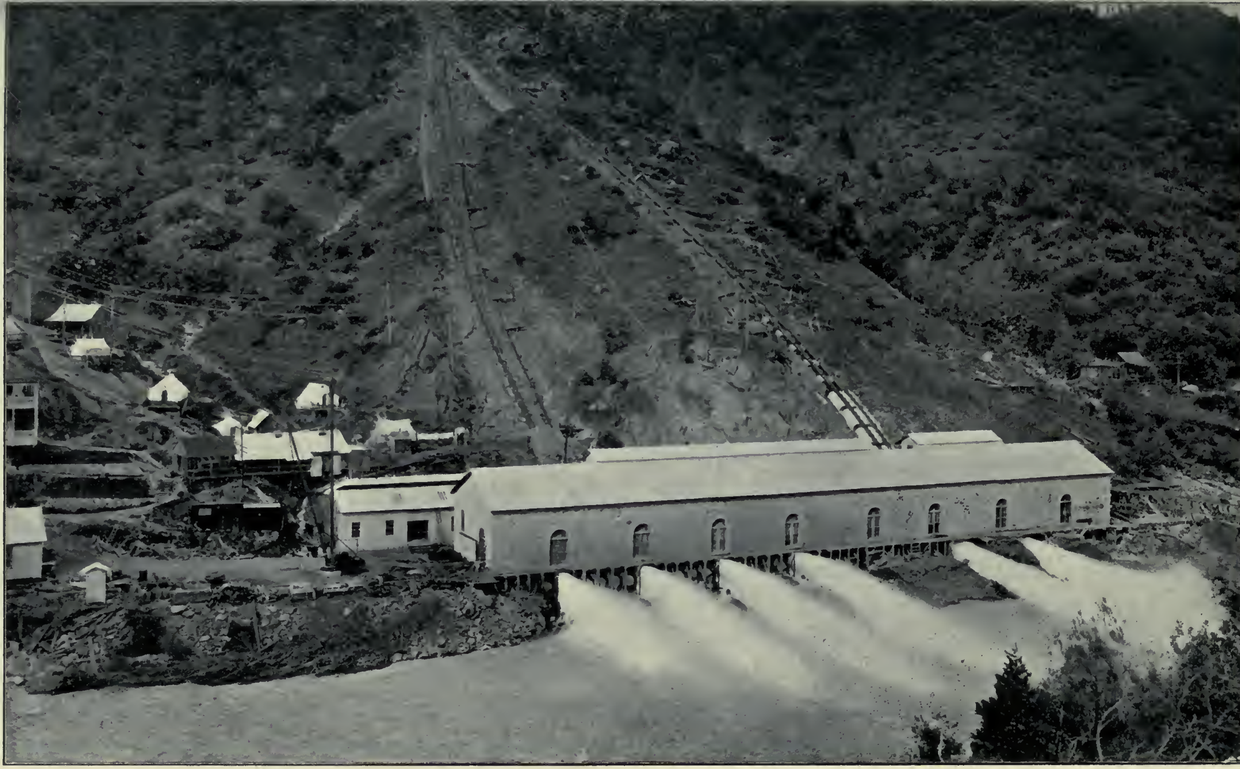
Enormous as these figures are, they are completely dwarfed by the Victoria Falls on the Zambesi, already described. The volume is less than that coming from the Niagara, but the fall is considerably higher. Here even in the driest seasons, when the flow is least, 500,000 h.p. can be developed, and in this fall we find running to waste a power equal to seven Niagaras, or between 35,000,000 h.p. and 45,000,000 h.p. It is, however, proposed by the Chartered Company to harness the Victoria Falls and distribute electrical energy for industrial purposes.

Who can foretell the far-reaching results of such an undertaking? Here is power sufficient to supply all Rhodesia with light and power for many years. This in itself is sufficient to revolutionise the present conditions of life in British Central Africa.

New Zealand is also taking up the consideration of similar works, for it is estimated that there is sufficient power available in her waterfalls to do all the transport work and lighting, and to drive all the factories in the Colony.

At Geneva it is proposed to develop 630,000 h.p. by the aid of falling water.

"In California, the water of the Sierra Nevada range, at altitudes up to 9000 feet, covering an area of 550 square miles, is impounded and carried by powerful steel mains to the power-house. With a head of 1500 feet, this altitude would develop a pressure of 645 lbs. per square inch, a pressure that only the initiated can fully grasp.



THE GREAT COLGATE POWER HOUSE IN THE SIERRA NEVADA MOUNTAINS OF CALIFORNIA.

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"Here it rotates enormous turbines, and they in turn rotate dynamos, dispensing power and light over an area of 26,000 square miles, driving tram-cars, and illumining the towns 200 miles distant" (*Sphere*).

Rochester, U.S.A., owes a great part of its prosperity to the power furnished by the Falls of Genesee, which are situated within the city limits; this power is principally employed in driving flour-mills and other industrial establishments which exist on a great scale.

"A dam has lately been erected across the Eifel valley (Aix-la-Chapelle district). It is a semicircular dam 180 feet high, forming an artificial lake about 7 miles long and 150 feet deep, and holding up about 7,500,000,000 gallons of water. This water will be utilised in driving eight turbines of 2000 h.p., which will supply electric light and power to the factories and towns: 35,000 volts will be available for the purpose" (*Sphere*).

A large tangential water-wheel, with a capacity of 13,000 h.p., which has been built for California, when operated under an effective head of 660 feet, delivers 8500 h.p. It is intended eventually to increase the pressure by delivering the water through a new pipe-line under an effective head of 1050 feet. This will bring the output of the unit up to the full capacity of the water-wheel, viz. 13,000 h.p., and make it the most powerful tangential hydro-electric unit in existence. It will operate at a speed of 300 revolutions per minute, and will drive a 5500 kilowatt generator.

Queensland is awaking to the value of its water power. A scheme is described in the *British Australasian* for utilising the Barron River Falls, near Cairns, Queensland, to generate electric power. The river has a fall of 700 feet, and pours over the precipice a large volume of water. Cairns is situated in a rich mineral country, and the power generated at the falls can be used in the treatment of copper, tin, wolfram, and other ores, found within a wide area stretching 150 miles inland.

The cataract on the river Yguassu is situated in the wild and uninhabited regions on the boundary of Brazil and the Argentine Republic. It is stated that the amount of water coming over this fall (15,000 feet wide, 210 feet high) is 50 per cent. more than that of Niagara; but here there is little chance of its power being converted to man's use.

In reference to our waterfalls at home, the following extract from Science Notes of the *Daily Telegraph* gives us a good idea of what is contemplated:—

"Whoever possesses a mountain, let him see if he cannot form a lake or loch somewhere on its slope and so produce a waterfall. Throughout the world, falling water —according to a paper read before the British Association by Mr Campbell Swinton, electrical engineer—at present yields to man's use an amount of energy equal to 1,483,390 h.p., of which total Great Britain figures for the insignificant quota of 11,906 h.p. But more is going to be done. The British Aluminium Company gets 7000 h.p. from the Falls of Foyers, and they expect presently to procure 17,000 h.p. from Loch Leven. The North Wales Electrical Power Company are about to tap Lake Llydaw, on Snowdon, and hope to obtain 8200 h.p. for every working day of nine hours. Finally, the Scotch Water Power Syndicate is peering round the land of the mountain and the flood in quest of waters that they can imprison at lofty levels, and so generate electric power. From Loch Sloy, 757 feet above Loch Lomond, they are going to get 6000 h.p., and at Ardlui, higher up, they propose to get further energy. All around Wales, Cumberland, Westmoreland, Devon, and Cornwall, as well as in stern and

IN A COOL CORNER OF MY GARDEN.

THE AUTHOR MEASURING THE RAINFALL.

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wild Caledonia, local authorities, as well as owners and syndicates, should be on the lookout. Even a modest stream that drops several hundred feet may be a source of power."

When we consider the endless centuries that these powers have been running to waste, we can but admire nature's sublime extravagance, or, as expressed by Sir Robert Ball, nature's boundless prodigality.

Hydraulic Rams, etc.

The use of water in the working of hydraulic machines is most interesting.

Water-power is silent and strong, and is capable of being developed up to a working pressure equal to 14,000 tons, or, on the other hand, to that only sufficient to crack a nut.

We have hydraulic rams, lifts, engines, cranes, swing-bridges, railway turn-tables, movable railway platforms, grids for raising ships above water, and trains, complete with engines, to higher levels; presses used in the manufacture of oils, sugar, and numerous other industries. By hydraulic power we bend armour plates for ships, do all kinds of punching, shearing, and riveting of iron and steel plates; cutting and bending rails and girders of steel, stamping and forging; opening and closing enormous dock-gates, and raising the massive cantilevers of the Tower Bridge.

When launching one of our mighty battle-ships, it is the hydraulic ram that gives it the first thrust out into the waters. There is no work water will not do under the influence of and by the aid of man's ingenuity.

We have also the floating dock which, when emptied, rises, lifting right out of the water our largest ironclads, fully equipped for war, and, as gently, lowering these thousands of tons back again into the sea.

Some hydraulic appliances use but little water; others, of course, require a considerable quantity. Up to the present time a turbine, recently fixed in Canada, is the greatest consumer, 400,000 gallons of water per minute flowing through its inlet, which is 10 feet in diameter.

The hydraulic ram is simply a small piston which forces water into a cylinder of larger area. There is practically no limit to the power that can be developed in this way, the governing factor being the ability of the cylinder to withstand the enormous strain developed.

If the end of a small tube, say ⅓ of an inch diameter and 46 feet long, be inserted upright into a closed cask full of water, and sufficient water to fill the tube (say 2 lbs.) be poured in at the top, this small quantity of water will transmit a pressure of 20 lbs. per square inch all over the 2000 square inches of the cask, giving a pressure of 40,000 lbs. on the cask, and will quickly burst it.

This simple example of the pressure exerted by water, with a height of only 46 feet, will give the reader an idea of the care that must be taken in the distribution of water to a town from a reservoir at a considerable altitude.

In the town of Chatham, one reservoir, from which a part of the district is supplied, is over 460 feet above sea-level, and in some parts of the district the pumping mains, service-pipes, valves, etc., have to withstand a pressure of about 170 lbs. per square inch.

The manufacturing uses to which water is put are too numerous to attempt mentioning, and the domestic use of water is well known.

We should not, however, forget the many uses to which water in the form of ice is put, principally for preserving food. Enormous quantities are shipped from the Nor-

THE CASCADES AND FOUNTAINS OF THE ROYAL PALACE OF CASERTA, NEAR NAPLES.

Mrs Aubrey Le Blond.

THE BATH OF VENUS.

(To illustrate the ornamental uses of water.)

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wegian and other lakes; from Dröbak, near Christiania, the amount shipped is said to be 150,000 tons per annum.

The ice is cut into large blocks. In some places, where the lakes are at a distance from the sea and at sufficient altitudes, rough railways are constructed; the ice then travels by gravitation down these lines direct to the ship.

Artificial ice is also largely manufactured by various processes, but not at a sufficiently remunerative price to prevent the import of the natural article.

We can do little more than record several other uses of water, including the peculiar property it possesses for absorbing heat, making it an ideal medium for heating our homes and conservatories. The work it performs by the tides and ocean currents, in the shipping world, can only be mentioned here; we can also only refer shortly to the useful and beautiful part water plays in ornamental gardens and beautiful lakes, fountains, and artificial cascades.

We cannot all have beautiful fountains, and few of us can boast of one so fine as that in the accompanying picture, but many who do not might possess a tiny pond, a little spurting, refreshing jet of water in a snug corner of their gardens, tastefully surrounded by pieces of old rock, with ferns and creepers running riot over them. Water plants, even small pieces, will thrive and bloom; the *Aponogeton distachyon* (Cape fragrant water-lily) will display its fragrant, graceful, curious-shaped flower, resembling the open mouth of a shark exposing its jagged teeth.

Other equally beautiful water-flowers will in their turn put forth bloom; even the despised duck-weed (*Lemna minor*), which many consider only fit to be destroyed, will greatly interest: a few pieces put in will quickly cover the water with a bright green carpet, most refreshing to the eyes.

Then the great variety of animal life that will exist in even a tiny pond, even if no more than 4 feet in diameter, is astounding. Such a pond will give scope for the enlargement of our knowledge of water plants and aquatic animals at our very door, thus increasing both our contentment and our intelligence.

Only those who have experienced it can form an idea of the comfort and serenity to be obtained, after a bustling day of business, by sitting beside such a tiny patch of water and listening to the gentle dropping from a tiny jet, perhaps no larger than a darning needle.

Hugh Miller, in giving his advice to young men desirous of adding to the amount of their enjoyment, says: "Do not seek happiness in what is misnamed pleasure; seek it rather in what is termed study. Keep your conscience clear, your curiosity fresh, and embrace every opportunity of cultivating your minds. Learn to make use of your eyes; the commonest things are worth looking at. If you are jealous of others (referring to those better off), there is only one way in which your jealousy of them can be well directed: do not let them get ahead of you in intelligence."

Sports and Pastimes

Our story would not be complete should we omit all reference to the inestimable boon, the tonic to muscle and brain, consequent upon games and exercises, especially those intimately connected with water—yachting, rowing, swimming, ski-ing, skating, sleighing, and even snowballing, and many other sports.

Referring to the benefits to be derived from the study of nature in the Alps, Tyndall writes: "The glaciers and mountains have been to me well-springs of life and joy. They have given me royal pictures and memories that

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SKATING ON A SWISS LAKE.

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cannot fade. They have made me feel in all my fibres the blessedness of perfect manhood, causing mind, and soul, and body to work together with a harmony and strength unqualified by infirmity or ennui."

The opportunity must not be missed to refer to swimming. How few, comparatively, know the pleasure of swimming! Of those that do, the greater part are fair-weather swimmers: conditions similar to those obtaining in Hampstead ponds are to them ideal.

One cannot but notice, at the seaside, first, how few bathe; of these again, how few swim. Many only clutch the ropes of the bathing machines and bob up and down with blue and cold fingers and a colder body. Go down to the beach on a "choppy" morning; the bathers can be counted on the fingers of one hand! We hear continually of swimming lessons and prizes, but surely we are on a wrong tack. The main idea in learning to swim is to save your own or another's life in an emergency. This is more likely to occur at sea and in rough weather, when all our fancy, smooth-water efforts will not avail much. Prizes for swimming should be given for the best work in the open sea, not under ideal conditions: a prize thus gained is one to be proud of. Young folks should be taught how to enter the sea safely by diving through the breakers, and how to avoid being hurled by them on to the beach. The swimming usually taught amounts to little more than a healthful exercise.

Especially at the seaside resorts, one cannot but notice the utter absence that exists of any form of encouragement or attempt to get the mass of the visitors to bathe; the energy of "the powers that be" seems rather to put a premium on bathing, especially beach-bathing; any paltry excuse is sufficient for them to put obstacles in the way and discourage the bather.

Surely, as a national good, people should be given every encouragement to bathe, instead of driving them into the beastly "machines" to extort a sixpence or ninepence from those who care to pay. But the existing conditions keep thousands from indulging in the pleasure of a swim. Why should a father, with three or four boys, be mulcted in twelve or fourteen shillings per week for a bathe in the glorious ocean?

If the local rates are at times used for purchase of pianos, for children to march to in dusty schoolrooms, those who are fortunately able to go to the seaside in their holidays should not be forced to stand, looking with longing eyes at the beautiful sea, because they do not possess the sixpence to admit them to a musty bathing machine!

It cannot be denied that the rivers and seas were given by the same good God that gave the air; surely they should be as free, and as a national possession should not be grasped by individuals; and the foreshore, where the geographical and geological conditions are such as to supply a national want, should be free for national use.

Of all sports and pastimes, none can eclipse aquatic sports in their benefit to the human frame: skating, mountaineering, and snow games come in a good second; cricket, football, and the similar games come third, at least in our story of water. But we must not overlook the educational advantage of the combination games, such as cricket and football; their value in the teaching of self-denial, discipline, co-operation, and *esprit de corps*, as well as individual excellence, is very great indeed.

Waste of Water

We will now proceed to a subject of great interest to those responsible for the water supply of a town, but not

Mrs Aubrey Le Blond.

TOBOGGANING, DAVOS PLATZ.

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generally of interest to the ordinary consumer, viz. the waste of water.

One of the principal causes of waste is the inevitable wearing out of the mains and pipes; sometimes the water escapes underground for considerable periods. There are, however, means of locating these leaks, and if careful records of consumption be kept, the authorities are soon aware when a pipe has given way, and remedy the defect.

Waste of Water by Frost

The loss of water when a thaw succeeds a severe frost is enormous.

The accompanying diagram is compiled from the register of an electrical recorder.

The line A B C represents the amount of water going out of a large reservoir, to supply a population of about 100,000 persons.

Each separate step or drop in the line indicates that 1 inch of water has gone out of the reservoir. The amount of water is not given in gallons, as this is unnecessary for our purpose, the idea being to show only comparative differences, not definite quantities.

The line A B C, which was recorded on the third day of a rather sharp frost, shows that at 6 A.M. there was 20 feet 8 inches of water (*see* large figures in centre), while twenty-four hours later the surface had fallen to 12 feet 6 inches (C).

The following day the atmospheric conditions remained the same until 6 P.M. (B), when the thaw set in. This was immediately apparent, the electrical recorder registering a more rapid loss, caused by the bursting of a considerable number of pipes about the district; the line which, if the thaw had not set in, would have fallen to about point (C) as on the previous day's record, in the twelve hours 6 P.M. to 6 A.M. fell nearly 4½ feet lower (B D). This enormous loss in only twelve hours will give an idea of what happens after a more severe frost. The work of repairing all defects takes a considerable time, and it is found that on the termination of winter a considerable period elapses before the district regains its normal state, although the district is thoroughly inspected at the termination of these conditions, and every care is taken to see that all repairs are executed as quickly as possible.

Waste from this cause, serious as it is, is only periodical; it is the waste that goes on all the year round, through the ignorance or neglect (generally both) of the consumer—to this cause principally are due the disgraceful records of some water boards.

The daily consumption of water per head in some towns has even reached 50, 60, and 70 gallons, and this where the population is not noted for its cleanliness; and the writer's experience is that the dirtier the family, the less the use and the greater the waste of water.

In school the young are taught to utilise carefully even waste food, but I have never heard of any instruction being given as to the seriousness of wasting water.

If we look carefully into the same diagram, line A B C, we shall see that from 11 P.M. to 5 A.M. there is a loss of 12 inches (these conditions are normal) for the period of six hours of midnight, when there should be but little water consumed. Presuming half only (say 6 inches) of this is waste, we must remember it is only a quarter of the day of twenty-four hours, and no doubt the same waste continues for the remaining three-quarters of the day, and is included in the first part of the line; we therefore have $4 \times 6 = 24$ inches of water from the reservoir per day running to waste.

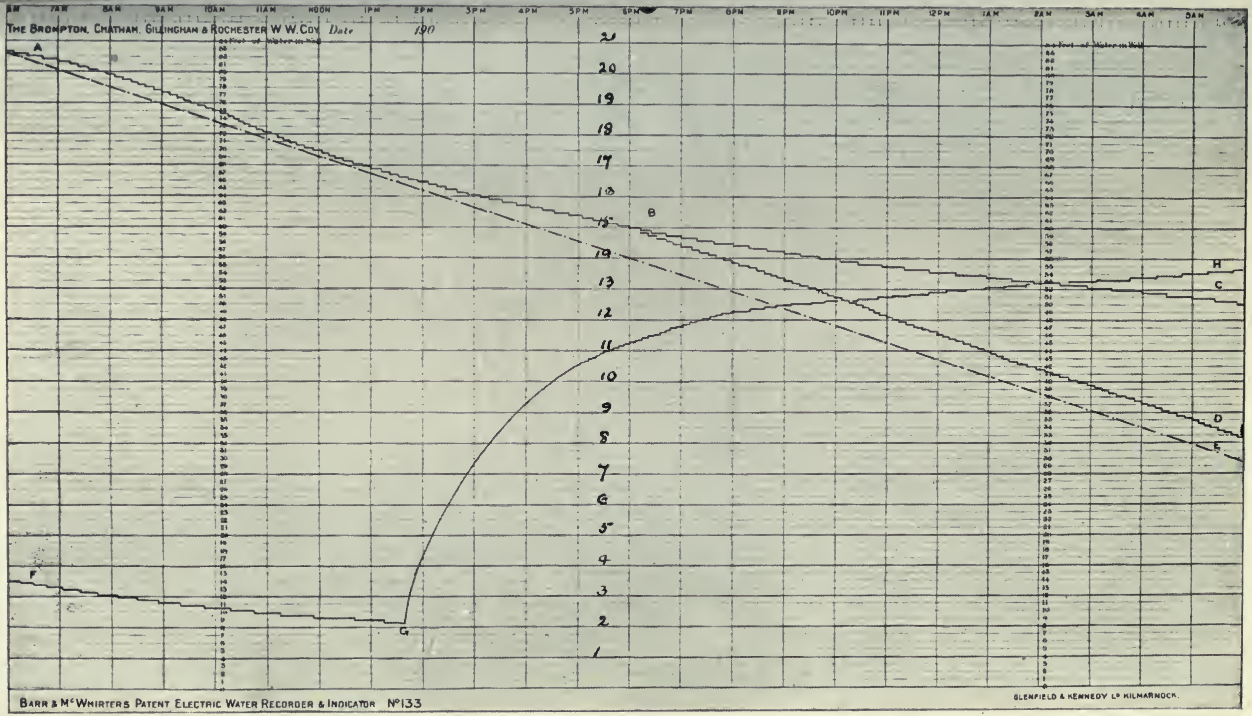

DIAGRAM FROM ELECTRICAL WATER-LEVEL RECORDING APPARATUS.

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Line A B C, 20 feet 8 inches to 12 feet 6 inches, recording a full day's consumption, indicates the withdrawal of, say, 8 feet of water from the reservoir, out of which 2 feet, or 25 per cent. at least, is waste; so, roughly, in every four days water enough for one day is wasted. No further remarks of mine are necessary to show the seriousness of this. I can also assure the reader that these figures are considered favourable and satisfactory compared with the experience of some water boards, and there is no attempt at exaggeration.

Before leaving this diagram, it is of interest to note that after a succession of hot, dry days the consumption would, roughly, follow the line A E, which will be seen to run parallel with that caused by thaw after a frost (B to D), proving that as far as consumption of water is concerned a severe winter is as bad as, in fact worse than, a dry summer; for in summer, on the fall of the first shower, the excessive demand or use ceases, and a normal state of supply immediately ensues: this is not so in winter.

The other line, F G H, is recorded by the well transmitter, to which the smaller figures on either side of the diagram refer.

It shows that after incessant pumping the water in the well was reduced from, say, 85 feet to 8½ feet (G); pumping was discontinued at 1.40 P.M.; the water rose in the well as shown, at first very rapidly, slowing down towards night, and at the end of 16½ hours' rest it had risen to 54½ feet (H).

It is from similar records that the diagram (Strength of Springs) was compiled, which shows conclusively that the deeper the well is below the line of saturation (generally) the greater the amount of water; the strength of the spring being on the bottom, as is apparent from the curve on the diagram.

Lavish Use or Abuse of Water

The term waste does not mean even lavish use, of which there is no doubt a considerable amount, for I have seen a person use, in the preparation for the table of two cabbages and a score of small potatoes, enough water to wash or rather bathe a whole family.

In my own home I have a fountain, which is a source of great pleasure to me. I need hardly say that, although the water is not metered, and I do not pay for it, it is periodically turned on for a short time, for the pleasure of myself or friends or for the benefit of my fishes ; but as soon as my friends cease admiring it, it is turned down, and is never allowed to play unseen or unnecessarily.

I mention this, for it is a common thing for fountains to be left continually running, day and night, almost perpetually. I have seen lawn-sprinklers busily at work on a rainy day ; and the consumer consoles himself that he is paying a small sum per quarter for the privilege (?) of wanton waste !

The mention of the sprinkler reminds me of a funny story in connection with this useful appliance. A friend, who loved the cool appearance of fresh green grass, was, one hot day last summer, showing his sprinkler to a lady, who thought it very clever, but said, on turning away : "But doesn't it make the lawn very damp ?"

Domestic Waste

There is also the individual with a mania for "flushing the drains," who pulls up the lever of the closet, and in an ingenious manner puts a clothes-peg on the rod so that it shall pass water continually, or drives a nail into the wall at a convenient spot, hooks the waste-preventer chain over it, to gain the same end, goes off for a fortnight's holiday, feeling sure that the drains will be clean, etc., on his return (forgetting it may choke them and perhaps flood the place). These are facts, and unfortunately there are innumerable similar ingenious contrivances all tending in the same direction.

There is also our friend who, when washing a carriage, puts the hose-pipe into the pail, argues with his mate about the Liberal majority, the Licensing Bill, free trade, or any other topic likely to lead to the final drink (not of *water*) which usually clenches most arguments. He returns in perhaps one hour, and proceeds to complete the washing of the carriage. The water has been pouring down the drain all this time, but what does it matter? his master pays so many shillings per quarter for the use of the water; he evidently thinks it includes the waste, or he would not permit it.

Similar cases are innumerable; I will trouble the reader with only one other instance in conclusion.

A poor woman had heard the water rushing down a drain in her yard, from a broken pipe, for over four months. At last the channel by which it had been escaping got filled up, and the water began to rise in her scullery floor. It had wet a half-worn-out door-mat, worth only a few pence, and this serious misfortune led her to inform the water authorities of the trouble she was in. This broken pipe had probably been wasting at least 10,000 gallons a day for four months, or about 1,000,000 gallons of water!

It will be seen from these instances that much waste is the outcome of sheer thoughtlessness or ignorance. Nature has supplied us bountifully with water, but our duty is, irrespective of what we pay, to appreciate the gift at its true worth, and not to waste it.

We have learned something of the difficulties that have to be overcome in providing water, or rather in obtaining, pumping, and distributing it, and this should tend to make us more careful in its use.

CHAPTER XX

LESSONS FROM NATURE

"Does it not seem to you that there must surely be many things worth looking at earnestly, and thinking over earnestly, in a world like this, about the making of the least part whereof God employed ages and ages, further back than wisdom can guess, or imagination picture?

"Happy truly is the naturalist. He has no time for melancholy dreams. The earth becomes to him transparent; everywhere he sees significances, harmonies, laws, chains of cause and effect endlessly interlinked, which draw him out of the narrow sphere of self-interest and self-pleasing into a pure and wholesome region of solemn joy and wonder."—CHARLES KINGSLEY (*Wonders of the Shore*).

NEXT to the study of the distant worlds which engage the contemplation of the astronomer, our highest aim should be the study of the world in which we live, and the many evolutions through which it has passed; these can only be traced by diligent research and patient observation. In this manner the geologist deciphers the Rosetta stone of our globe, which unfolds such an abundance of evidence of the goodness of God and the marvellous perfection of His works.

We have not here discussed the discrepancy between the various periods given and the Biblical account of the wonders of the Creation as in the book of Genesis: that has been done by many able scholars.

No doubt millions of years elapsed between that period referred to in the words, "In the beginning God created the heaven and the earth," and the first day of the Creation, in which "God said, Let there be light."

The study of geology will prove, rather than disprove, the Biblical story of the Creation, if we only look broadly into the subject.

"There is no employment more ennobling to man and his intellect than to trace the evidences of design and purpose in the Creator, which are visible in all parts of the Creation. Hence, to him who studies the physical relations of earth, sea, and air, the atmosphere is something more than the shoreless ocean, at the bottom of which he creeps along" (Maury).

In the present study of water the reader will have seen at least many of the wonders worked by its agency.

The subject is so vast—here we have but touched the fringe of it—we can hardly take up any book, periodical, or even newspaper, without finding something in connection with this most interesting subject.

The first point to be considered, as well as our knowledge permits, was the manner in which the world was created, for beyond this we cannot go: our finite minds, our power of comprehension, must stop there, be we ever so learned.

We have seen that our earth is but one of a little family, and this family one of innumerable families, for we are told by Dr Mill that "100,000,000 stars or suns have been proved to exist, and still there is no end."

> "An infinite of space,
> With infinite of lucid orbs replete:
>
> In motion all, yet what profound repose!
> What fervid action, yet no noise! as awed
> To silence by the presence of their God."

Darwin, referring to space, in which these countless worlds revolve, states: "The blue sky tells us there is a heaven,—a something beyond the clouds above our heads."

We have learned that meteorites by the million are daily burning themselves into dust in their impetuous passage through our atmosphere. And why? This dust is now proved to be absolutely essential to the formation of atmospheric precipitants in the form of rain, etc.

We have also seen how water first comes to be upon the surface of the earth and in the atmosphere. How it forms clouds, condenses and falls as rain or snow; how it becomes impure; its influence on vegetation and life; its composition and properties.

"I have watched," says Professor Tyndall, "clouds forming and melting and massing themselves together. It was nature's language addressed to the intellect." He writes elsewhere on the same subject: "The clouds were very grand; some seemed to hold thunder in their breasts, those at a distance lay like angels sleeping on the wing."

If acknowledged clever, scientific men can draw inspiration and find an education in nature's works, what a grand opportunity presents itself to us, for—

> "He who through nature's various walk surveys
> The good and fair her faultless line pourtrays,
> Whose mind, profaned by no unhallowed guest,
> Culls from the crowd the purest and the best."
>
> ROGERS.

We have also seen the influence of water on, and the part it plays in, natural phenomena; its beauty in the various forms it takes; the many points of interest that surround it when it takes the form of ice, as in glaciers, etc.

It is equally interesting to us, as we see it in springs and streams, rivers and lakes, and in the ocean:

> "The earth with its store of wonders untold,
> Almighty, Thy power hath founded of old;
> Hath 'stablish'd it fast by a changeless decree,
> And round it hath cast, like a mantle, the sea."

Reference has also been made to the action of water in conjunction with the earth's internal heat, causing volcanic

Mrs Aubrey Le Blond.

THE VALLEY OF CELERINA FROM ST MORITZ.

(The loveliest scene in the Engadine.)

movements of subsidence as well as of elevation, also its work of disintegration and reconstruction.

"The general inference seems to be that there have been long periods of subsidence during which strata were settled in shallow seas, these being followed by periods of compression and upheaval. The crust was then buckled into hills and mountains. In Britain these movements took place long ago, but in other parts of the world mountain ranges have been built up of recent strata, so that we have cause to wonder that the internal forces of the globe have left us quiet so long, not to imagine that those forces have ceased to exist" (Aubrey Strahan, F.R.S.).

It is equally interesting to note its work both in nature and in the service of man. If all these wonders can be traced in connection with water, what a field is open to us in other directions, for nature abounds with marvellous works!

By the study of nature is implied not only "things as created and existing," but the tracing and following these things through the changes that they undergo, noting their causes and effects, for, as Glanville remarks, "we cannot know anything of nature but by an analysis of it to its true initial causes; and till we know the first springs of natural motions, we are still but ignorants."

Sir Oliver Lodge says: "Every object we come across, even a stone, raises unanswerable questions: how came it into existence? Take a piece of sandstone, for instance; what is it? Compact sand pressed together. What was sand? Fragments of previous rock ground to powder. That rock was therefore compacted sand, and that was compound of previous rock.

"The earth has gone through long preparation for man," and in this sense Sir Oliver considered that the doctrine of evolution had a religious aspect.

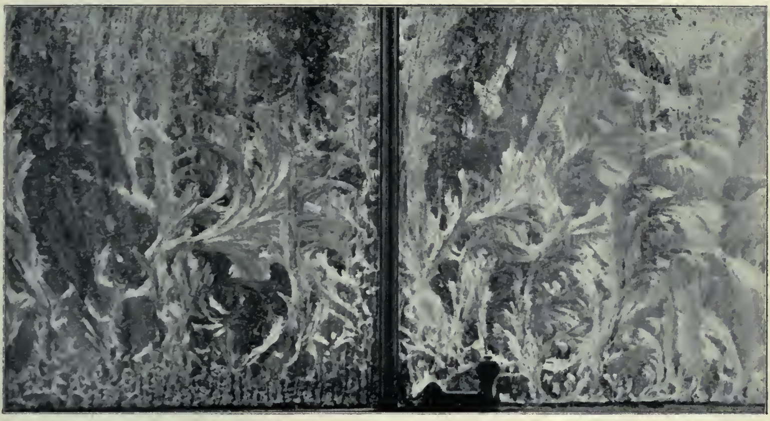
"This peak, and those adjacent," writes Professor Tyndall, "which are similarly shattered, exhibit a striking picture of the ruin which nature inflicts upon her own creations. She buildeth up and taketh down, she lifts the mountains by her subterranean energies, and then blasts them by her lightnings and her frost."

The study of the wonders of nature which surround us in no way tends to diminish the mystery and fascination that we may at first find in it; it rather increases our desire to learn more. As our knowledge expands our thoughts will deepen, and we shall be provided ceaselessly with new wonders that require our consideration and energy to unravel. In this manner, by pursuing our inquiries into nature's work, we, however wise, soon come to realise our own limitations and capabilities, and have to confess, after all, that we are still surrounded on every hand by mysteries and wonders passing our comprehension.

The late Lord Kelvin admitted that, after fifty-five years of strenuous effort, he had not yet solved many of the great mysteries that had engrossed his attention for so long; he could not, for instance, answer the self-imposed question, "What is electricity?" although he knew more of the subject than any living man. Few men, possessing such knowledge as he, would have been so modest, I fear.

Professor Tyndall, writing in much the same strain, asks himself a question also: "Are other grander powers still latent in nature, which shall come to blossom in another age? Let us question fearlessly; but having done so, let us avow frankly, that at the bottom we know nothing."

The glacier has been compared to human life. Mrs Aubrey le Blond, an enthusiastic mountaineer, and first president of the Ladies' Alpine Club, says: "The spotless snowflake, descending from above, keeps for some years its



ICE-FERNS ON WINDOW PANE.

PORTION OF ABOVE PHOTOGRAPHED NATURAL SIZE.

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whiteness and purity. Then the dust that falls upon it sullies its surface; its struggles in its life's journey leave it wrinkled and scarred. It has carried with it many a burden, sometimes of precious ores and sometimes of worthless stones and mud; but as it shrinks and wastes, it drops them one by one, till at last it lays itself to rest on the bosom of the earth.

"But this is not the end, for from within it leaps forth an arrowy stream, that starts on a new existence till it joins itself with the ocean."

The river is most frequently taken as a symbol of life. The following comparison was written by a personal friend; I give it, for it is full of deepest thoughts:

"And trickling down the mountain side
The rivers, snow sun-melted, glide;
A murmuring harmony, that flows
Eternal from the eternal snows;
Heaven's manna on the mountain top
To earth below, first drop by drop,
Then in the rushing river sent,
Leaping in boisterous descent
O'er crag and scar, and rocky tract;
Then like the mighty cataract
Bursting in swollen torrents, till
What first began the little rill,
Noiseless and quiet, sweeps and roars
In hoarser current to the shores
Of gorges, or the broader sea,
Lost in its vast eternity.
How like to man, how like our race!
Our starting-point a loftier place,
From God Himself, so small at first,
The infant, scarcely life, has burst
Into the youth, still broadening down
To riper manhood, then the town
And roar of busy commerce, life
In all its changes, headlong strife.
Then hoary age,
Life's silvery foam, the later stage
When, tired with toil, earth's busy roar
It seeks that far-off brighter shore."

There are similar lessons and parallels in all water's work, the boundless ocean, as well as the tiny flower, the roaring tempest, and the song of the skylark.

Some of nature's wonders thrust themselves upon our notice by their very magnitude and beauty, so that almost "he who runs may read"; but as a rule nature requires us to "seek and find," and it is by study only that her rarest beauties are revealed to us.

> "Thus studied, used, and consecrated thus,
> On earth what is, seems formed indeed for us:
>
> And sees, by no fallacious light or dim,
> Earth made for man, and man himself for Him."
>
> COWPER.

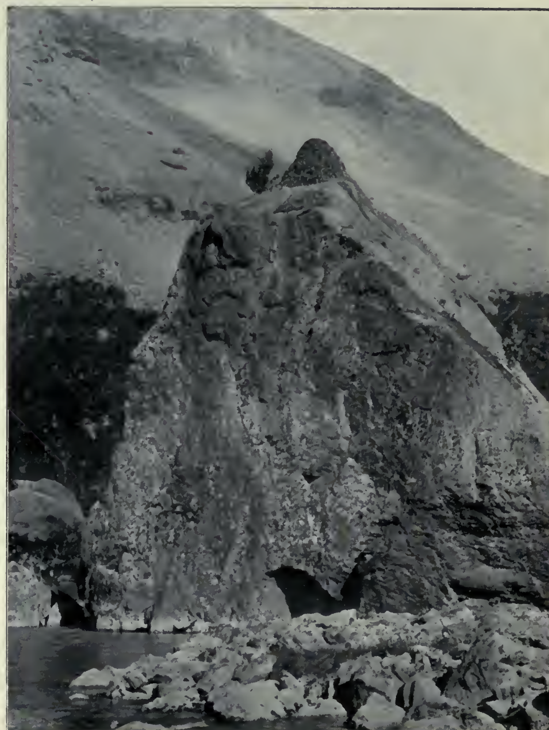
The ceaseless murmur of the ocean waves as they break upon the shore, which Longfellow calls "the grand, majestic symphony of the ocean," cannot but attract the attention of the most idle observer; but nature's masterpieces are not so easily discovered—there is no royal road to them, only the student becomes acquainted with them. And what does he find? Perfection everywhere; even the wing of the common house-fly is of marvellous and beautiful construction.

Surely this teaches us at least one lesson: that nothing is so small and mean in nature that it did not require infinite care and thought in its design; nature knows no jerry-building; scamping and make-believe are outside her domains; all is done thoroughly. Surely it tells us that nothing but our very best is acceptable, and our ambition and aim should be the gift of taking infinite pains with all that comes to our hands to do.

The pleasure to be derived from the study of nature must be experienced to be appreciated. This pleasure is not limited to the rich, the clever, or the man of leisure. The poor, those of limited ability, or those occupied by daily labour, can all, according to their gifts, enjoy such

Mrs Aubrey Le Blond.

AN ERRATIC BOULDER, ZERMATT.



Mrs Aubrey Le Blond.

AN ERRATIC BOULDER WITH OSPREY'S NEST ON TOP.

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recreation. How many take country walks and see nothing, neither bird, flower, butterfly, nor bee? To such nature exists in vain.

Let me again refer to the field that nature offers to a lad of deficient education, whose early life was perhaps one of stern work, not systematic education. Let him take heart, for he may succeed where others have failed; his very deficiencies may prove an advantage, for some of the well-educated take so much for granted, presuming on their knowledge, and so pass over innumerable treasures in "nature's realm" that are quickly discovered by one who perforce has had to look for, search after, and find out all he ever knew; his very life has made him naturally a keen observer, and has given him a disposition that will not shirk the idea of work, which in the study of nature is essential, for it is almost exclusively a matter of work and healthy recreation; the lackadaisical, "slack" youth, be his education of the best, will be left far behind. There are, of course, fortunately for science and the world, here and there men who possess every qualification and advantage, and the energy necessary to use them for the benefit of their fellow-men. From such I have not scrupled, as the reader will see, to draw freely, and quote often, I hope for the general benefit, their words of wisdom, the result of education and research, in the realms of which I am but a casual observer.

Canon Barnet says one of the saddest sights of the Lake District tourist season is the aimless wandering of the hard-worked folk, who have waited a whole year for their annual holiday, and having obtained it, do not know what to do with it. "They stand, with Skiddaw, glorious in its purple mantle of heather, on one side, and the blue hills of Borrowdale and the shining lake on the other, and ask, 'Which is the way to the scenery?'"

"How differently nature affects individuals!" says Professor Tyndall. "To one she is an irritant which evokes all the grandeur of the heart, while another is no more affected by her magnificence than are the beasts which perish."

What greater real joy can we have than that obtained in the study of natural works, both in heaven and on earth?

"The sun shines brightly from his throne,
Pavilion'd in the eastern sky;
The thousand tints that deck his crown
In beauty with the rainbow vie!
The modest daisy in the field,
Amidst the meadow half concealed,
The dew that sparkles in his ray
He kisses from his cheek away."

In nature the worker, whether mental or physical, can find a welcome change, recreation, and rest, a change that the idle can never know, for true pleasure and recreation come from within and not from without the man.

Many men roam the world over, exhausting every pleasure, place, and thing, and still complain of nothing to interest them.

From them the sublime works of nature cannot extort a single responsive thought, or call forth the faintest praise.

Let such beings follow nature in her works: they will find her a subject for study full of inexhaustible variety, endless surprises, and astounding revelations.

"The world we live in," says Lord Avebury, "is a fairyland of exquisite beauty, our very existence is a miracle in itself, and yet few of us enjoy as we might, and none as yet appreciate fully, the beauties and wonders that surround us."

What we do see depends mainly upon what we look for. Those who love nature can never be dull; they may have troubles and temptations, but at least they will run no risk of being beguiled by ennui, idleness, or want of occupation.

It is said: "Beautiful is God's earth, and beautiful it is to be a man thereon." We should also remember that it is possible to have eyes and see not, to hear and not to understand.

By interesting ourselves in nature we shall probably prolong our lives, and we shall certainly add to our pleasure and knowledge.

"I have so long," says Kingsley, "enjoyed the wonders of nature, never, I can honestly say, alone; because, when man is not with me, I have companions in every bee, and flower, and pebble."

Now that we are approaching the end of our survey, let us ask ourselves what we have to learn from it? what does it teach?

Surely that nothing is permanent, nothing lasting: "change and decay in all around we see"; but we see also renewal (rearrangement, reconstruction), endless evolution. Applying the lesson to ourselves, we, like everything in nature, change gradually day by day, from birth to death, slowly indeed, but surely—it is said that "something dies in us the moment we are born, and something is born in us the moment we die"; birth, life, death, are all part and parcel of our natural existence. Over the first we have no control, of the second but little control is in our hands; the last we should not fear, being as natural as the first, and probably, if we knew, shrouded in oblivion at the last, and not so fearful as we think.

This brings us to the crucial point, where to look for pleasure; for—

"The world can never give
The bliss for which we sigh;
'Tis not the whole of life to live,
Nor all of death to die."

Lord Avebury tells us that it is by no means the most prosperous men that are the happiest: many are indeed miserable. "If a man has not got the elements of happiness in himself, not all the beauty and variety, the pleasures and interests, of the world can give it him. Misfortunes we must all expect in this beautiful and glorious but complex world, but the darkest shadows of life are those which a man himself makes when he stands in his own light."

At times a man wearies of his possessions, as a child does of his toys; therefore, with our pleasure as with our investments, "we must not put all our eggs in one basket"; put some interest in gilt-edged securities. Get at least some recreation by the study of nature; observe her habits, look into her secrets, whether it be the action of water, the testimony of the rocks, the wonders of the deep, the beauties of plants, the mysteries of the heavens, etc.; otherwise, if our pleasure comes from relying on others, or in aimless wandering about in search of new amusement, we may become bored. Let us seek, anyway, some recreation from a sure source, where it will not fail us, whereby we become refreshed, not wearied.

An eminent writer calls attention to the general idea that the good God created for man all the wonders of which we have read. That God created our universe and all the unknown worlds of space for His pleasure, and man for a similar purpose, may be, but all this marvellous display was not for man. "Are those immense bodies," says Dr Buckland, "the fixed stars, hung up for nothing but to twinkle in our eyes by night, or to find employment for a few astronomers? Surely he must have an overwhelming conceit of man's importance who can imagine this stupendous frame of the universe made for him alone."

The same writer, in concluding one of his works, says: "The whole course of the inquiry, which we have now

C. J. Hawkins.

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conducted to its close, has shown that the physical history of our globe, in which some have only seen waste, disorder, and confusion, teems with endless examples of economy and order and design; and the result of all our researches, carried back through the unwritten records of past time, has been to fix more steadily our assurance of the existence of one Supreme Creator of all things."

Surely this is an ideal conclusion of our study of water.

"The world," says Channing, "from our first to our last hour, is our school; and the whole of life has but one great purpose—education."

This will also lead us to look from nature to nature's God. We may then hope to say:

> "This our life, . . .
> Finds tongues in trees, books in the running brooks,
> Sermons in stones, and good in everything."

THE END

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