TRANSACTIONS

OF THE

CONNECTICUT ACADEMY

OF

ARTS AND SCIENCES.

VOLUME II.

NEW HAVEN:
PUBLISHED BY THE ACADEMY.
PRINTED BY TUTTLE, MOREHOUSE & TAYLOR.

1871 TO 1873.

CONTENTS OF VOL. II, PART 1.

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I. Notice of the Crustacea collected by Prof. C. F. Hartt on the coast of Brazil in 1867. By Sidney I. Smith.

Read, May 19th, 1869.

In the first volume of these Transactions, Prof. Verrill has noticed the Radiata of the collection made by Prof. Hartt upon the coast of Brazil during the summer of 1867, and the Crustacea of the same collection, having been submitted to me for examination, was found to contain so many species new to the Brazilian fauna that the publication of the following list seemed desirable.

The collection, although quite small in number of specimens and representing only the higher groups of the class, is interesting from the large proportion which it contains of species heretofore known only from the West Indies or Flordia. This is, perhaps, due chiefly to the fact that most of the collections brought from Brazil have been made at Rio de Janeiro where there are no coral reefs, while Prof. Hartt's collection was made principally on the rocky and reef-bearing parts of the coast.

BRACHYURA.

Milnia bicornuta Stimpson.

Pisa bicornuta Latreille, Encyclopédie méthodique, tome x, p. 141 (*teste* Edwards).
Pericera bicorna Edwards, Histoire naturelle des Crustacés, tome i, p. 337, 1834.
Pisa bicorna Gibbes, On the Carcinological Collections of the United States, Proceedings American Association, 3d Meeting, p. 170, 1850.
Pericera bicornis Saussure, Crustacés nouveaux des Antilles et du Mexique, p. 12, pl. 1, fig. 3, 1858.
Milnia bicornuta Stimpson, Notes on North American Crustacea, Annals Lyceum Nat. Hist., New York, vol. vii, p. 180, 1860.

A single specimen collected at the Reefs of the Abrolhos does not differ from Bermuda, Florida and Aspinwall specimens.

Mithraculus coronatus Stimpson.

Cancer coronatus Herbst, Naturgeschichte der Krabben und Krebse, Band i, p. 184, Tab. 11, fig. 63, 1782, and *Cancer Coryphe*, Band iii, zweytes Heft, p. 8, 1801.
Mithraculus coronatus (pars) White?, List of Crust. in the British Museum, p. 7, 1847.

Mithraculus coronatus Stimpson, American Journal Sci., 2d series, vol. xxix, 1860, p. 132; Annals Lyc. Nat. Hist., New York, vol. vii, p. 186, 1860.

Two females of this species were collected by Prof. Hartt at the Reefs of the Abrolhos. They do not differ perceptibly from Aspinwall specimens.

The two specimens give the following measurement:—

Length of carapax, 12·8mm	Breadth of carapax, 17·6mm	Ratio, 1 : 1·37
" " " 17·2	" " " 23·4	" 1 : 1·36

The differences pointed out by Stimpson at once distinguish this species from *M. sculptus*, but White cites the figures of both species under his *Mithraculus coronatus*, so that it is not possible, without an examination of his specimens, to tell which species he had in view.

Mithrax hispidus Edwards.

Cancer hispidus Herbst, op. cit., Band i, p. 247, Tab. 18, fig. 100, 1782.

Mithrax hispidus Edwards, Magasin de Zoölogie, 2e année, 1832; Historie naturelle des Crust., tome i, p. 322, 1834; DeKay, Zoölogy of New York, Crust., p. 4, 1844; Gibbes, loc. cit., p. 172; Stimpson, American Journal Sci., 2d series, vol. xxix, 1860, p. 132; Annals Lyc. Nat. Hist., New York, vol. vii, p. 189, 1860.

Several specimens collected at the Reefs of the Abrolhos agree well with Edwards' and Stimpson's descriptions of this species. The carapax is wholly naked above, the elevations anteriorly are smooth and polished, and there are no spines or prominent tubercles on the median regions. There are two small tubercles just at the base of the frontal teeth, and two more just behind these on the anterior lobes of the gastric region; there are also traces of two tubercles on each of the antero-lateral gastric lobes, and several small tuberculiform elevations on the hepatic and branchial regions near the antero-lateral margin. The external angle of the orbit forms an obtuse tooth not projecting so far forward as the external lobe of the inferior margin; the succeeding tooth of the antero-lateral margin (the second normal) is quite small and obtuse, but the three remaining teeth are spiniform, slender and curved forward; in addition, there is a very small tooth just behind the posterior spine of the antero-lateral margin.

Several specimens give the following measurements:—

Sex.	Length of carapax.	Breadth of carapax including spines.	Ratio.
Male.	15·5mm	18·0mm	1 : 1·16
"	18·9	22·7	1 : 1·20
Female.	13·4	15·4	1 : 1·15
"	15·4	18·0	1 : 1·17

Xantho denticulata White.

Xantho denticulata White, List of Crust. in the British Museum, p. 17 (no description), 1847; Annals and Mag. Nat. Hist., 2d series, vol. ii, p. 285 (*X. denticulatus*), 1848 (*non* Stimpson); Smith, Proc. Boston Soc. Nat. Hist., vol. xii, p. 274, 1869.

A single specimen collected at the Reefs of the Abrolhos does not differ from specimens from Bermuda and Aspinwall.

It seemes to be an uncommon species as it is not mentioned by Dana, Gibbes, or Stimpson, and I have only seen a single one from each of the localities mentioned.

Chlorodius Floridanus Gibbes.

Chlorodius Floridanus Gibbes, loc. cit., p. 175, 1850; Stimpson, Annals Lyc. Nat. Hist., New York, vol. vii, p. 209.

Several specimens, not differing perceptibly from those from Florida and Aspinwall, were collected at the Reefs of the Abrolhos.

Three specimens give the following measurements:—

Sex.	Length of carapax.	Breadth of carapax.	Ratio.
Male.	20·8mm	33·8mm	1 : 1·62
Female.	15·6	23·8	1 : 1·53
"	18·4	29·4	1 : 1·60

Panopeus politus Smith, loc. cit., p. 282, 1869.

Plate I, figure 4.

This species is allied to *P. transversus* Stimpson, and resembles somewhat the *crenatus* of Edwards and Lucas.

The carapax is entirely naked above, broad, moderately convex in two directions, slightly granulous and uneven on the front and along the antero-lateral border, but smooth and highly polished on the median regions and posteriorly. The regions are slightly but distinctly indicated. The gastric region is surrounded by a well marked sulcus, but its lobes are not distinctly indicated except the anterior extremity of the median, which is slender and acutely pointed; the frontal lobes are indicated by slight prominences. The hepatic region is not divided, but there are one or two slight plications on its anterior part parallel to the antero-lateral margin. The cervical suture is distinct in its outer portion but is not indicated near the gastric region. The median and posterior lobes of the branchial region are separated by a distinct depression. The front is strongly deflexed, the edge somewhat beveled from above and four-lobed; the median lobes are very broad, project prominently and are separated by a sharp notch; the lateral lobes project as small narrow teeth. The antero-lateral margin is divided by small notches into four lobes, the first of which is composed of the angle of the orbit coalesced with the second normal tooth; the first lobe is broad, its edge slightly concave and projecting a little at the angle of the orbit; the second and third lobes are broad and truncate; the fourth lobe is small and obtuse and forms the lateral angle of the carapax. From each of the notches slight sulci extend a little way back upon the carapax.

Beneath, the edge of the front is thin, projects obliquely downward and is not expanded in front of the antennulæ. The epistome is smooth, and its labial border has a prominent median lobe and a slight incision each side. The external maxillipeds are smooth; the merus is quadrilateral, its outer edge not projecting, and the antero-exterior angle rounded. The inferior margin of the orbit is divided into two lobes by a broad and shallow sinus; the inner lobe forming a prominent tooth which projects as far forward as the lateral lobe of the front, and the outer lobe broad and slightly prominent. The external hiatus of the orbit is rather broad and shallow. The sub-orbital and sub-hepatic regions are quite granulous. The tubercle beneath the anterior lobe of the antero-lateral margin is depressed, forming only a slight granulous prominence. The sub-branchial region is somewhat hairy. The female abdomen is broadly ovate, the greatest breadth being at the fourth segment.

The chelipeds are slightly unequal, the carpi and hands smooth and evenly rounded above and on the outside. The hands are stout, the fingers obscurely marked with longitudinal impressed lines, and irregularly toothed within, and in the dactylus of the larger hand there is a prominent cylindrical tooth at the base. The ambulatory legs are smooth and nearly naked except a close pubescence upon the dactyli, penultimate segments, and slightly on the carpi.

In an alcoholic specimen the color is light brown above, tinged with bluish purple on the anterior part of the carapax and the upper side of the chelipeds. The fingers are black, lighter at the tips, and the black not spreading upon the palm.

Length of carapax in the single female specimen, $13{\cdot}8^{mm}$; breadth, 21·4: ratio of length to breadth, 1 : 1·55.

Collected at the Reefs of the Abrolhos.

The *P. transversus* Stimpson (Annals Lyc. Nat. Hist., New York, vol. vii, p. 210, 1860) of the west coast of Central America, differs from this species in having the carapax much less distinctly areolated, more regularly oval in outline and smoother and more evenly convex above. The front also projects much less prominently; the antero-lateral margin is smooth and even and the lobes separated by very slight incisions, and the edge of the first lobe is slightly convex and does not project at the angle of the orbit ; there is no noticeable depression between the median and posterior lobes of the branchial region ; the inferior margin of the orbit is divided by a very slight sinus, and the inner lobe is not at all prominent ; and finally, the external maxillipeds are slightly granulated. The color of alcoholic specimens is quite different, being dark slate-brown on the upper side of the carapax and chelipeds.

The *P. crenatus* of Edwards and Lucas is a much smoother species than the *politus*, the regions being scarcely at all defined and the carapax almost perfectly smooth along the front and antero-lateral border. The front is not deflexed, its edge is nearly straight, and beneath it is expanded horizontally in front of the antennulæ ; the sub-orbital and sub-hepatic regions are quite smooth, and there is no tubercle beneath the first lobe of the antero-lateral margin ; and finally, the antero-exterior angle of the merus of the external maxillipeds projects laterally somewhat beyond the lateral margin and is broadly rounded.*

Panopeus Harttii Smith, loc. cit., p. 280, 1869.

Plate I, figure 5.

The carapax is clothed with scattered hairs along the borders, is broadest at the penultimate teeth of the antero-lateral margins, con vex anteriorly but flattened behind, and coarsely granulous on the front and along the lateral borders, but nearly smooth on the median and posterior regions. The gastric region is surrounded by a very deep sulcus, which is particularly marked posteriorly next the cardiac and the posterior part of the branchial region ; its median lobe is separated from the antero-lateral lobes by a slight but distinct sulcus ; and the anterior lobes are prominent and marked anteriorly by a sharp plication. The hepatic region is prominent, somewhat projecting and bears a transverse, granulous ridge. The cervical suture is very marked and extends as a broad depression quite to the gastric region. The median and posterior lobes of the branchial region are separated by a slight depression. The front is very much deflexed and the edge

* The figure of the facial region of this species given in the *Voyage dans L'Amérique Méridionale* (pl. 8, fig. 1 a) improperly represents the external maxillipeds with this angle truncate and not at all produced laterally.

thin and four lobed; the median lobes are very much the largest, are evenly rounded, and a little more prominent than the lateral, which project as small obtusely triangular teeth. The superior margin of the orbit is broken by two incisions leaving the margin between them projecting as a slight, rounded lobe. The post-orbital tooth is short and slender, and is separated from the second tooth of the antero-lateral margin by a broad sinus which breaks the margin completely. The remaining teeth of the antero-lateral margin are triangular in form, much thickened vertically, and separated by quite broad sinuses, and the posterior two on each side are very slender and of nearly equal prominence.

Beneath, the edge of the front is thin and projects sharply downward. The epistome is smooth and its labial border has a small lobe in the middle, a slight notch each side and another at each angle of the buccal area. The external maxillipeds are smooth except the merus, which is slightly granulated and also has the antero-exterior angle very slightly produced laterally and not at all rounded. The inferior margin of the orbit is prominent and divided into two lobes by a deep and narrow sinus; the inner lobe forms a stout tooth which projects as far forward as the inner angle of the superior margin; the outer lobe is broad and its exterior angle projects slightly in advance of the post-orbital tooth. The external hiatus of the orbit is a deep triangular notch. In one specimen, however, it is wholly closed on one side, possibly from some accident. The sub-orbital and sub-hepatic regions are quite coarsely granulous. The tubercle of the sub-hepatic region forms a slight granulous prominence just beneath the post-orbital tooth. The sub-branchial region is pubescent and slightly granulous. In the male, the sternum is smooth and the abdomen quite narrow, being narrowest at the penultimate segment, and the terminal segment is about five-sixths as long as broad, and its extremity evenly rounded. In the female the abdomen is broadly ovate, the greatest breadth being at the fourth segment.

The chelipeds are a little unequal. The carpi are granular-rugose externally and have a deep groove along the outer margin next the articulation with the hand. The hands are slightly rugose above, and the fingers are slender, deflexed, marked with slight, impressed longitudinal lines and slightly and obtusely toothed within, and the dactylus in the larger hand usually has a stout tooth at the base. The ambulatory legs are slender, and pubescent along the edges of all the segments and over the whole surface of the dactyli.

Alcoholic specimens are light olive brown above and on the chelipeds. The fingers are black, lighter at the tips, and the black not spreading upon the palm.

Several specimens give the following measurements:

Sex.	Length of carapax.	Breadth of carapax.	Ratio.
Male.	15·0mm	22·5mm	1 : 1·50
"	15·9	23·6	1 : 1·49
Female.	9·6	14·4	1 : 1·50
"	12·6	18·8	1 : 1·49

Seven specimens were collected by Prof. Hartt at the Reefs of the Abrolhos.

This species is very distinct from all other described species of the genus. Its broad and deeply areolated carapax give it somewhat the aspect of a *Chlorodius.*

Eriphia gonagra Edwards.

Cancer gonagra Fabricius, Supplementum Entomologiæ systematicæ, p. 337, 1798.

Eriphia gonagra Edwards, Histoire naturelle des Crust., tome i, p. 426, pl. 16, fig. 16, 17, 1834; Annales des Sciences naturelles, 3me série, tome xvi, 1851, pl. 8, fig. 10; White, List of Crust. in the British Museum, p. 22; Gibbes, loc. cit., p. 177; Dana, United States Exploring Expedition, Crust., p. 250; Stimpson, Annals Lyc. Nat. Hist., New York, vol. vii, p. 217; Heller, Reise der österreichischen Fregatte Novara um die Erde, p. 24, 1865.

A large number of specimens are in the collection, all of them obtained at the Reefs of the Abrolhos. It seems to be a common species from southern Florida to Rio de Janeiro.

A number of specimens give the following measurements:

Sex.	Length of carapax.	Breadth of carapax including spines.	Ratio.
Male.	17·2mm	24·8mm	1 : 1·44
"	24·0	34·5	1 : 1·44
"	25·6	36·8	1 : 1·44
"	26·8	37·8	1 : 1·41
"	30·8	43·5	1 : 1·41
Female.	17·6	25·7	1 : 1·46
"	19·6	28·2	1 : 1·44
"	23·0	33·2	1 : 1·44
"	28·2	41·3	1 : 1·46

Callinectes Danæ Smith.

Lupa diacantha Dana, United States Exploring Expedition, Crust., p. 272, pl. 16, fig. 7, 1852.

Callinectes diacanthus Ordway, Monograph of the genus Callinectes, Boston Journal Nat. Hist., vol. vii, p. 575, 1863. (*Non Portunus diacanthus* Latreille, *nec Lupa diacantha* Edwards, *nec Callinectes diacanthus* Stimpson.)

A number of specimens which agree perfectly with the description of this species given by Ordway, were collected at Pernambuco by Prof. Hartt.

A single female from Bahia does not differ from the Pernambuco specimens except in having the sub-median tooth of the front very short, scarcely projecting beyond the median teeth—probably an accidental character.

Several specimens give the following measurements:—

	Sex.	Length of carapax including sub-frontal spine.	Breadth of carapax including lateral spine.	Ratio.
Pernambuco.	Male.	41·9mm	93·0mm	1 : 2·22
"	"	44·3	97·4	1 : 2·20
	"	47·2	106·5	1 : 2·26
"	Female.	41·8	91·0	1 : 2·17
"	"	44·8	94·8	1 : 2·12
Bahia.	"	34·4	76·0	1 : 2·21

This species was known to Ordway only from Dana's original specimen collected at Rio de Janeiro.

Callinectes ornatus Ordway, loc. cit., p. 571, 1863.

A male specimen collected at Caravellas agrees perfectly with Ordway's description and with a specimen from Bermuda.

Length of carapax including sub-frontal spine, 36·2mm; breadth of carapax including lateral spines, 80·5mm; ratio of length to breadth, 1 : 2·22.

A sterile female collected at the same locality may belong to this species. It differs from the male in being thicker and more convex, the areolation more strongly marked, and the granulations coarser; the teeth of the antero-lateral border are less prominent and more obtuse; and the chelipeds are quite short, the merus not reaching, by considerable, the tip of the lateral spine.

Length of carapax, 34·6mm; breadth of carapax, 75·0; ratio 1 : 2·14.

In the deeply areolated carapax it approaches the *larvatus*, and it may possibly belong to that species.

The description and figure of *Neptunus marginatus* A. Edwards* agrees very closely with this specimen, the figure of the abdomen and sternum representing it perfectly, and there can be little doubt that Edwards' species was based on a sterile female of some species of *Callinectes*. If the habitat, *Côte du Gabon*, given by Edwards be correct, it is safely inferred that the genus *Callinectes* is not confined to the American coasts.

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* Archives du Muséum d'Histoire naturelle, tome x, p. 318, pl. 30, fig. 2, 1861.

The *C. ornatus* was previously known from South Carolina, Tortugas, Hayti, and Cumana.

Callinectes larvatus Ordway, loc. cit., p. 573, 1863.

One specimen of this species, a male, was collected at Bahia. It is very much like the *Danæ* and the *ornatus* in the carapax, etc., but differs remarkably in the male abdominal appendages of the first pair (intromittent organs), which are very short, directed inward till they cross and then the extremities curved abruptly outward.

Length of carapax including sub-frontal spine, 38·8^{mm}; breadth including lateral spines, 82·4^{mm}; ratio of length to breadth, 1 : 2·11.

Ordway's specimens were from Florida, Bahama, and Hayti.

Achelous spinimanus DeHaan.

Portunus spinimanus Latreille, Encyc., t. x, p. 188 (*teste* Edwards).

Lupa spinimana Leach, Desmarest, Considérations générales sur la classe des Crust., p. 98, 1825; Edwards, Histoire naturelle des Crust., tome i, p. 452, 1834; Gibbes, loc. cit., p. 178; Dana, United States Exploring Eexpedition, Crust., p. 273; Stimpson, Annals Lyc. Nat. Hist., New York, vol. vii, p. 57.

Achelous spinimanus, DeHaan, Fauna Japonica, p. 8, 1833; White, List of Crust. in the British Museum, p. 28, 1847; Stimpson, Annals Lyc. Nat. Hist., New York, vol. vii, p. 221, 1860; A. Edwards, Archives du Muséum d'Histoire naturelle, tome x, p. 341, pl. 32, fig. 1, 1861; Heller, op. cit., p. 27.

Three specimens, all females, collected at Bahia, give the following measurements:—

Length of carapax including frontal teeth.	Breadth of carapax including lateral spines.	Ratio of length to breadth.
37·0^{mm}	61·5^{mm}	1 : 1·66
44·4	77·4	1 : 1·74
56·0	95·0	1 : 1·70

All the specimens have the lateral spine of the carapax nearly or quite twice as long as the one next in front of it. They appear to differ in no way from specimens from Florida.

Achelous Ordwayi Stimpson.

Achelous Ordwayi Stimpson, Annals Lyc. Nat. Hist., New York, vol. vii, p. 242, 1860.

Neptunus Ordwayi A. Edwards, op. cit., *addenda*, 1861.

A male specimen of this fine species was collected, with the last, at Bahia.

The carapax is narrower than in *A. spinimanus*, and the front more advanced. In areolation it resembles the *spinimanus* very much, the elevations however are not quite so thickly granulated. The teeth of the front are very long and slender, the length of the median ones exceeding slightly the distance between their tips. The teeth of the antero-lateral margin are much longer and slenderer than in *spinimanus*, the posterior one (lateral spine) being but slightly longer, in proportion to the other teeth, than in that species. The chelipeds are slender and fully as long as in *spinimanus*. The ambulatory legs are long and very slender, those of the first two pairs extending nearly to the middle of the dactyli of the chelipeds.

The sternum is convex in an antero-posterior direction, while in the *spinimanus* it is quite flat. In the male the terminal portion of the abdomen is narrowly triangular, the penultimate segment being quite narrow and its lateral margins straight or very slightly concave, while in the *spinimanus* it is broad and the lateral margins of the penultimate segment quite convex.

The male abdominal appendages of the first pair are very different in the two species. In both they are stout and separated by quite a broad space. In the *spinimanus* they reach beyond the middle of the penultimate segment of the abdomen, the thick basal portion curving strongly inward from the base, the slenderer portion at first directed nearly straight forward, then curved strongly outward, and the tips inward again. In the *Ordwayi* they are much shorter, reaching but slightly beyond the antipenultimate segment of the abdomen, and have but a single curve, curving inward from the base, then outward to the tip.

Length of carapax in the single specimen, 37·0^{mm}; breadth of carapax, 61·8^{mm}; ratio of length to breadth, 1 : 1·67; breadth excluding lateral spines, 48·0^{mm}; ratio of length to this breadth, 1 : 1·29; greatest length of merus segments of chelipeds, 31·0^{mm}; length of hand, right, 47·2, left, 47·0^{mm}. A male specimen of *A. spinimanus* from Florida gives the following:—length of carapax, 40·4^{mm}; breadth of carapax, 69·5^{mm}; ratio of length to breadth, 1 : 1·72; breadth excluding spines, 58·5^{mm}; ratio of length to this breadth, 1 : 1·44.

This species differs from the figure of *Neptunus cruentatus* (A. Edwards, op. cit., p. 326, pl. 31, fig. 2) in having much longer chelipeds, the merus projecting much farther beyond the sides of the carapax, and the hands when folded in front lapping by each other considerably. The teeth of the front and of the antero-lateral margin are very much more slender and prominent than in his figure. And in the description of the *cruentatus* no mention is made of the smooth and highly iridescent spaces on the supero-exterior surface of the hand, which is mentioned by Stimpson in his description of *A. Ordwayi*, and is a very conspicuous character in the species.

I have retained this species in the genus *Achelous* of DeHaan instead of *Neptunus* of the same author, because the narrow carapax, prominent front, and the form of the external maxillipeds and of the male abdomen ally it very closely to the *spinimanus*, and, together with the narrow dactyli of the first three pairs of ambulatory legs, separate it widely from *Neptunus pelagicus*, the type of the genus *Neptunus*.

The length of the lateral spine of the carapax, which appears to have been A. Milne Edwards' principal character for separating these genera, seems to be of slight importance, and in the present case, if used alone, is scarcely sufficient for a specific distinction.

Stimpson's specimens of *A. Ordwayi* were from Florida and St. Thomas.

Goniopsis cruentatus DeHaan.

Cancer ruricola DeGeer, Mémoires pour servir á l'histoire des Insectes, tome vii, p. 417, pl. 25, 1778 (*non Cancer ruricola* Linné).

Grapsus cruentatus Latreille, Histoire des Crust. et Insects, tome vi, p. 70, 1803; Desmarest, op. cit., p. 132; Edwards, Histoire naturelle des Crust., tome ii, p. 85; Gibbes, loc. cit., p. 181.

Goniopsis cruentatus DeHaan, op. cit., p. 33, 1835; Edwards, Annales des Sciences naturelles, 3^{me} série, tome xx, 1853, p. 164, pl. 7, fig. 2; Stimpson, Proceedings Acad. Nat. Sci., Philadelphia, 1858, p. 101; Heller, op. cit., p. 43.

Grapsus longipes Randall, Journal Acad. Nat. Sci., Philad., vol. viii, p. 125, 1839.

Goniopsis ruricola White, List of Crust. in the British Museum, p. 40, 1847; Saussure, op. cit., p. 30, pl. 2, fig. 18, 1858.

Goniograpsus cruentatus Dana, American Journal Sci., 2d series, vol. xii, p. 285, 1851; United States Exploring Expedition, Crust., p. 342, pl. 21, fig. 7, 1852.

A single male of this beautiful species was collected at the Reefs of the Abrolhos.

Cryptograpsus cirripes, sp. nov.

Plate I, figure 3.

The carapax above is granulous and naked The front as seen from above is nearly straight with only a slight median immargination. The orbits are broad, the margin slightly upturned and broken by a broad notch near the inner angle. The outer orbital teeth are long, acutely pointed, project straight forward, and the distance between their tips is nearly equal to two-thirds the breadth of the carapax. The succeeding teeth of the antero-lateral margin are prominent and acutely pointed, the third tooth much smaller than the others, and the fourth or last tooth with a slender spiniform tip directed forward and upward and with a sharp granulated ridge extending from its base inward upon the branchial region and nearly parallel to the postero-lateral margin. The areolation is well pronounced and agrees in the main with *C. angulatus* Dana. In the depression on each side just in front of the anterior lobes of the branchial region there is a transverse line of three obscure, oval, smooth spots. From the small tooth in the postero-lateral margin, a short ridge extends backward just above and parallel to the margin as far as the lateral angle of the carapax.

The chelipeds are stout and equal. The merus is triangular and the angles granulous. The carpus, and the hand nearly to the tips of the fingers, are sharply granulous. The fingers are slender and their inner edges nearly straight and armed with regular rounded tuberculiform teeth.

In the ambulatory legs the meral segments are granulous above and on the angles. The dactyli of the first three pairs are naked except a few hairs on the posterior edge at the base, slender, somewhat curved, smooth and deeply sulcate; those of the posterior pair are shorter, compressed, and their edges thickly clothed with soft hairs. In the first pair of legs the posterior edge of the propodus is clothed nearly its whole length with a brush of soft hair; in the second pair there is a similar brush but only on the terminal half; in the third pair it is wholly wanting, or represented only by a few hairs near the articulation with the dactylus. In the posterior pair of legs the edges of the dactylus, propodus and carpus are densely clothed with soft hair.

The male sternum is concave in a lateral direction, and the articulations between the segments of the abdomen are nearly straight instead of curved as in *C. angulatus*.

Length of carapax in a male, $31{\cdot}0^{mm}$; breadth of carapax, $35{\cdot}6^{mm}$; ratio of length to breath, 1 : 1·15. Breadth between outer orbital teeth, $24{\cdot}8^{mm}$; ratio of this breath to breath of carapax between lateral teeth, 1 : 1·43.

This species was not obtained by Prof. Hartt. The only specimens which I have seen are two males, in the collection of the Peabody Academy of Science, Salem, Mass., brought from Rio de Janeiro by Capt. Harrington.

The *C. cirripes* differs from *C. angulatus* Dana (United States Exploring Expedition, Crust., p. 352, pl. 22, fig. 6), from Rio Negro, Northern Patagonia, and heretofore the only known species of the genus, in having the front as seen from above nearly straight instead of deeply bilobed, in the much greater breadth of the carapax between the outer orbital teeth—the ratio of this breadth to the breadth of the carapax between the lateral teeth being in *C. angulatus*, 1 : 1·68,—and in the ciliated posterior legs.

Uca cordata.

Cancer cordatus Linné, Amœnitates Academicæ, tome vi, p. 414, 1763; Systema Naturæ, editio xii, tome i, p. 1039; Herbst, op. cit., Band i, p. 131, Tab. 6, fig. 38.
Cancer uca Linné?, Systema Naturæ, editio xii, tome i, p. 1041.
Uca lævis? Dana?, United States Exploring Expedition, Crust., p. 375.
(*Non Uca una* Guérin, Iconographie du Règne animal, Crust., pl. 5, fig. 3, *nec* Edwards, Histoire naturelle des Crust., tome ii, p. 22, et Règne animal de Cuvier, 3me édit., pl. 19, fig. 1.)

A single specimen of this species was obtained by Prof. Hartt at Bahia. There are also specimens from Pará in the collection of the Peabody Academy. All the specimens examined were males.

The carapax is entirely naked and perfectly smooth above, very broad, the greatest breadth being much anterior to the middle, and very convex in an antero-posterior direction. The cervical suture is very distinctly indicated, especially in the middle of the carapax, where there is a broad depression on each side at the antero-lateral angle of the cardiac region. The gastric region is broad and flattened in the middle, the antero-lateral lobes are only indistinctly separated from the median, and the posterior portion is rounded and slightly protuberant but is still lower than the branchial region. The cardiac region is very large, scarcely divided, and the posterior portion extends far back between the bases of the posterior pair of legs. The branchial regions are swollen, evenly rounded above and wholly undivided, and the lateral margins are very convex in the anterior portion and are indicated by a very slight denticulated ridge. The whole front is bordered by a sharply raised margin; the median lobe projects almost perpendicularly downward between the orbits, and its margin is regularly curved. The orbits are very large, and the margin is broken by a broad and deep hiatus on the lower side at the outer extremity, just over which the outer angle of the superior margin projects as a rounded lobe; the inferior margin is nearly straight and is formed of two nearly parallel ridges, the inferior of which is armed with a line of small tubercles, and the superior is irregularly granulous. The inferior obital regions are perfectly smooth and separated from the buccal area by deep sulci. The inferior lateral regions are swollen and nearly smooth, there being only a few small and scattered granules on the anterior portion near the inferior orbital region. On each side of the buccal area there is a high ridge which is armed with a few small tubercles.

The external maxillipeds are smooth and naked on the outside, and the inner edge and the palpus thickly clothed with coarse hairs.

The chelipeds are somewhat unequal and very large. The merus is stout, sharply triangular, both the inferior angles are armed with stout spines and the superior angle is coarsely granulous. The carpus is broad, smooth and evenly rounded on the outside, and spinous along the inner edge and on the anterior edge beneath. The hand is broad, compressed, spinous on the superior margin and on the inside, the inferior margin granulous, and the outer side smooth; the fingers are high and compressed, their tips strongly incurved, and the inner edges slightly separated in the middle and armed with small irregular teeth except at the tips, which are slightly spoon-shaped with the edges horny, continuous and sharp.

The ambulatory legs are smooth and naked above, but all the segments in the first three pairs, except the basal ones, are thickly clothed beneath and on the anterior side with very long coarse hair. Those of the anterior pair are longer than the others, and those of the posterior pair are much shorter than the others and but slightly hairy. The dactyli of the first two pairs are very long and stout, slightly curved downward, their extremities compressed vertically and five-sided with the angles sharp; those of the third pair are much shorter and curved backward as well as downward; those of the posterior pair are still shorter, strongly curved backward and six-sided, the superior side being much broader than the others.

The sternum is narrow, very convex in an antero-posterior direction, and the depression for the lodgement of the abdomen is broad, very deep, and extends quite to the base of the maxillipeds. The male abdomen is broadest at the third segment; the second segment is very small, and the two segments which precede it are completely coalesced. The appendages of the first segment are triquetral and very stout and extend to the extremity of the penultimate segment. The appendages of the second segment are very small, extending scarcely beyond the third segment.

Length of carapax, 54·0^{mm}; breadth of carapax, 73·4^{mm}; ratio, 1 : 1·36. Length of merus in right cheliped, 33·8^{mm}; in left cheliped, 33·0. Length of right hand, 49·5; length of left hand, 49·0.

One of the specimens in the collection of the Peabody Academy of Science has the chelipeds much more unequal than in the specimen described above but agrees with it in all other characters.

There are at least three American species of *Uca*:—the *U. cordata*, described above and the *U. una* (the species figured by Guérin and Edwards), from the east coast, and *U. lævis*, the species described and figured by Edwards in the Archives du Muséum d'Histoire naturelle, tome vii, p. 185, pl. 16, from the west coast.

The synonymy of these species appears to be in much confusion. The *Cancer cordatus* of Linné is described at length in the Amœnitates Academicæ, and is evidently the species described above and the same as the one figured by Herbst. The description of *C. uca* in the Systema Naturæ is very short and indefinite and no characters are given by which it could be distinguished from the *C. cordatus.*

Milne Edwards in his Historie naturelle de Crust., 1837, quotes both these species under his *Uca una* Latreille; he gives "l'Amérique méridionale" as the habitat of *U. una*, and describes a new species, *U. lævis*, from "les Antilles." The slight descriptions of his *lævis* here given would not distinguish it from the *U. cordata.* In his review of the Ocypodoidea in the Annales des Sciences naturelles, 3me séries, tome xx, 1853, these species are again briefly characterized and the same habitas given. In 1854, in the Archives du Muséum, loc. cit., he describes *U. lævis* at length and figures it, but says, "Je ne connais que des individus mâles de cette espéce; la plupart ont été rapportés des environs de Guayaquil, par M. Eydoux." The description and figure here given apply well to specimens in the Museum of Yale College collected at Guayaquil by Mr. Bradley, and distinguish it readily from the Atlantic species. To add to the confusion, Lucas in D'Orbigny's Voyage dans l'Amérique méridionale, Crust., p. 23, 1843, gives, without description, "*Uca una* Latr." as coming from "Environs de Guayaquil: M. Eydoux," evidently having the same specimens before him that Edwards has described and figured in the Archives du Muséum! If Edwards' original specimens of *lævis* were from the West Indies as stated, they are probably the *U. cordata*, but, even if this be the case, since the east coast species is evidently the *Cancer cordatus* of Linné, the name *lævis* may be retained for the west coast species to which Edwards's last and fullest description and his figure apply.

White, in the list of Crustacea in the British Museum, p. 31, 1847, has "*Uca cordata*" from the West Indies and Brazil, but quotes as synonyms, *Cancer uca* and *C. cordatus* of Linné, *C. cordatus* of Herbst, and *Uca una* of Guérin and Edwards, evidently confounding the two Atlantic species and intending to restore the older of the Linnean names.

Cardiosoma quadratum Saussure

Cardisoma quadrata Saussure, op. cit., p. 22, pl. 2, fig. 13, 1858.

Cardisoma diurnum Gill, Annals Lyc. Nat. Hist., New York, vol. vii, p. 42, January, 1859. [Wrongly printed 1858 on the third signature.]

A number of specimens were collected at Pernambuco.

It is at once distinguished from the *C. Guanhumi* by the more quadrate form of the carapax, the branchial regions being much less swollen, by the lateral margin being marked by a distinct carina instead of evenly rounded, and by the sharply triangular and spiny merus of the chelipeds. Some of the specimens collected by Prof. Hartt are nearly as large as ordinary specimens of *C. Guanhumi* and still retain the distinctive characters, so that it seems scarcely possible that it can be the young of that species as suggested by Saussure.

This species is in fact more nearly allied to the *C. carnifex* than to *C. Guanhumi*, and it resembles so closely a species in the collection of the Peabody Academy of Science from the west coast of Africa —apparently the *C. armatum* of Herklots,—that it might readily be mistaken for it. The African species differs however in having the carapax less convex and the carina of the lateral margin less prominent; the front is broad and high, the anterior lobes of the gastric region are protuberant and the depressed space between them and the frontal margin is coarsely granulous, while in the *quadratum* the anterior gastric lobes are not protuberant and the depressed space between them and the frontal margin is scarcely granulous. The epistome and the nasal lobe are quite different in the two species; in the *quadratum* the epistome is nearly straight and its anterior margin is not granulated, the nasal lobe is high, forming rather more than a semicircle, and the lobes of the front on each side of it do not reach down to the anterior margin of the epistome, while in the African species the epistome is higher, more curved and the anterior margin granulated in the middle, and the nasal lobe is much lower, so that the lobes of the front on each side of it reach quite down to the anterior margin of the epistome. Finally the chelipeds and ambulatory legs in the African species are more spiny and granulous.

Specimens of *C. quadratum* give the following measurements:—

	Male.	Male.	Female.	Female.
Length of carapax,	42·6mm	45·6mm	43·3mm	46·8mm
Breadth of "	53·4	55·8	53·3	56·6
Ratio of length to breadth,	1 : 1·25	1 : 1·22	1 : 1·23	1 : 1·21
Length of merus in right cheliped,	21·7mm	28·4mm	20·8mm	24·4mm
" " hand " " "	29·0	51·8	30·2	37·0
" " merus in left "	26·8	23·2	23·4	——
" " hand " " "	46·0	31·8	35·5	——

ANOMOURA.

Dromidia Antillensis Stimpson.

Dromidia Antillensis Stimpson, Proceedings Acad. Nat. Sci., Philadelphia, 1858, p. 225, 1859; Annals Lyc. Nat. Hist., New York, vol. vii, p. 71, 1859.

Several specimens of this species were obtained by Prof. Hartt at the Reefs of the Abrolhos. They give the following measurements and ratios:

Sex.	Length of carapax including frontal teeth.	Breadth of carapax.	Ratio.
Male.	15·5mm	15·6mm	1 : 1·01
"	18·2	18·5	1 : 1·02
Female.	16·0	16·0	1 : 1·00
"	18·0	18·2	1 : 1·01

All the specimens have a covering of tough, fleshy sponge, much broader than themselves, held closely upon the carapax.

Stimpson's specimens were from Florida and St. Thomas.

Petrochirus granulatus Stimpson.

Pagurus granulatus Olivier, Encyclop., tome viii, p. 640 (*teste* Edwards); Edwards, Observations Zoologiques sur les Pagures, Annales des Sciences naturelles, 2de série, tome vi, p. 275, 1836; Histoire naturelle des Crust., tome ii, p. 225; Dana, United States Exploring Expedition, Crust., p. 453.

Petrochirus granulatus Stimpson, Proceedings Acad. Nat. Sci., Philadelphia, 1858, p. 233, 1859; Heller, op. cit., p. 85.

A single specimen in a *Scolymus* was collected by Prof. Hartt at the Reefs of the Abrolhos.

Calcinus sulcatus Stimpson.

Pagurus sulcatus Edwards, Annales des Sciences naturelles, 2de série, tome vi, p. 279, 1836; Histoire naturelle des Crust., tome ii, p. 230.

Pagurus tibicen White (*variety*), List of Crust. in the British Museum, p. 61.

Calcinus sulcatus Stimpson, Proceedings Acad. Nat. Sci., Philadelphia, 1858, p. 234.

A male of this species was collected at the Reefs of the Abrolhos. Length of body from front of carapax to tip of abdomen, 23·5mm; length of left hand, 7·6; breadth of left hand, 4·5.

It is closely allied to *C. tibicen* Dana and *C. obscurus* Stimpson, but differs remarkably from both of them in the deep and rugose sulcus on the outer side of the propodus of the left leg of the second ambulatory pair. This sulcus is very marked, extends the whole length of the segment, and is limited on the upper side by a sharp carina. From the *obscurus* it differs moreover in having the carapax broader in front, and the antero-lateral angle more prominent, and not rounded, as it is in that species. The larger hand is much narrower and more cylindrical, and the dactyli of the ambulatory legs are not so strongly curved as in *C. obscurus.*

Clibanarius vittatus Stimpson.

Pagarus vittatus Bosc, Histoire naturelle des Crust., tome ii, p. 78, pl. 12, fig. 1, 1802; Edwards, Histoire naturelle des Crust., ii, p. 237; Gibbes, loc. cit. p. 189.

Clibanarius vittatus Stimpson, Proceedings Acad. Nat. Sci., Philad., 1858, p. 335, 1859; Annals Lyc. Nat. Hist., New York, vol. vii, p. 84.

Several specimens were collected at Caravellas, Province of Bahia. They do not differ perceptibly from Florida specimens, except that the hands are perhaps a little less tuberculose.

Clibanarius sclopetarius Stimpson.

Cancer sclopetarius Herbst, op. cit., Band ii, p. 23, Tab. 23, fig. 3, 1796.

Pagurus sclopetarius Bosc, Histoire naturelle des Crust., tome ii, p. 76, 1802; Edwards, Histoire naturelle des Crust., tome ii, p. 229.

Clibanarius sclopetarius Stimpson, Proceedings Acad. Nat. Sci., Philadelphia, 1858, p. 235, 1859; Annals Lyc. Nat. Hist., New York, vol. vii, p. 85.

A single specimen was collected in shoal water at the mouth of the Caravellas River, Province of Bahia.

Clibanarius Antillensis Stimpson.

Clibanarius Antillensis Stimpson, Proceedings Acad. Nat. Sci., Philadelphia, 1858, p. 235, 1859; Annals Lyc. Nat. Hist., New York, vol. vii, p. 85.

I refer to this species a large number of specimens collected at the Reefs of the Abrolhos.

It is certainly very closely allied to *C. Brasiliensis* Dana (United States Exploring Expedition, Crust., p. 467, pl. 29, fig. 7), but the opthalmic scales are somewhat larger than represented in Dana's figure, and the right leg of the third pair convex upon the outside. In the alcoholic specimens the ground color of the hands and ambulatory legs is reddish-yellow, instead of olive.

MACROURA.

Scyllarus æquinoxialis Fabricius.

Scyllarus æquinoxialis Fabricius, Supplementum Entomologiæ systematicæ, p. 399, 1798; Bosc, op. cit., tome ii, p. 19; Edwards, Histoire naturelle des Crust., tome ii, p. 285, pl. 24, fig. 6.

A single male specimen collected at Bahia appears to belong to this species.

The carapax is broad, the breadth in front exceeding slightly the length of the lateral margin, evenly convex above, the regions scarcely indicated, and covered, as is also the upper side of the abdomen, with small squamiform tubercles of uniform size, and each bearing several small fascicles of short setaceous hairs. The anterior margin, the margin of the orbits, and the lateral margin are armed with numerous, small, obtusely rounded, tuberculiform teeth.

The antennulæ extend slightly beyond the tips of the antennæ; the basal segments are clothed below with short setæ; the terminal segments of the peduncle are smooth and cylindrical; the inner flagella are nearly as long as the last segment of the peduncle, sparsely ciliate and tapering regularly to a slender point; the outer flagella are stouter, and considerably shorter than the inner. In the antennæ, the basis is very short and broad, so that, on the outside, the base of the ischium nearly touches the anterior margin of the carapax; the ischium is much broader than long, the middle portion rough and hairy, the outer and anterior margins smooth and naked, and the edges slightly and irregularly toothed, except the process on the inner side which has two strong teeth upon its inner edge and a smaller one on the anterior edge toward the articulation with the merus; the carpal, or last segment, is broader than long, the edge arcuate and crenulated, the middle portion above and below roughened with short, stiff hairs, but a broad space along the margin smooth.

All the inferior surface of the thorax and the exposed parts of its appendages are rough with short, stiff hairs or setæ. The thoracic legs have a carina upon the posterior edge of the merus and carpus, which is very high and thin on the merus in all except the posterior pair. The dactyli in the first and second pairs are smooth and unarmed, but in the second pair they are longer and much slenderer than in the first; in the last three pairs they are armed with fascicles of stout horny setæ.

The lamellæ of the appendages of the second segment of the abdomen are lanceolate, and the inner and outer of about equal size. The appendages of the three succeeding segments are rudimentary and scarcely project below the edge of the segments. The lamellæ of the appendages of the penultimate segment are broadly rounded at the extremities, and the inner ones project beyond the tip of the terminal segment. The terminal segment is broader than long, and the extremity truncate with the angles rounded.

The following description of the colors was taken from the specimen when recently preserved in alcohol, and when, according to Prof. Hartt, the colors were as in life.

General color above reddish-brown; antennæ lighter, bordered with bright purple, and the teeth of the edge orange-red; antennulæ light reddish; carapax with the frontal and median tubercles, the tubercles of the orbits and of the anterior and lateral margins orange-red; first segment of the abdomen bright orange, the median portion slightly mottled with purplish-red, and with two large circular reddish-purple spots; the succeeding segments with the smooth anterior portion, orange mottled with purplish-red; terminal segment and the lamelliform appendages of the penultimate segment brownish-yellow, almost white at the extremities. Beneath, dirty yellowish; antennæ with the colors of the upper side dimly repeated; legs with slight purple annulations at the articulations.

Length of body from tip of rostrum to extremity of abdomen,	190·0mm
" of carapax from tip of rostrum to middle of posterior margin,	86·0
Breadth of carapax,	71·2
Length of antennulæ, below,	55·0
" antennæ, "	52·0
" first thoracic legs,	76·0
" second "	92·0
" third "	83·5
" fourth "	72·0
" fifth "	75·0

Panulirus echinatus, sp. nov.

This species is closely allied to *P. guttatus.*

The carapax is armed with numerous stout spines, those on the anterior part of the carapax larger than those behind; the surface between the spines is closely filled with small tubercles, which are beset with short, stiff hairs, and many of the tubercles in front of the cervical suture are tipped with spinules. The cervical suture is marked by a deep depression.

The antennulary segment is armed with two straight and slender spines which project forward and upward, their length twice as great as the distance between their tips. The superior orbital spines are stout and long, and extend slightly beyond the tips of the eyes. On the anterior border below the eye, there are two other spines projecting over the base of the antennæ; from the inner of these there is a line of about eleven smaller spines, three of which are in front of the cervical suture, extending to the postero-lateral angle of the carapax; below this line there are no spines on the branchial region. Just behind each of the superior orbital spines there is a stout spine as large as the spines on the anterior margin below the eye; behind these spines, and in front of the cervical suture, there are four smaller spines, thus forming, with the orbital spines, two-subdorsal lines of four spines each, which are succeeded behind the cervical suture, by two lines of five small spines each. On the median line of the anterior part of the gastric region there are three small, sharp spines. The remaining spines of the carapax are disposed irregularly.

The peduncle of the antennula extends slightly beyond the peduncle of the antenna; the basal segments are armed with short setæ. The inner flagellum is about as long as the carapax, quite slender and wholly naked; the outer flagellum is shorter, much stouter, and the terminal portion ciliated beneath.

The peduncle of the antenna is a little longer than the breadth of the carapax, and is armed with stout spines, three of which are on the anterior edge of the basis, and another on the inner side, below and near the outer of the three spiniform teeth of the anterior edge of the epistome. The flagellum is about three times as long as the carapax, tapers to a slender point, and is armed with sharp spines.

The external maxillipeds, when extended, reach nearly to the anterior extremity of the basis of the antennæ, and all the segments are thickly clothed on the inside, and the dactylus all round, with stiff hairs; the exognath is rudimentary, about half as long as the dactylus of the endognath, quite slender, and is wholly without a flagellum.

The thoracic legs are smooth and naked, except the dactyli and the outer portion of the under side of the propodi; the meral segments are each armed with two sharp spines, one above and another on the inside at the extremity next the articulation with the carpus. The legs of the first pair are shorter than the others, do not reach quite as far forward as those of the second pair, and the dactyli are stout and thick. Those of the second and third pairs are more slender than the others, especially the penultimate segments, the dactyli straight nearly to the tips, which are hooked abruptly down. The third pair reach slightly beyond the second. The fourth pair extend only to the middle of the propodi of the third pair; the carpus is armed with a stout and sharp spine on the upper edge of the extremity next the propodus, where there is no spine in the other legs; the dactylus is stout, the basal portion armed beneath with slender spines, which are articulated at the base and movable, and the terminal portion tapering to a slender point and curved evenly downward. The legs of the fifth pair reach to the middle of the propodi of the fourth; the coxa is armed with a long, sharp spine on the posterior side and near the articulation with the basis; the dactylus in the male is similar to that in the fourth pair, but shorter and more curved; in the female the dactylus is somewhat shorter than in the male, and armed on the posterior side of the base with a stout process which closes against a similar process from the extremity of the propodus, both processes being hairy upon the outside and having horny, spoon-shaped tips.

The abdomen is nearly smooth, and all the segments, except the terminal, are crossed by a narrow and thickly ciliated sulcus, which is interrupted in the middle on the third, fourth and fifth segments. The first segment has a single, short lateral tooth. The remaining segments, except the last, have this tooth spiniform and very large, and a small additional one behind it; the larger tooth is armed, except in the penultimate segment, with one or two small spines or denticles on the anterior edge, near the base. The posterior edge of the penultimate segment above is armed with close set, sharp teeth.

The lamelliform appendages of the sixth segment of the abdomen are of about equal length, broad and truncate at the tips. The lamella of the last segment is slightly narrowed and truncate at the tip, and does not extend beyond the lamellæ of the sixth segment. In the male, the lamellæ of the second to the fifth segment are ovate and all of about the same size. In the female, these lamellæ are very much larger; in the second segment, the inner one is of the same form and nearly of the same size as the outer; in the three following segments the outer lamellæ decrease in size successively, and the inner lamellæ are each composed of two branches, the outer branch being narrow, triangular, its edges thickened, multi-articulate and clothed with long hairs; the inner branch slender, not tapering, articulated at the base of the outer branch, not jointed like the outer branch, but composed of a single piece, and clothed beneath and at the tip with long hairs.

Two specimens give the following measurements:—

	Male.	Female.
Length of body from base of antennulæ to extremity of abdomen,	135·0mm	165·0mm
Length of carapax from base of antennulæ to middle of posterior margin,	59·5	68·5
Breadth of carapax,	36·2	42·2
Length of antennulæ,	103·0	109·0
" inner flagellum of antennulæ,	61·4	64·0
" outer " "	48·0	50·8
" antennæ,	260·0	290·0
" first thoracic legs,	81·0	89·0
" second, "	92·5	102·2
" third, "	101·0	111·0
" fourth, "	83·0	92·5
" fifth, "	72·5	77·0

Several specimens were obtained at Pernambuco.

This species appears to be closely allied to the *P. guttatus* of the West Indies, but that species, according to Edwards' description and figure

(Histoire Naturelle des Crust., tome ii, p. 297, pl. 23, fig. 1 and 2,) has the thoracic legs of the second pair longer than those of the third; he also states that the transverse sulci of the abdomen are not interrupted on the first three segments; and moreover, in his figures no spines are indicated upon the bases of the antennæ, or upon the coxæ of the posterior thoracic legs, and the flagella of the antennæ and the antennulæ are much shorter than in our species.

Heller (op. cit., p. 95) and DeHaan (op. cit., p. 159), both state that in the *guttatus* the spaces between the spines of the carapax are smooth, while in our species they are tuberculose and hairy. Neither Edwards, De Haan nor Heller mention the sub-cheliform posterior thoracic legs as a character of the female of *P. guttatus.*

Alpheus heterochelis Say.

Alpheus heterochelis Say, Journal Acad. Nat. Sci., Philadelphia, vol. i, p. 243, 1818; Edwards, Histoire naturelle des Crust., tome ii, p. 356; Gibbes, loc. cit., p. 196.
Alpheus armillatus Edwards?, Histoire naturelle des Crust., tome ii, p. 354, 1837.
Alpheus lutarius Saussure, op. cit., p. 45, pl. 3, fig. 24, 1858.

A large number of specimens collected at the Reefs of the Abrolhos agree perfectly with specimens from Florida and Aspinwall.

Palæmon Jamaicensis Olivier.

Cancer (*Astacus*) *Jamaicensis* Herbst, op. cit., Band ii, p. 57, Tab. 27, fig. 2, 1796. *Palæmon Jamaicensis* Olivier, Encyclop., tome viii, (*teste* Edwards,); Desmarest, op. cit., p. 237; Edwards, Histoire naturelle des Crust., tome ii, p. 398, Règne animal de Cuvier, 3e édit., pl. 3, fig. 4; Saussure, op. cit., p. 49.

Of this species there are in the collection two specimens, both males, from Penêdo, Rio Sao Francisco.

In both specimens the rostrum is stout, a little shorter than the antennal scale, and is armed above with twelve, and below with four teeth. The anterior legs are longer than the carapax, and nearly naked, except a few fascicles of hairs on the fingers; the hands are slender, and about half as long as the carpus, which is slightly shorter than the merus. In the smaller specimen the second pair of legs are equal, stout, very long, and thickly beset with small spines; the hands are cylindrical, much longer than the carapax, and the fingers half as long as the palmary portion of the hand. In the larger specimen the legs of the second pair are quite unequal, the left one being considerably longer and much stouter than the right, and the fingers only a third as long as the palmary portion; the right hand is much as in the other specimen, but considerably smaller in proportion. In both specimens the penultimate segment of the abdomen is broad, the lamellæ of its appendages are broadly rounded at their extremities, and the outer ones slightly broader, but scarcely longer, than the inner. The terminal segment of the abdomen is stout, its extremity broad, rounded, ciliate, and has a small movable spine on each side.

A single, small and somewhat imperfect specimen, also a male, from Caravellas, Province of Bahia, is apparently the young of this species, but presents some differences. The rostrum is armed with fifteen teeth above and three below, and the legs of the second pair are quite short, extending but little beyond the first pair, sparsely spinulose, and the hands quite slender. In other respects it agrees closely with the larger specimens.

The three specimens give the following measurements:—

	Penedo,	Sao Francisco.	Caravellas.
Length from tip of rostrum to extremity of abdomen,	151·0mm	126·0mm	54·4mm
Length of carapax from orbit to middle of posterior margin, - - - - - -	48·0	41·2	18·0
Breadth of carapax, - - - -	27·2	23·5	9·8
Length of rostrum from its tip to base of eyes, -	21·8	18·6	8·0
" basal scale of antenna, - -	23·0	19·0	8·8
" first thoracic legs, - - -	68·0	57·8	26·0
" merus in first thoracic legs, -	17·8	15·0	7·0
" carpus, " " - -	21·0	16·6	8·4
" hand, " " - -	12·0	10·5	4·3
" dactylus, " " - - -	5·8	5·2	2·1
" second thoracic legs, - -	114·0—132·0	115·0	31·2
" merus in second thoracic legs, -	20·0— 25·5	25·0	5·9
" carpus, " " - -	16·8— 24·0	17·2	6·0
" hand " " - - -	54·0— 58·0	59·0	10·8
" dactylus, " " - -	27·2— 21·0	30·0	5·3

Palæmon forceps Edwards.

Histoire naturelle des Crust., tome ii, p. 397, 1837; Saussure, op. cit., p. 51; White, List of Crust. in the British Museum, p. 78.

A large number of specimens of this species was obtained by Prof. Hartt at the mouth of the Pará.

The larger males agree with Edwards' description. The carapax is granulous, especially on the sides. The rostrum is stout, nearly straight, extends slightly beyond the antennal scale, and is armed above with nine or ten, and below with five to seven teeth. The antennal and hepatic spines are stout and of about equal size. The legs of the second pair are very long, cylindrical, the inner and the inferior sides of the merus, carpus and the basal half of the hand are armed with about four longitudinal lines of slender spines, the upper and outer sides thickly set with short spinules and slightly hairy; the fingers are slender, cylindrical and thickly covered with a woolly pubescence. The lamelliform appendages of the penultimate segment of the abdomen are broadly rounded at their tips, and the outer ones are scarcely longer than the inner. The terminal segment of the abdomen is narrower than in *P. Jamaicensis*, the sides are straight, and the tip has a strong median tooth and a slender spine each side.

The young males are quite similar to the full-grown, but the carapax is nearly smooth, the rostrum somewhat upturned at the extremity, and the legs of the second pair are smaller in proportion, and the spines and spinules less developed.

The females differ remarkably from the males, all the specimens being considerably smaller, and resembling the young males. The carapax is much more gibbous and quite smooth, even in the largest specimens. The rostrum in front of the eyes curves upward considerably, and much more strongly in the small than in the large specimens. The legs of the second pair are quite slender, much shorter than in the male, only slightly spinulose in the large specimens, and almost wholly smooth and naked in the smallest. Of the ten specimens in the collection every one has large masses of eggs under the abdomen.

Five specimens given the following measurements :—

	Male.	Male.	Male.	Female.	Female.
Length of body from tip of rostrum to extremity of abdomen,	142·0mm	125·0mm	75·0mm	106·0mm	76·0mm
Length of carapax from orbit to middle of posterior margin,	36·4	33·5	19·6	27·4	18·0
Breadth of carapax, -	23·8	20·4	11·8	18·4	11·2
Length ef rostrum from its tip to base of eyes, - -	31·0	29·0	17·2	22·6	20·0
Length of basal scale of antenna,	26·5	23·0	15·2	19·7	14·5
" first thoracic legs,	57·0	50·0	31·0	40·0	27·4
" merus in first thoracic legs, - - -	15·2	13·0	7·6	10·4	7·4
Length of carpus, - -	19·2	17·4	10·5	13·4	9·4
" hand, - -	8·0	7·6	4·8	6·0	4·0
" second thoracic legs,	171·0—158·0	143·0	67·0—43·0	75·0	43·0
" merus in second thoracic legs, - - -	35·0— 32·4	28·0	13·4— 9·8	15·0	8·5
Length of carpus, -	50·2— 44·0	40·0	20.0—10·0	20·2	14·0
" hand, - -	60·2— 56·0	50·0	22·6—14·0	22·5	10·8
" dactylus, - -	28·0— 25·0	24·0	11·0— 7·5	11·0	5·2

Palæmon ensiculus, sp. nov.

Plate I, figure 2.

The carapax is somewhat gibbous, and the antennal and hepatic spines are slender, sharp and of about equal size. The rostrum is very long, strongly curved downward for the basal half of its length, the terminal half very slender, nearly straight, but strongly inclined upwards; it is armed above with nine to twelve short teeth, which are ciliated along their edges, and of which seven or eight are on the basal portion, and the others near the tip, and below with eight to twelve teeth.

The eyes are large and the peduncles rather long and slender. The flagella of the antennula are very long, the outer flagellum about as long as the whole body and the inner a little shorter. The peduncle of the antenna is armed with a small spine on the outside just below the articulation of the basal scale; the basal scale is long but not reaching, by considerable, the tip of the rostrum, the extremity evenly rounded and extending considerably forward of the small, acutely pointed tooth at the anterior extremity of the outer margin; the flagellum is very long, considerably exceeding in length the flegella of the antennulæ. The external maxillipeds are slender, reaching slightly beyond the base of the flagella of the antennæ.

The first pair of thoracic legs are very slender, reaching slightly beyond the basal scales of the antennæ, smooth and naked, except a few fascicles of hairs on the hands. The second pair of legs in the male are very long and quite slender, in full-grown specimens the merus reaching beyond the tip of the antennal scale and all the segments to the base of the fingers closely beset with short spinules; the hands are cylindrical, not swollen, the fingers slender and sparsely clothed with short, downy pubescence. In the females and young the second pair of legs are considerably smaller and much less spinulose. The third pair of legs reach to the tips of the basal scales of the antennæ. The fourth and fifth pairs are successively a little longer.

The abdomen is rather slender. The penultimate segment is long and narrow, the length above being nearly or quite twice as great as the breadth; the lamelliform appendages are rather narrow, the inner ones rather acutely rounded at the tips and reaching a little beyond the terminal segment of the abdomen, the outer ones evenly rounded at the tips and considerably longer than the inner ones. The terminal segment is narrow and tapers regularly to a very slender and acute point.

Several specimens give the following measurements:—

	Male.	Male.	Female.	Female.
Length of body from tip of rostrum to extremity of abdomen, - - -	108·0mm	91·0mm	89·0mm	65·0mm
Length of carapax from orbit to middle of posterior margin, - - - -	25·0	19·3	21·0	14·4
Breadth of carapax, - - -	15·5	12·0	13·6	9·0
Length of rostrum from its tip to base of eyes,	29·0	26·0	21·0	20·6
" basal scale of antenna, - -	19·0	16·0	16·0	12·8
" first thoracic legs, - -	36·4	27·0	28·5	20·0
" merus in first thoracic legs, -	9·6	7·5	8·0	5·7
" carpus " " -	11·8	9·0	8·8	6·6
" hand " " -	4·8	4·2	4·0	3·0
" second thoracic legs, - -	103·0	54·0	55·7	32·0
" merus in second thoracic legs, -	21·0	11·4	11·2	7·2
" carpus " " -	30·0	16·7	17·0	10·4
" hand " " -	32·5	14·4	15·5	7·0
" dactylus " " -	14·8	6·7	6·5	2·8

A large number of specimens of this fine species were obtained by Prof. Hartt at Pará.

Peneus Brasiliensis Latreille.

Peneus Brasiliensis Latreille, Nouveau Dictionnarie d'Histoire naturelle, tome xxv, p. 154 (*teste* Edwards); Edwards, Histoire naturelle des Crust., tome ii, p. 414; White, List of Crust. in the British Museum, p. 80; Gibbes, loc. cit., p. 198.

I refer to this species a large number of small specimens obtained by Prof. Hartt at Bahia. They agree perfectly with a specimen from the west coast of Florida, which is undoubtedly the same as the species described by Gibbes from South Carolina.

Xiphopeneus, gen. nov.

The carapax is much as in *Peneus*, but the rostrum is very long, its extremity very slender, and the gastro-hepatic sulcus is scarcely perceptible, while the cervical and branchio-cardiac sulci are distinct. The antennulæ are long and slender, and the peduncle has only a very small lamelliform appendage on the inside, which is not foliaceous and expanded over the eye as in *Peneus;* the flagella are very long and slender, the upper ones being much stouter and longer than the lower. The antennæ, maxillipeds and the three anterior pairs of thoracic legs are nearly as in *Peneus.* The fourth and fifth pairs of thoracic legs are very long, and the terminal segments very slender and flagelliform. The abdomen is quite similar to *Peneus*, but the lamellæ of the appendages of the first five segments are much longer than is usual in that genus.

This genus has much the aspect of *Peneus*, and is closely allied to it in the antennæ, maxillipeds, anterior thoracic legs and abdomen, but differs from it remarkably in the carapax, antennulæ and posterior thoracic legs.

Xiphopeneus Harttii, sp. nov.

Plate I, figure 1.

The carapax is not at all swollen; a very slight, rounded dorsal carina extends from the base of the rostrum to the posterior border; the cervical and branchio-cardiac sulci are very distinct, and together form a nearly straight groove from near the base of the antennæ almost to the posterior border; the inferior margin of the carapax is nearly straight, projecting slightly along the branchial region; the antennal spine is prominent and rather stout, and the hepatic spine slender and acute. The rostrum is very long and slender, in length nearly equalling or considerably exceeding the carapax, wholly unarmed below, but the basal portion armed above with a thin and high carina, which extends back upon the carapax a short distance, and forward as far as the eyes, and is armed with five sharp and prominent teeth, and at its posterior extremity with another tooth which is smaller, much below the level of the others, and separated from them by a considerable space; the portion in front of the eyes is nearly straight or a little upturned, sub-cylindrical, slightly flattened laterally, unarmed, perfectly smooth and tapers to a very slender point far in front of the antennal scales.

The eyes are of moderate size, and the peduncles much shorter than in most species of *Peneus*.

The appendages upon the inside of the peduncle of the antennulæ are surmounted by a tuft of hairs which fills a little depression in the ocular peduncle. The first antennulary segment in advance of the eye is sub-cylindrical, flattened on the under side, and nearly as long as the peduncle of the eye; the next anterior segment is cylindrical and one-half as long as the last. The upper flagellum of the antennula is slender, about three times as long as the carapax, and has a short portion at the base slightly thicker than the rest; the lower flagellum is very slender and about half as long as the upper.

The basis of the antenna is armed with a small, sharp spine just below the articulation of the antennal scale. The antennal scale reaches to the base of the flagella of the antennula, is much narrowed toward the tip, the outer margin is straight and armed with a sharp tooth at the anterior extremity, and the inner margin is nearly straight and thickly ciliated. The three anterior segments of the peduncle are cylindrical, and the last (carpal) is much longer than in most species of *Peneus*, so that it reaches to the middle of the antennal scale. The flagellum is very much longer than the whole length of the body.

The second pair of maxillipeds, when extended, reach nearly to the base of the antennal scale; the merus is nearly three times as long as broad, and thickly hairy on the inner edge; the exognath is very slender, clothed along the edges with long cilia, and scarcely reaches the tip of the extended dactylus. The external maxillipeds reach slightly beyond the middle of the antennal scale and are thickly setose along the inner edges; the exognath is slender, extends slightly beyond the merus of the endognath, and is ciliated as in the maxillipeds of the second pair.

The thoracic legs of the first pair reach about to the middle of the propodus of the external maxillipeds, are slender and beset with stiff hairs along the edges, and the basis is armed with a short spine on the inner side near the articulation with the ischium. The second and third pairs of legs are successively a little longer, perfectly smooth, and the basal segments unarmed. The legs of the fourth and fifth pairs are smooth and unarmed, and all the segments, except the coxal and basal, are very slender and very much prolonged, the terminal segments being fully as slender as the terminal portions of the flagella of the antennulæ.

The abdomen is compressed, and upon the fourth, fifth and sixth segments there is a dorsal carina which is high and sharp upon the sixth, and terminates posteriorly in a slight tooth upon the fifth and sixth. The terminal portion of the appendages of the first segment is long, slender and ciliated along the edges; in the appendages of the four succeeding segments the outer of the terminal branches are like the terminal portion of the appendages of the first segment, and of about the same length, while the inner branches are but half as long. The penultimate segment is strongly compressed, and its lamelliform appendages are rather long and narrow, the inner ones projecting considerably beyond the terminal segment, ciliated along both edges and narrowly triangular at tip, the outer ones ciliated along the inner edges and rounded at the tip. The terminal segment tapers regularly to a very slender and acute point, the edges of the terminal half are ciliated, and there is a deep median groove upon the dorsal surface.

In the male, the appendages of the first abdominal segment (plate I, fig. 1[a]), are connected together near their bases by a peculiar sexual organ which depends between them, and consists of a central tubular portion articulated with the bases of the abdominal appendages by a short process on each side and furnished at the lower extremity with two stiff, horn-like, tubular processes. The central portion is open on the posterior side for its whole length, and the membrane of which it is composed is folded into deep longitudinal grooves, except on the anterior side which is smooth and flattened, and traversed longitudinally by a median suture. The horn-like, terminal processes curve slightly backward and downward, and have an opening on the lower side at the tips. The inner of the terminal branches of the appendages of the second abdominal segment are furnished at the base on the anterior side with a small, ovoid, flattened, cushion-like organ which is wanting in the appendages of the other abdominal segments, and in all of those of the female.

Three specimens give the following measurements:—

	Male.	Female.	Female.
Length of body from tip of rostrum to extremity of abdomen, - - - - - -	87·0mm	133·0mm	112·0mm
Length of carapax from orbit to middle of posterior margin, - - - - - -	18·0	31·8	25·5
Breadth of carapax, - - - -	8·5	15·0	12·5
Length of rostrum from tip to base of eyes, - -	22·0	31·5	26·0
" basal scale of antenna, - -	13·4	20·8	18·4
" first thoracic legs, - - - -	17·5	29·0	25·4
" hand in first thoracic legs, - -	4·3	7·7	6·1
" second thoracic legs, - - -	22·2	41·5	35·0
" hand in second thoracic legs, - -	5·4	10·0	8·2
" third thoracic legs, - - - -	31·5	58·0	46·0
" hand in third thoracic legs, - -	6·2	12·8	9·8
" merus in fourth thoracic legs, - -	14·2	32·2	20·0
" carpus, " " - -	14·6	——	——
" fifth thoracic legs, - - - -	85 +	——	——
" merus in fifth thoracic legs, - -	17·5	27·0	23·5
" carpus " " - - -	21·0	27·5	29·4
" propodus " " - -	23·0	——	——
" dactylus " " - - -	16 +	——	——
" first pair of abdominal appendages, -	21·6	32·0	29·0
" second " " - -	22·0	32·5	29·4

Several specimens of this remarkable species—all of them somewhat broken and in rather bad condition—were obtained by Prof. Hartt at Caravellas, Province of Bahia.

SQUILLOIDEA.

Gonodactylus chiragra Latreille (?).

Squilla chiragra Fabricius, Supplementum Entomol. systematicæ (*teste* Edwards).

Gonodactylus chiragrus Latreille, Encyclopédie méthodique, tome x, p. 473, plate 325, fig. 2 (*teste* Edwards); Edwards, Histoire naturelle des Crust., tome ii, p. 528, Gibbes, loc. cit., p. 201.

A species of *Gonodactylus* was collected by Prof. Hartt at the Reefs of the Abrolhos and at Caravellas, Province of Bahia, which does not differ from the common West Indian and Florida species. The American species is, however, very likely distinct from the true *G. chiragra* of the old world.

In the foregoing list 32 species are mentioned, of which 21 appear to be new to the fauna of Brazil; and of these 21 species, 6 are described as new to science, and the remaining 15 are all species previously known from the West Indies or Florida.

In order to give a better idea of the crustacean fauna of the whole Brazilian coast, I append the following list.

List of the described species of Brazilian Podopthalmia.

Previous to Milne Edwards' general work,* scarcely anything was known of the crustacea of South America, and even in this work Edwards records Brazil as the habitat of very few species. Some additional species, however, are recorded in his later papers on the Ocypodoidea,† and Alphonse Milne Edwards has added a single species in his monograph of the Portunids.‡ A few other species are mentioned in short papers by Bell,§ Weigman,‖ and Bate,¶ and quite a

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* Histoire naturelle des Crustacés. Paris; tome i, 1834; ii, 1837; iii, 1840.

† Observations sur la Classification des Crustacés. Annales des Sciences naturelles, 3me série; De la famille des Ocypodides, tome xviii, 1852, pp. 128–166, pl. 3–4; Suite (1), tome xx, 1853, pp. 163–228, pl, 6–11.—Notes sur quelques Crustacés nouveaux ou peu connus. Archives du Muséum d'Histoire naturelle, Paris, tome vii, pp. 145–192, pl. 9–16, 1854.

‡ Etudes zoölogiques sur les Crustacés récents de la famile des Portuniens. Archives du Muséum d'Histoire naturelle, Paris, tome x, pp. 309–428, pl. 28–38, 1861.

§ Some Account of the Crustacea of the coasts of South America. Transactions Zoölogical Society, London, vol. ii, pp. 39–66, pl. 8–13, 1841, and Proceedings Zoölogical Society, 1835, pp. 169–173.

‖ Beschreibung einiger neuen Crustaceen des Berliner Museums aus Mexiko und Brasilien. Archiv für Naturgeschichte, 1836, Band i, pp. 145–151.

¶ Carcinological Gleanings, No. III. Annals and Magazine of Natural History, 4th series, vol. i, June, 1868, p. 447.

number of species are indicated by White in the list of Crustacea in the British Museum,* but unfortunately descriptions of many of the new species have not yet appeared. But by far the largest accessions to our knowledge of the crustacea of this coast were made by Prof. Dana in his work on the Crustacea of the United States Exploring Expedition.† Although the expedition touched on the Brazilian coast only at Rio de Janeiro, over forty species of Podophthalmia alone were collected and described. More recently Heller has enumerated the species taken by the naturalists accompanying the Austrian Expedition round the world during the years 1857–1859.‡ Unfortunately, however, this expedition also touched only at Rio de Janeiro, and consequently but few species were obtained which were not observed by Dana.

From the works of these authors, Prof. Harrt's collection, and a few species in the collection of the Peabody Academy of Science, the following list has been compiled.

A few species, of which the localities are questionable or suspected are preceded by a mark of doubt, thus (?), but all queries which are not inclosed in parenthesis are quoted directly from the author whose name they precede. When I have personally examined specimens from the localities mentioned, they are followed by an !. In all other cases the authority on which it is inserted follows the locality.

BRACHYURA.

MAIOIDEA.

Maiidæ.

Libinia spinosa Edwards.

"Les côtes du Brésel" (Edwards, Hist. nat. des Crust., tome i, p. 301).

Libidoclea Brasiliensis Heller.

Rio de Janeiro (Heller, op. cit., p. 1).

Mithracidæ.

Mithrax hispidus Edwards.

Abrolhos! (Hartt). — Antilles (Edwards). Tortugas, Key Biscayne (Stimpson). South Carolina (Gibbes).

Mithraculus coronatus Stimpson.

Abrolhos! (Hartt).—Aspinwall! (F. H. Bradley). Tortugas (Stimpson).

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* List of the specimens of Crustacea in the collection of the British Museum. London. 1847.

† United States Exploring Expedition, during the years 1838–42, under command of Charles Wilkes, U. S. N., vol xii. Crustacea. Philadelphia, 1852. Plates, 1855.

‡ Reise der österreichischen Fregatte Novara um die Erde. Zoöl. Theil, zweiter Band, dritte Abtheilung, Crustaceen. Wien, 1865.

Eurypodidæ.

(?) *Eurypodius Latreillii* Guérin.

Rio de Janeiro (Bell, Transactions Zoölogical Society, London, vol. ii, p. 40).—Chili (Edwards and Lucas, Bell, White, Dana).—"Les îles Malouines" (Edwards, Hist. nat. des Crust., tome i, p. 284).

There is probably some confusion of localities here. Bell alone mentions the species as coming from Brazil, and as he had it also from Chili, some interchange of specimens may have taken place. The Chilian species is very likely distinct from the East Indian one.

Periceridæ.

Milnia bicornuta Stimpson.

Abrolhos! (Hartt).—Aspinwall! (F. H. Bradley). Antilles (Edwards, Saussure). Jamaica (White). Florida Keys! (E. B. Hunt). Bermudas! (J. M. Jones).

Peltinia scutiformis Dana.

Rio de Janeiro (Dana).

Acanthonyx Petiverii Edwards.

"Coast of Brazil" (Bell).—Antilles (Edwards).—(?) Valparaiso (Dana). (?) Galapagos Islands (Bell).

Epialtus Brasiliensis Dana.

Rio de Janeiro (Dana).

Epialtus marginatus Bell.

"Ad oras Brasiliæ" (Bell, Proceedings Zoöl. Soc., London, part iii, 1835, and Transactions Zoöl. Soc., London, vol. ii, p. 62).—"Ad Insulas Galapagos" (Bell, Transactions Zoöl. Soc., loc. cit.).

The specimens from the two coasts are probably distinct species, and if so the name *marginatus* should be retained for the Brazilian one, as in the first description Bell mentions only the Brazilian specimen. There is some confusion in regard to the locality from which the west coast specimen came, the habitats being given as quoted above, but in the remarks following the description in the Transactions, it is stated that the male specimen came from Valparaiso, where it was found in company with *E. dentatus* by Mr. Cuming.

Lucippa levis Dana.

Rio de Janeiro (Dana).

CANCROIDEA.

Xanthidæ.

Xantho parvula Edwards.

Brazil (Edwards).—Antilles (Edwards). Cape de Verdes (Stimpson).

Xantho dispar Dana.

Rio de Janeiro? (Dana).

Xantho denticulata White.

Abrolhos! (Hartt).—West Indies (White). Aspinwall! (F. H. Bradley). Bermudas! (J. M. Jones).

(?) *Menippe Rumphii* DeHaan.

Rio de Janeiro? (Dana). Pernambuco (White).—Jamaica (White).—East Indies (Herbst, Edwards, etc.).

The American species is probably distinct from the true *Rumphii* of the East Indies.

Panopeus politus Smith.

Abrolhos! (Hartt).

Panopeus Harttii Smith.

Abrolhos! (Hartt).

Panopeus Herbstii Edwards.

Rio de Janeiro (Heller, op. cit., p. 16).—Aspinwall! East and west coast of Florida! Bahamas! South Carolina!

Chlorodius Floridanus Gibbes.

Abrolhos! (Hartt)—Key West! (Gibbes). Aspinwall! (F. H. Bradley).

Pilumnus Quoyi Edwards.

Rio de Janeiro (Edwards).

ERIPHIDÆ.

Eriphia gonagra Edwards.

Rio de Janeiro (Dana, Heller). Abrolhos! (Hartt).*—Aspinwall! (F. H. Bradley). Tortugas (Stimpson). Florida Keys! (E. B. Hunt). Bahamas! (Coll. Bost. Soc. Nat. Hist.).—(?) Panama (Stimpson).

PORTUNIDÆ.

Callinectes ornatus Ordway.

Caravellas! (Hartt).†—Cumana; Hayti; Tortugas; Bahamas; South Carolina (Ordway). Bermudas! (J. M. Jones).

Callinectes larvatus Ordway.

Bahia! (Hartt).—Hayti; Tortugas; Key West; Bahamas (Ordway).

Callinectes Danæ Smith.

Pernambuco! (Hartt). Rio de Janeiro (Dana).

Acheloüs spinimanus DeHaan.

Rio de Janeiro (Dana, Heller). Bahia! (Hartt).‡—South Carolina (Stimpson, A. Edwards). West Florida! (E. Jewett). Martinique (A. Edwards).

Acheloüs Ordwayi Stimpson.

Bahia! (Hartt).—St. Thomas; Tortugas; Bay Biscayne (Stimpson).

Acheloüs Sebæ. (*Neptunus Sebæ* A. Edwards).

"Les côtes du Brésil" (A. Edwards).—Martinique (A. Edwards).

Cronius ruber Stimpson.

Brazil (Edwards, White, A. Edwards). Rio de Janeiro (Heller).—St. Thomas (Stimpson). Gulf of Mexico; Vera Cruz (A. Edwards). Key West (Gibbes).—Panama (Stimpson).

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* This species was collected from the whole coast. It is very lively, running over the rocks and hiding in holes at low water.—C. F. H.

† Taken in nets in shallow water on the borders of the bay.—C. F. H.

‡ Taken in shallow water and sold in the market for food.—C. F. H.

Arenæus cribrarius Dana.

Rio de Janeiro (Dana).—Guadaloupe; Gulf of Mexico; Vera Cruz (A. Edwards). Key West; South Carolina (Gibbes). New Jersey (Leidy).

Platyonychidæ.

(?) *Carcinus Mœnas* Leach.

Rio de Janeiro (Heller, op. cit., p. 30)—European coast.

OCYPODOIDEA.

Gonoplacidæ.

Eucratopsis crassimanus. (*Eucrete crassimanus* Dana).*

Rio de Janeiro ? (Dana).

Ocypodidæ.

Gelasimus maracoani Latreille.

Rio de Janeiro (Dana). Pernambuco (White). Porto Seguro; St. Cruz (Hartt).—Cayenne (Edwards). West Indies (White).

Gelasimus palustris Edwards. (*G. vocans* Dana).

Rio de Janeiro (Dana, Stimpson).—Aspinwall; Hayti; Texas; South Carolina; Old Point Comfort (Stimpson).

Gelasimus mordax, sp. nov.

Pará! (Caleb Cooke, Coll. Peabody Acad. Sci.).

(?) *Gelasimus stenodactylus* Lucas.

"Brésil" (Edwards, Annales des Sci. nat., 3me série, tome xviii, 1852, p. 149).—Chili (Lucas, Edwards).

Ocypoda rhombea Fabricius.

Rio de Janeiro (Dana, Heller).—Jamaica (White).

Gecarcinidæ.

Gecarcinus sp. White (List of Crust. in British Museum, p. 32).

Pernambuco (White).

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* Stimpson, from an examination of alcoholic specimens of *Eucrate crenatus* De Haan, has shown (Boston Journal Nat Hist., vol. vii, p. 588, 1863) that De Haan's genus *Eucrate* is distinct from the *Eucrate* as described by Dana, De Haan's genus having the male organs, or verges, arising from the coxæ of the posterior legs, and therefore belonging to the *Carcinoplacidæ* of Edwards, while Dana's species has sternal verges, and must therefore form the type of a new genus, for which I propose the name *Eucratopsis.* The genus thus constituted appears to be nearest allied to *Speocarcinus* Stimpson (Annals Lyc. Nat. Hist., New York, vol vii, p. 59, 1859), from which it is distinguished by the larger orbits, by the approximation of the inner margin of the maxillipeds, and by the much greater narrowness of the posterior part of the sternum.

Pelocarcinus Lalandei Edwards. (*Gecarcoidea Lalandei* Edwards).
Brazil (Edwards).

*Cardiosoma Guanhumi** Latreille.
Brazil (White).—Antilles (Edwards, Saussure). Florida Keys! (Gibbes). Cape de Verdes (Stimpson).

Cardiosoma quadratum Saussure.
Pernambuco! (Hartt).†—Aspinwall! (F. H. Bradley). Hayti (Saussure). Barbadoes; St. Thomas (Gill).

Uca cordata.
Bahia! (Hartt). Pará! (Coll. Peabody Acad. Sci.).—Surinam (Linné).

(?) *Uca una* Latreille, Edwards.‡
"Amérique méridionale" (Edwards). Rio de Janeiro (Von Martens, Zoöl. Record, vol. iv, 1867, p. 613).

TRICHODACTYLIDÆ.

Trichodactylus quadratus Edwards. (*T. fluviatilis* Latreille?).
Brazil (Edwards). Rio de Janeiro (Heller).

(?) *Trichodactylus punctatus* Eydoux et Souleyet?, Dana.
Rio de Janeiro (Dana).

Trichodactylus (?) *Cunninghami.* (*Uca Cunninghami* Bate).§
Tijuca, Province of Rio de Janeiro (Bate).

Sylviocarcinus Devillei Edwards (Archives du Muséum d'Hist. nat., tome viii, p. 176).
"Dans la rivière de l'Araguya, à Salinas, province de Goyas" (Edwards).

Dilocarcinus emarginatus Edwards (Archives du Muséum d'Hist, nat., tome viii, p. 181).
"Loretto, sur la Haute-Amazone" (Edwards).

Dilocarcinus pictus Edwards (Archives du Muséum d'Hist. nat., tome viii, p. 181).
"Loretto (Haute-Amazone)" (Edwards).

Dilocarcinus Castelnaui Edwards (Archives du Muséum d'Hist. nat. tome viii, p. 182).
"Salinas (province de Goyaz)" (Edwards).

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* Prof. Hartt informs me that this species, which lives in the mangrove swamps, is called *Guayamú*, and that it is mentioned under that name by Fonséca, so the specific name *Guanhumi* is probably a mistake for *Guayamú*.

† Taken in swamps.—C. F. H.

‡ According to Prof. Hartt a species of *Uca* is still called in Brazil *Vça-úna.* A tracing of the original figure of Marcgrave, however, indicates that his *Vça-úna* was not the *Uca una* of Latreille and Edwards, but more likely the *U. cordata.*

§ Annals and Mag. Nat. Hist., 4th series, vol. i, June, 1868, p. 447, pl. 21, fig. 3.

Grapsidæ.

Goniopsis cruentatus DeHaan.

Rio de Janeiro (Dana, Heller). Abrolhos! (Hartt).*—Surinam (Randall). Cuba (Saussure). Florida Keys! (Coll. Bost. Soc. Nat. Hist.).

Pachygrapsus simplex Stimpson. (*Goniograpsus simplex* Dana).

Rio de Janeiro? (Dana).—Madeira (Stimpson).

Pachygrapsus intermedius Heller (op. cit., p. 44).

Rio de Janeiro (Heller).

(?) *Pachygrapsus innotatus* Stimpson (*Goniograpsus innotatus* Dana).

"Locality uncertain; probably from the South American coast" (Dana).—Madeira (Stimpson).

If Dana's specimens came from South America, as supposed, they were undoubtedly from Brazil, since Stimpson's discovery of it at Madeira shows it to be an Atlantic species and the Wilkes Exploring Expedition touched, on the east coast of South America, only at Rio de Janeiro and on the coast of Patagonia.

Pachygrapsus rugulosus. (*Leptograpsus rugulosus* Edwards).

"Brésil" (Edwards).

This species is very likely the same as *P. innotatus*, which, according to Stimpson, is scarcely to be distinguished from *P. transversus* Gibbes. Edwards' description, three lines in length, is, however, too imperfect to determine anything in regard to the affinity of the species.

Pachygrapsus maurus Heller (Lucas).

Rio de Janeiro (Heller).—Mediterranean (Lucas, Edwards, Heller).

(?) *Pachygrapsus marmoratus* Stimpson. (*Goniograpsus varius* Dana?).

Rio de Janeiro? (Dana).—Madeira (Stimpson, Heller). Gibraltar (Heller). Mediterranean (Edwards, Heller).

Cryptograpsus cirripes Smith.

Rio de Janeiro! (Coll. Peabody Acad. Sci.).

Nautilograpsus sp. ("*Planes* ——" White).

Brazil (White, List of Crust. in British Museum, p. 42).

Cyclograpsus integer Edwards.

Brazil (Edwards).—Florida (Stimpson).

Helice granulata Heller (op. cit., p. 61). (*Chasmagnathus granulatus* Dana).

Rio de Janeiro (Dana, Heller). Rio Grande! (Capt. Harrington, Peabody Acad. Sci.).

(?) *Sesarma angustipes* Dana.

South America (Dana).—Aspinwall; on the east coast of Central America, neae Graytown; Florida (Stimpson).

Since this has proved to be an east coast and tropical species, there can be littl doubt that Dana's specimens were from Rio de Janeiro.

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* Found running about over the rocks at low tide on the fringing reef. It did not appear to be common.—C. F. H.

Aratus Pisonii Edwards. (*Sesarma Pisonii* Edwards).
Rio de Janeiro (Heller).—Antilles (Edwards). Jamaica (White). Florida (Gibbes, Stimpson).

CALAPPOIDEA.

Hepatidæ.

Hepatus angustatus White. (*H. fasciatus* Latreille, Edwards).
Rio de Janeiro (Dana, Heller).—Aspinwall (Stimpson).

ANOMOURA.

Dromidæ.

Dromidia Antillensis Stimpson.
Abrolhos! (Hartt).—St. Thomas!; Tortugas; Key Biscayne (Stimpson).

Porcellanidæ.

Petrolisthes leporinus. (*Porcellana leporina* Heller).
Rio de Janeiro (Heller).
The figure and description given by Heller would scarcely distinguish this species from the *P. armatus* Stimpson (Gibbes sp.).

Petrolisthes Brasiliensis, sp. nov. (*Porcellana Boscii*? Dana, p. 421, pl. 26, fig. 11, *non* Savigny, Crust. Egypt, pl. 7, fig. 2).
Rio de Janeiro (Dana).

Pachycheles moniliferus Stimpson (Dana).
Rio de Janeiro (Dana).

Porcellana frontalis Heller.
Rio de Janeiro (Heller).

Minyocerus angustus Stimpson (Dana).
Rio de Janeiro (Dana).

Hippidæ.

Hippa emerita Fabricius.
Rio de Janeiro (Dana, Heller).

Cenobitidæ.

Cenobita Diogenes Latreille.
Brazil (White, List of Crust. in British Museum, p. 61).

Paguridæ.

Petrochirus granulatus Stimpson (Olivier).
Rio de Janeiro (Dana, Heller). Abrolhos! (Hartt).—Antilles (Edwards) Key West (Gibbes). West coast of Florida! (E. Jewett).

Calcinus sulcatus Stimpson (Edwards).

Abrolhos! (Hartt).—Antilles (Edwards).

White reports *C. tibicen* Dana from Brazil and the West Indies, but as he included *C. sulcatus* as a synonym, his specimens were perhaps all of this species.

Clibanarius Brasiliensis Dana.

Rio de Janeiro (Dana).

Clibanarius Antillensis Stimpson.

Abrolhos! (Hartt).—Barbadoes (Stimpson).

Clibanarius vittatus Stimpson (Bosc).

Abrolhos! (Hartt).—Key West; Charleston (Gibbes). West coast of Florida! (E. Jewett).

Clibanarius sclopetarius Stimpson (Herbst).

Caravellas River, in the Province of Bahia! (Hartt).—Trinidad (Stimpson). Aspinwall! (F. H. Bradley, Stimpson). Tortugas (Stimpson).

Eupagurus criniticornis Stimpson (Dana).

Rio de Janeiro (Dana).

(?) *Eupagurus scabriculus* Stimpson (Dana).

Brazil ? (Dana).

(?) Galateidæ.

Under the name of *Galathea amplectens*, Fabricius, in his supplementum Entomologiæ systematicæ, p. 415 (*teste* Edwards), has described a crustacean from Brazil which seems to be unknown to subsequent writers. It is probably not a true *Galathea*.

MACROURA.

Scyllaridæ.

Scyllarus æquinoxialis Fabricius.

Brazil (White). Bahia! (Hartt).*—Antilles (Edwards). Key West (Gibbes).

Palinuridæ.

Panulirus argus White. (*Palinurus argus* Latreille, Edwards).

Bahia (White).—Antilles (Edwards, White).

Panulirus echinatus Smith.

Pará! (Hartt) †

Palæmonidæ.

Alpheus heterochelis Say.

Abrolhos! (Hartt).—Aspinwall! (F. H. Bradley.) Cuba (Saussure). Key West (Gibbes). West coast of Florida! (E. Jewett). South Carolina (Gibbes. Say).

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* Taken in shallow water on the borders of the bay and used for food.—C. F. H.

† Used for food and sold in the market. I have seen it from much farther south.—C. F. H.

Alpheus tridentulatus Dana.
Rio de Janeiro ? (Dana).

Alpheus malleator Dana.
Rio de Janeiro ? (Dana).

Hippolyte exilirostratus Dana.
Rio de Janeiro (Dana).

Hippolyte obliquimanus Dana.
Rio de Janeiro (Dana).

Palæmon Jamaicensis Edwards.
Penêdo, Rio Sao Francisco! (Hartt).* Pernambuco (White).—Antilles (Edwards). Antilles and Gulf of Mexico (Saussure).

Palæmon spinimanus Edwards.
Brazil (Edwards, White).—Antilles (Edwards). Cuba (Gibbes).

Palæmon Olfersii Weigman (Archiv für Naturges. 1836, p. 150).
"An der Küste Braziliens" (Wiegman).

Palæmon forceps Edwards.
Pernambuco (White). Rio de Janeiro (Edwards). Mouth of the Pará! (Hartt).—Antilles, Gulf of Mexico (Saussure).

Palæmon acanthurus Wiegman (loc. cit., p. 150).
"Das Vaterland ist die Küste Braziliens" (Wiegman).

Palæmon ensiculus Smith.
Pará! (Hartt).

(?) "*Palæmon Lamarrei* Edwards?" (White).
Pernambuco (White).—Côtes du Bengale (Edwards).

PENEIDÆ.

Sicyonia carinata Edwards.
Rio de Janeiro (Edwards, Dana).

Peneus Brasiliensis Latreille.
Brazil (Latreille, White). Bahia! (Hartt).—West coast of Florida! (E. Jewett). South Carolina (Gibbes).

Peneus setiferus Edwards.
Rio de Janeiro (Heller).—Florida (Edwards). South Carolina (Gibbes).

Xiphopeneus Harttii Smith.
Caravellas, Province of Bahia! (Hartt).

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* This species, called *pitú*, is quite common in the river Sao Francisco and the larger streams flowing into it.—C. F. H.

SQUILLOIDEA.

Squillidæ.

Lysiosquilla inornata Dana.
Rio de Janeiro (Dana).

Squilla rubro-lineata Dana.
Rio de Janeiro (Dana).

Squilla prasino-lineata Dana.
Rio de Janeiro (Dana).

Squilla scabricauda Latreille.
Brazil (White).

Gonodactylus chiragra Latreille. (?)
Abrolhos! (Hartt). Caravellas, Province of Bahia! (Hartt).—Aspinwall! (F. H. Bradley). Florida Keys! (Gibbes). Bermudas! (J. M. Jones).—Mediterranean Red Sea; Pacific Ocean (Authors).

Erichthidæ.

Erichthus vestitus Dana.
South Atlantic, lat. 25° south, long. 44° west (Dana).

Erichthus spiniger Dana.
South Atlantic, between Rio Janeiro and Rio Negro (Dana.)

MYSIDEA.

Mysidæ.

Macromysis gracilis Dana.
Rio de Janeiro (Dana).

Rachitia spinalis Dana.
Atlantic, off the harbor of Rio de Janeiro (Dana).

Luciferidæ.

Lucifer acicularis Dana.
Harbor of Rio de Janeiro (Dana).

Zoea rubella Dana.
South Atlantic, lat. 24° 45′ south, long. 44° 20′ west (Dana

Zoea echinus Dana.
Atlantic, lat 23° south, long. 41° 5′ west (Dana).

EXPLANATION OF PLATE I.

Figure 1.—*Xiphopeneus Hartii*, male. cephalothorax; a, b, c, d, e, thoracic legs, those of the fourth and fifth pairs incomplete. 1a, appendages of the first segment of the abdomen in the same specimen. 1b, rostrum of a larger, female specimen; 1c mandible enlarged two diameters,

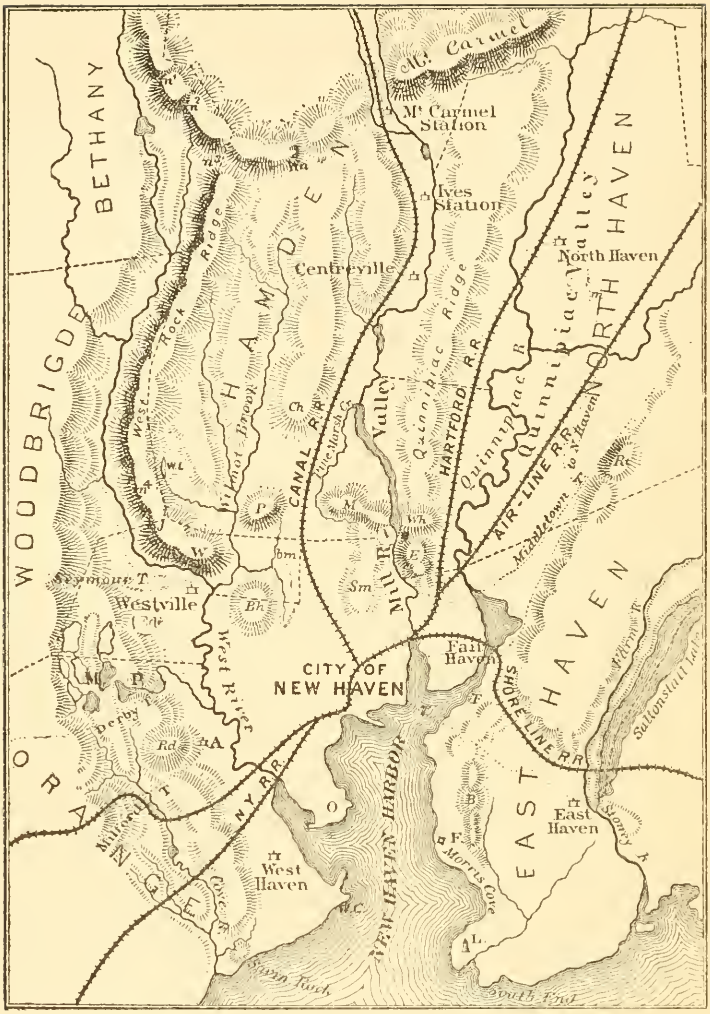
Figure 2.—*Palæmon ensiculus*, male. carapax; 2a. leg of the second pair; 2b, extremity of abdomen, seen from above; 2c, rostrum of a small female.

Figure 3.—*Cryptograpsus cirripes*, male; 3a. sternum and abdomen of the same specimen.

Figure 4.—*Panopeus politus*, female, carapax enlarged two diameters.

Figure 5.—*Panopeus Hartii*, male, carapax enlarged two diameters.

All the figures are natural size, except 1c, 4 and 5, and all are copied from photographs, except 1a and 1c.



Topographical Map of the New Haven region.

Explanations.—A, Allingtown village. B, Beacon Hill. Bh, Beaver Hills. Ch, Cherry Hill. E, East Rock range, consisting of East Rock proper to the northwest, Indian Head, and then Snake Rock. Ed, Edgewood, the estate of Donald G. Mitchell, Esq. F, Fort Hale *F*, Ferry Point, or Red Rock, on the Quinnipiac near its mouth. J, Judges' Cave, on the West Rock ridge. L, Light House. M, Mill Rock. M P, Maltby Park, only three of the proposed lakes of which are constructed. O, Oyster Point. P, Pine Rock. Rd, Round Hill. Rt, Rabbit or Peter's Rock. Sm, Sachem's ridge. T, Turnpike; also Tomlinson's bridge, across the head of New Haven bay. V, the village of Whitneyville. W, West Rock, the south end of West Rock ridge. WC, West Cape, or West Haven Point. Wh, Whitney Peak. WL, Wintergreen Lake, just north of Wintergreen Falls. Wn, Warner's Rock.

bm, Beaver Pond Meadows; *m*, Mineral Spring, southeast of North Haven; n^1, n^2, n^3, n^4, different notches in the West Rock ridge; n^1, n^2, the upper and lower Bethany Notches; n^3, the Hamden Notch; n^4, Wintergreen Notch. The names of the towns ORANGE, WOODBRIDGE, BETHANY show the course of the Woodbridge plateau; and from W in the word Westville to Savin Rock is the course of the Edgewood series of hills, the eastern border of the plateau.

Scale 4-10ths of an inch to the mile.

II. On the Geology of the New Haven Region, with special reference to the Origin of some of its Topographical Features. By James D. Dana.

WITH A MAP.

1. The New Haven region.

Either side of New Haven bay,—an indentation of the coast about four miles in depth,—there is a north-and-south range of hills, the trap and sandstone ridges of East Haven and North Haven on the east, and the eastern portion of the Woodbridge plateau on the west; and these make the eastern and western boundaries of the New Haven region. Their height, which is greatest to the north, probably nowhere exceeds 600 feet. The width of the region varies from about four miles on the south to seven on the north, and the whole length from the Sound to Mt. Carmel—its true northern topographical limit—is twelve miles. The northern half of the region is divided longitudinally by two lines of ridges: (1) the long West Rock trap ridge near the western side, four hundred feet and upward in height; and (2), nearly midway in the area east of West Rock, the short isolated East Rock (E) range of trap and sandstone, and the continuation of this range northward to Mt. Carmel in the low Quinnipiac sandstone ridge which divides the waters of Mill River and the Quinnipiac. The New Haven region hence consists in its northern half of three subordinate north-and-south regions; (1) a narrow valley west of West Rock, drained by West River; (2) a broad central plain (the Hamden plain), continuous with the New Haven plain, rising into hills to the northward, and drained along the east side by Mill river; and (3) a wide eastern portion occupied by the river-course and the extensive meadow lands of the Quinnipiac, in other words, the wide valley of the Quinnipiac. South of East Rock, the central New Haven plain blends with that of the Quinnipiac. The West Rock ridge to the north throws off a branch on the east which curves around to Mt. Carmel and forms the northern boundary of the central of the three subordinate regions. This central region is partly subdivided across, on a line, nearly, with West and East Rocks, by two short trap ridges; Pine Rock, (P) a third of a mile from West Rock, and Mill Rock, (M) which adjoins East Rock; the width of the interval between the two is nearly a mile. Mill River passes through a deep cut in the Mill Rock ridge, at the village of Whitneyville. A clear idea of the topography of the region is necessary in order to an appreciation of the observations that follow.

2. General course of Geological events before the Post-tertiary era.

One of the last events of the Paleozoic ages was the formation of the Connecticut River valley, by the bending of the earth's crust; and this took place as a sequel to, or in connection with, the crystallization of the granite, gneiss, crystalline schists, and other similar rocks, which make the bottom of the valley.

The first fact of the *succeeding* age, the Reptilian, of which there is record, is the existence of a Connecticut valley estuary, twenty miles or more wide, stretching from New Haven to northern Massachusetts, (New Haven being the proper southern termination of the valley and estuary), and the commencing deposition in this estuary of the Red Sandstone formation. The production of this formation is believed to have taken the whole of the Triassic period, the first period of the Reptilian age, and also part of the next or Jurassic period.

After, if not before, the close of the Sandstone era there were eruptions of trap—a rock that came up melted through wide fissures in the sandstone and subjacent rocks. East and West Rock, Pine Rock, Mill Rock, Mt. Carmel, the Meriden Hills, are ridges of trap along with what remains of the old sandstone walls. The sandstone in the vicinity of the dikes, or near any fissures, through which heat and vapor escaped, was more or less hardened by the heat, and rendered comparatively durable; while other portions were left unhardened or but little so, and therefore in a state admitting of easy erosion and removal. Cotemporaneously with the ejections of trap, veins of copper were made, as those of Bristol, Simsbury, Cheshire, etc.; and veins of barytes, as those of Cheshire.

The thickness of the sandstone formation in the New Haven region is not yet ascertained; in Massachusetts, it is according to the lowest estimate three or four thousand feet. There is abundant evidence that its beds once covered the top of East Rock, now 360 feet in altitude, and if so it reached upward to a level which is now at least 400 feet above the sea. Many of the trap ridges to the north in the Connecticut valley were also once topped with sandstone, although much higher than East Rock. West Rock has a height of 400 feet, and the West Rock ridge, between Hamden and Woodbridge, over 500 feet; Mount Carmel about 800 feet; Middletown mountain is 899 feet high; West Peak, the western summit of the Meriden Hanging Hills, 995 feet; Mount Holyoke 985 feet, but the highest point of the Holyoke ridge, a little farther to the east, 1126 feet; and Mount

Tom, 1211 feet. (The last four altitudes are from Prof. Guyot's measurements.) Although the precise original elevation of the sandstone about these heights is not certain, there is no doubt of the great increase of height to the north. This however was not one of the original conditions of the rock, for the beds were made in one common estuary and nearly to a common level. It has resulted from an uplift which affected the interior of New England more than its southern borders; and the trap also owes much of its greater height to the north to the same uplift.

The sandstone mass intersected by dikes of trap constituted the block out of which the future New Haven region was to be carved by various denuding forces. The hard dikes of trap, and the distribution of the hardened sandstone among those feebly hardened, had great influence in guiding the modeling agencies and determining the future features of the country.

At the time of the eruptions, or soon after, the land before submerged rose above the level of the waters; rivers took size and direction according to the slopes; the estuary dwindled into the Connecticut; and the Connecticut, finding in its way the trap dikes of Weathersfield, Berlin and Meriden, and also elevations of sandstone, took a route, in the latitude of these hills, to the eastward. So the river was lost to New Haven.* Other changes in the old hydrographic basin of the Connecticut valley have taken place since the throwing up of the trap dikes, and part of the following may date from that event. Farmington river, which in Triassic times flowed into the estuary from the western heights of Massachusetts and northern Connecticut, still enters the Farmington region; but near Farmington it turns abruptly *north*, flows in that direction sixteen miles, at the foot of Talcott mountain and other trap hills of the range, then makes a cut through the range into the Connecticut river valley and joins that river. The Quinnipiac, which starts in the Farmington valley just below the northward bend of the Farmington river, on approaching the region of the trap hills of Cheshire bends eastward out of the valley in front of the Hanging Hills of Meriden, into the valley where the Connecticut river might have had its course but for the trap eruptions and disturbances; and finally, the Farmington valley being thus deserted by the Quinnipiac, Mill river at this point commences its flow, taking its rise in the adjoining hills, and becomes the principal stream for the rest of the valley southward to New Haven bay.

During the Cretaceous period closing the Reptilian age, and the

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* This view was brought out by the writer in Ward's Life of Percival, p. 420.

Tertiary period which opened the Mammalian age, no marine formations were here made; and there is hence no proof that in the long interval between the origin of the trap dikes and the Glacial epoch, the land of the region, or of any part of central New England, was at any time under the sea. Whatever the fact, there must have been, during the time that elapsed, a large amount of denudation over the region; so that West Rock, Pine Rock, Mill Rock and East Rock finally became prominent above the plain, although much less so than now.

3. General character and results of the Post-tertiary period.

Next came the Post-tertiary period, the last in Geological history. In order to understand the following remarks it is necessary to bear in mind that the Post-tertiary in America, as the writer has elsewhere shown,* included three eras, corresponding to three great changes of level over the northern portion of the Continent.

1. The *Glacial* epoch; when the land stood at a *higher* level than now, and a universal glacier and a frigid climate covered the continent north of the parallel of 40°, (not a sea with icebergs, as facts about New Haven demonstrate.) 2. The *Champlain* epoch, an era of subsidence; when there was a sinking of the land below its present level, resulting in a mild climate and a melting of the great glacier; submerging beneath the sea the land along the coast, and giving great extent to lakes and rivers. 3. An epoch of elevation; bringing the land up to its present level, and raising the submerged sea-shore and river flats to a habitable and cultivable height, thus making them available for man. The movements were up—down—up; *up* for the *Glacial* era, *down* for the era following, and *up* again for the third or finishing era. The origin of the features of the New Haven region cannot be understood without keeping constantly in view these three great movements of the land. In the first of these eras this region stood probably one or two hundred feet *above* the level of the sea; in the second sixty-five feet or more, and afterward forty and less, *below* the present level; and in the third it passed gradually to its present condition.

With reference to the question whether icebergs may not have been the agent in the glacial era instead of glaciers, a single argument only need here be brought forward. Icebergs, as is well known, are fragments of glaciers broken off in the sea into which they descend; and the freight of stones and gravel they bear was received mainly when they were in the glacier condition. The boulders of the Connecticut

* Am. Jour. Sci., II, xxii, 325, 346, 1856, and Manual of Geology.

valley if brought by icebergs, should hence have come from the White Mountains, or perhaps from some Green Mountain peak, for these would have been the only summits above the water in a sea covering the valley to a depth of four thousand or more feet (the depth that the distribution of boulders requires). But, on the contrary, the boulders of the New Haven region, 1000 tons and smaller in size, are mainly from the trap and sandstone hills of the valley itself, either in Connecticut or Massachusetts, and the adjoining plateau of gneiss, etc.; they are from the depths of the imagined sea, and not from the heights above it. Icebergs could not therefore have done the work of transportation. In the Glacial era, then, all New England and, probably, the whole northern portion of the continent, was covered with ice. It is well known that the Glacier theory is sustained by the explorers of the Alps, Professors Agassiz and Guyot.*

4. Condition and Effects during the Glacial era.

The Connecticut valley glacier lay under the general glacier-blanket of the continent, or rather was a part of the lower portion of it. It extended from the summits of the Green Mountains on the west to the dividing height of land on the east, having a width of 100 to 120 miles; it was therefore sufficiently large to have almost entirely an independent motion, determined by the slope of the valley; which would make the prevailing direction of movement southward, or mostly between south and 12° west of south.

The direction, according to Prof. Hitchcock, of the scratches on Mt. Monadnoc in New Hampshire, which extend even over its summit 3,718 feet in altitude, is southward; and the same authority gives this as the course in Deerfield, Greenfield and other places in the Connecticut valley, as well as on Mt. Tom and Mt. Holyoke. It is the course also in one of the gorges of Mt. Carmel. East of the Hanging Hills of Meriden it is south-southwest, and Percival attributes the unusual amount of westing to the trend of the adjoining

* Dr. Newberry, in an excellent paper on the Surface Geology of the Great Lakes and the Valley of the Mississippi (Ann. Lyc. N. York, ix, 1869), sustains the glacier theory of the drift for the country, but gives reasons for making part of the area of the Great Lakes an *iceberg* region in the closing Glacial era. The author presents many other points of interest with regard to the successive events of the Glacial and Champlain eras, and in the course of his remarks, observes that there could have been no true lateral moraines. He makes the depositions of drift over the hills and the stratified material of the valleys and plains essentially cotemporaneous, regarding them as having resulted partly from iceberg transportation, and partly from distribution by waters flowing away from the margin of the ice, or from beneath it, as it slowly melted.

trap hills. Some deviation from the general course would take place wherever there are high ridges or deep valleys varying in direction but little from the main course of the movement, just as a deep trough in the bottom of a stream of water set a little obliquely to the current would deflect the waters and give them more or less nearly its own course;* and this is what Percival observed in the valley between the Hanging Hills of Meriden and Lamentation Mountain. In East Haven, on the eastern border of the New Haven region, the direction is S. 13° E. The facts sustain the conclusion that the general course was that of the Connecticut river valley. To the westward of the central portion of the valley, over the eastern Green Mountain slope, the general course, as various observers have shown, is to the *east* of south, or about *south-southeast*, which is a natural resultant of the two forces—that producing the main southerly movement, and that arising from the eastward, or E. by S. slope of the surface.

As the slope southward was very small compared with that in the Alps, the motion was much slower—probably not exceeding a mile in a century, which is equivalent to about a foot a week. The movement was not continuous at this rate, but by starts, at longer or shorter intervals—weeks, months or years—as the resistance could be overcome. Having a thickness to the north of more than four thousand feet, the pressure it exerted wherever its lower surface rested was enormous, and when it did move the abrasion was commensurate with it. It was not, like an Alpine glacier, confined between the sloping sides of a valley, the declivities of which aided largely in its support, and so relieved the bottom partly from pressure; it lay spread out over the plains and hills resting heavily upon the most of the surface beneath it.

The movement produced three results, as has been well illustrated by the principal authorities with regard to glaciers. First, a breaking of the brittle ice wherever there was friction, resulting in opening immense crevasses where the resistance was great (for the glacier owes its power of movement to the facility with which it breaks and mends itself); secondly, the abrasion of the rocks beneath, resulting in a ploughing out of the soft half-hardened sandstone to

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* In the case of *large* continental valleys, the glacier followed the course of the valley even when this course was east-and-west, as is shown by the author to have been true of the Mohawk valley, in his Geology (p. 751), and in the American Journal of Science, [2], vol. xxxv, p. 243, and by Dr. Newberry, with reference to other regions, in the paper referred to on the preceding page.

great depths,* and less deeply the harder rocks, and in dislodging masses from the dikes and other rock formations which had been previously loosened in any way, the masses sometimes many tons in weight; thirdly, the taking up of the sand or gravel, stones and rocks, thus separated or dislodged, into its own mass, which it was enabled to do because of the attendant breaking up of the ice just alluded to, and the readiness with which ice becomes solid again by regelation after a short rest. Thus the glacier moved slowly on, engorging itself with whatever loose material it made, as well as with what it found in its path.

The glacier was made ready for its great work of abrasion either in the way of rasping, planing, channeling or ploughing through the sand, stones and rocks with which it was shod. The hard granite rocks east of New Haven, as is exhibited at Stoney Creek, were marked by the glacier not only with scratches but with broad furrows six inches to a foot in depth; and this in addition to an unknown amount of planing above the present surface. The soft red sandstone of the region easily yielded under the pressure, and was ground up and ploughed out in some places to a depth of several hundred feet, the material being absorbed at the same time into the icy mass. Hills and ridges lost much of their height, and those of trap were extensively stripped of their associated sandstone. The isolated East Rock, lying north and south, or in the direction of the movement, between the Mill River valley and that of the Quinnipiac, was abraded both along its western front and on the rear, and left nearly bare of sandstone on both sides. Pine Rock, an east and west ridge, besides undergoing an unknown amount of decapitation, lost the sandstone on its northern side for the upper sixty feet, and a wall of trap of this height is left bare. Mill Rock suffered a like fate with Pine Rock; for the north wall of the trap dike projects in places twenty or twenty-five feet above the sandstone. Whitney Peak is in like manner bare of sandstone on its north side for forty feet from the summit. At the Fair Haven sandstone quarries and over the country near the

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* While this sandstone is hard enough for an excellent building stone in some portions of the Connecticut valley, and often very hard-baked in the vicinity of the trap dikes, a large portion of that exposed to view over the New Haven region a little remote from the trap is so soft that it is easily dug up by a pick, and sometimes even by an ordinary shovel; so that we have reason for regarding the strata of it underlying the most of the New Haven plain, or its alluvium, as of this soft kind. Part at least of the hardening and reddening of the sandstone was evidently due, as stated above, to the heat that escaped in connection with the trap eruptions and from fissures opened in their vicinity; and in regions where there was no heat from these sources the rock was but little hardened.

Milford turnpike, the removal of the soil in several places has exposed large surfaces that were planed and grooved by the glacier; and there is no doubt that but for the covering of earth the rocks in all directions would be found glacier-marked.

The stones, or boulders, in the foot of the glacier, that were scratched and polished while doing this work of abrasion, are often to be found where the drift of the hills has been freshly uncovered. One of four tons weight lies on the roadside along the Milford turnpike, a few rods above Allingtown; and many others of smaller size have been thrown out at the recent excavation for the Derby railroad, near the toll-gate on the same road.

By the means mentioned an immense amount of rock material was taken aboard the glacier for transportation southward; and yet there were no *lateral moraines* in the ordinary sense of this expression. The *surface* of the Connecticut valley glacier was white and spotless. From the Green Mountain ridge to the White Mountains of New Hampshire there was not a projecting peak to afford a grain of dust.

The special effects of the glacier over the New Haven region included the making (*a*) of hills, and (*b*) of valleys or excavations.

First—*Its Excavations.*—The excavations would naturally have been most extensive where there was no trap or other hard rock in the way to prevent deep ploughing. The valleys of the Quinnipiac and West River beyond doubt date their origin long back of the Glacial era, from the time the trap and sandstone ridges which bound them were first thrown up above the level of the sea; but still they must have been scoured out by the moving ice, and have had their depth and width much increased. Whether the work of the ice or not is uncertain; yet it is a fact that the whole western side of the West river valley is stripped clean of the sandstone which once existed there, and which was a part of the formation that originally stretched across to the top of the West Rock ridge; not a square yard of sandstone is left in place over the metamorphic rocks of its western slope. The close shaving of the sandstone on the east side of East Rock, and its still more complete removal on the west side, have been already alluded to as probably part of the effects of the glacier. Besides the excavations in these valleys, others very extensive must have been made over the whole central part of the New Haven region, from its southern limits to the mountains on its northern border in Hamden; for this was the great central valley of the region.

Among the depressions over this region, the most remarkable is that of the *Beaver Pond Meadows* (*bm*, in the map). It is a large marshy area sunk 20 feet below the general surface, lying in the center of the

New Haven plane, between the trap hills, Pine Rock and Mill Rock.* It crosses the borders of the towns of New Haven and Hamden, and has a length from north to south of 1½ miles, and an average breadth in its southern half of a fourth of a mile. The basin receives almost no outside water, and yet gives exit to a stream which in its descent of 22 feet to West river affords water power to two or three manufacturing establishments. In its wide and flat meadows, and its high sloping bank of 20 to 30 feet, looking like the terrace slope of the river valleys, it appears as if it were once the course of a large stream; yet it not only receives no water at its head, but not even an old dried up channel; moreover the outcrops of sandstone less than a mile to the north afford no evidence of the former existence of such a channel leading toward the Meadows. This absence of proof that any river ever discharged itself through the depression is part of the evidence that its excavation was the work of the glacier, as explained beyond.

If the Beaver Pond depression was excavated by the glacier, we should naturally look for a continuation of the channel southward to the New Haven bay. This channel was probably that of the old *West Creek*—a valley with similar broad meadows and distinct terrace slopes, terminating in the northwest angle of New Haven bay.† Although now nearly dry throughout and covered by streets and houses, two and a half centuries since it was large and deep enough to give entrance to Whiting street for vessels of considerable size, and as far as College street for boats. The connection between the Beaver Pond meadows is cut off by the alluvium—a deposit of the era following the Glacial; but a series of large and once deep depressions lies between them and *both are in nearly the same north-and-south line.*

There are also two other broad valley like depressions leading off

* Owing to a defect in the engraving, the position of only the southern part of the Beaver Pond basin (*bm*) is given on the map. The dotted outline should have been extended northward, by the east end of Pine Rock (P.).

† East and West Creeks, as they are now obliterated channels, are not on the map. They may be put on, with a lead pencil: for *East Creek*, by drawing a line from a point just east of the southern end of the Beaver Pond depression (*bm*) *eastward* to the Canal road, then along the course of this road southward, and thence to the head of the New Haven bay west of its cent-r; and for *West Creek*, by starting the line a little west of south of the extremity of the Beaver Pond basin and continuing it to the northwest angle of the bay. Each was about 1½ m. long; yet for half a mile the channel in both cases was a broad tidal inlet. The city of New Haven was originally laid out at the head of the bay, *between* these two creeks, the west side of its *half mile square* (George street) against the *West* Creek valley, and the south and east sides (State and Grove streets) near *East* Creek.

from near the southern extremity of the Beaver Pond basin, but to the *eastward.* One passes near Webster street, and the other by Munson street, and the two unite in the valley of the former *East Creek*, now occupied by the Canal Railroad. They are evidently continuations of the Beaver Pond depression, and it may be questioned whether these were not also courses of the Beaver Pond glacier excavation. But although broad, they are comparatively shallow and have *gently sloping* sides; and the course of each is east-and-west, or *transverse to that of the glacier movement.* We conclude therefore that they were probably a result of the tidal currents and waves of the following or Champlain epoch, and of the later action of surface waters. It is to be remembered that the glacier made its excavations in the strata underlying the superficial alluvium.

We should naturally look also for a *northern* continuation of the Beaver Pond depression. But we have already stated that the appearances at its northern extremity indicate its rather abrupt commencement at that point. Half a mile to the eastward of the depression, and as far south of its northern end, there is a broad channel leading *northward* which is the course of what is called on the map Pine Marsh Creek; and the question comes up whether this was not the *northern* part of the Beaver Pond depression, and therefore whether Mill river did not once discharge its waters through it and thence enter the bay by *West Creek* valley. The southwestern part or extremity of this great depression (situated near the junction of Goodrich street and the Canal railroad and close by the present terminus of the Shelton Avenue railroad), reaches within 300 yards of two broad northeasterly channels leading down into the eastern bays of the Beaver Pond basin. The valley is so broad, and so abrupt in the slopes which bound it, that it appears as if large enough to be the course of a river. Through its now sluggish waters, clumps of bushes rise in most parts from the shallow bottom.*

These facts *seem* to favor the conclusion that we have here actually found the northern continuation of the Beaver Pond channel. But the valley widens *northward* instead of toward the Beaver Pond depression, and the creek flows at the present time in that direction, starting just south of Mill Rock and entering Mill River 1½ miles north of Whitneyville (V.) Another view with regard to it we regard as much more probable.

* Owing to the dam at Whitneyville, the water of Mill River is not only set back for two miles and more up the valley, but also flows back into Pine Marsh Creek valley for more than a mile, to within a short distance of Mill Rock (See Map.)

At the mouth of Pine-Marsh Creek, Mill River takes a bend a little to the *eastward* of south, while the creek has a course as much to the *westward* of south, and Mill Rock stands between the extremities of the V thus made by the two channels. In this position of Mill Rock, we find the explanation of the facts referred to.

The great glacier having had its ploughing under-surface shaped by the gap west of Mt. Carmel, through which Mill River passes, moved southward, excavating the valley of Mill River, while, at the same time, abrading the soft strata over the hills and plains. The Mill Rock dike, making now a ridge 200 feet in height, stood in its path, the brittle ice confronting the unyielding trap mountain. Under such circumstances, it would have been a natural consequence that at some point north, the brittle ploughshare should have divided, the smaller part to pass toward the Whitneyville opening, by the east end of Mill Rock, and make a shallow furrow because of the hard trap rock under foot at the gap; the larger part, encountering only the soft sandstone, to plough out the deep broad valley of Pine-Marsh Creek, leading by the west end of Mill Rock and almost directly toward the Beaver Pond region.

The question arises whether the excavation was continued into the Beaver Pond basin and thence southward to the bay, or whether there was a lifting of the ploughing portion of the glacier through the elevating action of Mill Rock and merely a transfer of the excavating pressure to a line more to the westward—the process of transfer producing the six or eight bays characterizing the eastern side of the Beaver Pond depression and the broad southwesterly surface channels which lead into them. In the former case, Mill River would have run through the Beaver Pond excavation and West Creek; in the latter, the waters of Pine-Marsh Creek would always have been tributary to Mill River in its present position; for in the Glacial era they would have been those of a sub-glacier stream, and these would have become far more abundant in flow during the melting of the glacier, and thus have made a stream commensurate with the Pine-Marsh Creek valley.

There are three objections to the view that Mill River once discharged itself through the Beaver Pond Meadows. (1.) The Beaver Pond depression is prolonged half a mile north of the point where the Pine-Marsh valley makes its nearest approach to it, and this northern extremity does not bend toward the valley or show any inclination that way. There is here evidence that the Beaver Pond excavation had its own independent beginning.

(2.) If Mill River once flowed through the Beaver Ponds and thence through West Creek to the bay, the force of its waters would have continued to keep this channel open, and West Creek would not have been disjoined from the part above.

(3.) If, during the Glacial era, Mill River had had no channel through the Whitneyville gap, it could hardly have afterward gained a foothold there where the alluvium has a height of 60 feet or more above mean tide level.

There is hence not only no proof of a former connection between Pine-Marsh valley and the Beaver Pond depression, but strong reason against it in the condition and character of Mill river and its present channel.

Secondly—*The Elevations, or Hills and Ridges made by the Glacier.* Besides extensive excavations, there are also *elevations* which were due to the glacier. They were a consequence mainly of the interrupted series of trap ridges in its way. The hard trap-rock dikes, Mill Rock and East Rock, were fenders both to the sandstone lying on their northern side, and also that on the southern, and especially to the latter. The glacier, moving from the north and approaching Pine Rock, would have had its under surface forced up into an arch by the resisting mass, and the ice thus shaped would have been made firm and solid by the pressure; and as such an arching of the ice below is an arching of the abrading surface of the glacier, an elevation of sandstone corresponding to it should have been left by the glacier on its southward march. *An elevation was thus left south of Pine Rock—that of the Beaver Hills* (*Bh.*) The Hills are now disjoined from the Rock because of erosion (*a*) by the waters and ice that descended the slope during the declining Glacial era; (*b*) by the waves and marine currents of the subsequent period of submergence in the sea; (*c*) by streamlets down the declivities due to the rains and melting snows of later time when the land was elevated to its present level—an era of greater elevation or emergence. It was the eastern abutment of this great Pine-Rock arch that scooped out the Beaver Pond basin.

In the same manner the narrow north-and-south Sachem's ridge (*Sm*,) a mile and a half in length, was evidently made through the lifting action of Mill Rock. Similarly also, the small Cedar Hill, south of East Rock, owes its existence, apparently, to the arch made by the East Rock range; it is *small* because the East Rock range has a north-and-south direction, or lies with its end toward the moving glacier; and also because the ice of the wide Quinnipiac valley would have pressed westward as it escaped the limits of the valley and passed the southern extremity of the Rock, and so have swept away the sandstone there remaining.

The great glacier did not succeed in ploughing out the Mill Rock dike at the Whitneyville notch below the level of the bottom of the present dam, for the dam is built on the solid trap dike. The ice must therefore have plunged down the front of it (the land having been higher than now), and with it the sub-glacial stream descended. South of this it appears to have made a deep Mill River channel.

The glacier acted like the moulding tool in the plough of the carpenter. But the convexities and concavities on the cutting or abrading edge of the tool were not needed in the pliant material; for by the fenders placed in its front, in Pine Rock, Mill Rock, and East Rock, the edge was made in these parts to rise or arch upward, and by this means long ridges of various heights were made beween the furrows.

The correspondence between the channeling of the plain and the position of the trap ridges is so close (especially if it is considered to what an extent subsequent river and marine action must have tended to modify the features of the surface and obliterate the tracks of the glacier) that there seems to be here visible demonstration of glacier action, and of the insufficiency of the iceberg theory of the drift.

If Sachem's ridge, the Beaver Hills and Pine Hill were the only examples of north-and-south sandstone elevations due to hard-rock fenders, the correctness of the explanation offered might be reasonably questioned. But they are the least remarkable instances. Over Hamden there are three north-and-south ranges three to four miles long, as exhibited on the map, and they may be distinctly followed northward to elevations in the transverse range of heights west of Mt. Carmel. Cherry Hill (Ch) is the termination of one of these lines. A still more striking example is the Quinnipiac ridge, the dividing ridge between Mill River valley and the Quinnipiac. It stretches from the south side of Mt. Carmel to Whitney Peak, a distance of *six miles*, and while broad and broken into hills to the north, is to the south an evenly rounded elevation, looking from the summit of Mt. Carmel like a splendid example of landscape grading. According to the theory presented, this long ridge of sandstone owes its existence to the arching upward of the ice by the high east-and-west Mt. Carmel range, the ridge being a part of the great sandstone formation left thus elevated in consequence of this arching. The arch, although narrowing somewhat, did not flatten out before reaching Whitney Peak, as the continuation of the ridge shows; and here it was raised into a new arch by this dike, losing in the encounter the red sandstone from the back (or north side) of its head, down nearly one-third way to its base. Either side of this dividing ridge the glacier, besides abrading the general surface of the sandstone formation and thereby preparing the rocky basement for the alluvial plains, was ploughing out the river channels adjoining—that of the small Mill River on the west, and that of the broad Quinnipiac on the east. It is a strong confirmation of the view brought forward that the direction of the Quinnipiac ridge, (as well as that of Sachem's ridge,) is S. 12° W. (true course), thus coinciding with the average direction of the Connecticut valley, and therefore with that *of the movement in the glacier.*

The largest of the valleys in the Hamden portion of the New Haven region lies along side of the West Rock ridge, where the erosion of the glacier, and of the waters flowing from them would have been greatest in consequence of the height of the rock and its slopes, and where, moreover, erosion from running waters has been going on ever since from the streamlets that the rains and melting snows have made over the long declivities. In this valley lie Wintergreen Lake (due to a recent damming of one of the streams), and farther north the sites of other "contemplated" lakes.

This western part of Hamden is drained by Wilmot brook with its tributaries, which flows through the gap between Pine Rock and West Rock and soon after enters West River. The northern portion of the brook, which lies among the sandstone ridges, points southward nearly toward the northern extremity of the Beaver Pond depression, and approaches it within two-thirds of a mile. It might therefore be queried whether Pine Rock had any effect toward dividing the excavating action of the glacier on the north, like that from Mill Rock above described. But there is this great difference in the two cases, that the gap between Pine Rock and West Rock is very much broader than the Whitneyville gap, being about a quarter of a mile across, and besides there is no continuous pavement of trap at bottom. Moreover Pine Rock has an oblique position with reference to West Rock, its direction being E. 20° N. true course, (about E. 12° N., compass course,) and owing to the convergence of these two ridges and the broad opening intermediate, and also to the S. 12° W. direction of the glacier movement, the principal part of the excavating portion of the glacier would naturally have passed between them, where Wilmot brook has its actual course.

Looking beyond the limits of the New Haven region, still other examples of this north-and-south ridging of the soft sandstone occur.

South of the Hanging Hills of Meriden an elevation commences which stretches southward to Mt. Carmel, showing that the ice was arched up by the Meriden mountains, and the arch continued to Mt. Carmel. And here, as just observed, it was thrown anew into a high arch for the ridging and ploughing southward, in the course of which the Quinnipiac ridge was formed; then it was raised by Whitney Peak again, and its continuation East Rock; and finally it died out as it left the region of Cedar Hill south of the East Rock range.

Besides the large ridges and excavations made by the glacier, the ledges over the hills are often approximately north-and-south in course, and were probably a result of glacier ploughing. The chlorite schist of the Woodbridge plateau is easily torn up in consequence of its slaty structure and its joints or lines of fracture, and also readily reduced to fragments by the freezing of water or growing of vegetation in the crevices. A large trap dike, intersecting this rock on the Woodbridge heights west of Westville, often stands up above the schist, as a prominent ridge, which sometimes has on one side or the other a bare precipice of forty feet. But much of this wear is undoubtedly the work of subsequent centuries.

Without adducing other cases, it appears safe to conclude that over the region of the Connecticut valley the principal part of the coarse gouging out of the plains, and shaping of the mountains and valleys, were performed by glaciers and by the streams that were in action during the progressing and declining Glacial era. The same agents also carried southward the earth, sand and gravel that were afterward to be deposited by the ice, and worked over by the rivers, or, near the sea-shore by the rivers, tidal currents and waves, into terraced "alluvial" plains, or *stratified* drift formations.

Scratches having the course S. 33° W.—A wide variation from the usual course of the glacier scratches (South, to S. 12° W.) occurs over the chlorite rock along the Milford turnpike half a mile to a mile west of Allingtown. The place is about two and a half miles south of West Rock, and one and a half miles south of the line of East Rock. The course (true) of the scratches is quite uniformly S. 33° W., *or full 20° west of the usual direction;* and they are so deep and numerous and so completely free from crossings by scratches in any other direction, that S. 33° W. must be viewed as the course of the under surface of the glacier over this part of the western margin of the New Haven region. The scratches are seen at the top of the first ascent on the turnpike, about 130 feet above the sea, (or 90 above the level of the New Haven plain), and at many other points where the rock has been recently exposed, for half a mile west. The ledges that have been long bare have lost their scratches by weathering; on this account, and owing also to the covering of soil over other parts, observations have not yet been extended farther west. The following is offered in explanation of this southwestern throw of the under portion of the glacier.

It has been stated on page 45 that the New Haven region, between the summits of the ridges confining it on the east and west, has a width of *seven* miles to the north, and narrows to *four* at the south. While the mass of the glacier was continuing its southward movement, the portion below filling this depression would have had to accommodate itself some way to the narrowing limits. This accommodation might have taken place, through an increasing depth of the depression southward. But if this was insufficient to meet the whole, there would have been a tendency to a thickening upward of the glacier and relief would have been obtained from the accumulating pressure by a lateral escape of the ice.

There was evidently no yielding or escape on the *east* or Quinnipiac side, the side of the broadest and deepest valley, and therefore of deepest or of thickest ice; for the ploughings of the glacier which are exhibited along that side on a grand scale over the East Haven sandstone, have the usual southward (S. 13° W.) course. Hence the escape, if any where, must have been on the west side; and here it is that we find these S. 33° W. scratches. The place is southwest of where the Quinnipiac valley opens on the New Haven plain, and consequently it is situated just where such an effect from the expansion and pushing action of this part of the glacier would be produced. Now to the *west* of the region of these scratches within three-fourths of a mile, there is the rather broad valley of Cove river, which extends southward and reaches the Sound two and a half miles below; it is parallel nearly with the New Haven region, but *has a much steeper slope*, the descent to the salt water flats being at the average rate of about 125 feet in a mile. This slope of the valley would have given the ice that fille l it (the under portion of the glacier, if not the whole above) relatively a rapid movement. The overflow from the New Haven depression caused by the conditions stated would therefore have naturally taken a course into this valley. The direction of the scratches, S. 33° W. accords well with this view.

Making of Lake-basins.—The lifting of the lower or abrading surface of the glacier by hard rocks, which has been shown to have resulted in the production of the north-and-south ridges, and which appears to have terminated southward the basin of Pine-Marsh Creek, might under other circumstances have made basins for lakes. Lake Saltonstall, four miles east of New Haven, probably owes its existence to this action. The lake is 3½ miles long and has an average breadth of a third of a mile. The basin is scooped out of a very soft, crumbling shaly sandstone, and lies between two bow-shaped trap dikes, three-fourths of a mile apart, whose average trend is north-northeast. Its depth is stated at 112 feet; and since its surface is only half a dozen feet above high-tide level, the bottom is more than 100 feet below that level. At the present outlet the waters flow over solid trap at a low cut in the western trap ridge, so that the basin is here rock-bound on the south. The stream from the lake (called Stoney River, but properly the lower part of Farm River), flows for its last mile between granite shores and has in some places a rocky bottom. Thus there is a granite as well as a trap barrier between the lake and the sea, and the depression it occupies is a true basin. We may believe therefore that the long narrow basin occupied by the lake is an excavation made in the soft sandstone by the ploughing glacier, and that it was not continued to the sea because the ploughshare was lifted out of its trench by the hard unyielding rock before it.

Height of the Land in the Glacial era.—With regard to the height of this portion of Connecticut above the sea in the Glacial era we have as yet few facts for definite conclusions.

a. In sinking an artesian well on Green st., 120 yards from the harbor, a bed of fine clay 14 feet thick was struck at a depth of 140 feet, or 126 feet below mean tide level. Above this clay there were the ordinary sand or gravel deposits of the New Haven plain. The clay bed was evidently a mud deposit made in the harbor as it existed immediately before the deposition of the sand; and as the sand beds of the New Haven plain date from the era following the Glacial, the harbor very probably was that of the Glacial era. If the land then stood 125 feet above the present level, the mud bed would have lain just at the water's surface, like those of the present day. The evidence as to the level of the land in the Glacial era is uncertain; still it affords a presumption that it was at least 125 feet higher than now. No clay has hitherto been found in any other part of the New Haven plain.

b. Near Stoney Creek, eleven miles east of New Haven, on Smith's Island, one of the "Thimbles," there are two pot holes in the hard gneiss rock; one of them is 7½ feet deep, and 3 in diameter, and the other 3 feet deep and 10 inches across. They are situated within a few yards of one another upon the coast, but above high tide level. The large one contained, when recently opened by Mr. Frank Smith, its discoverer, many large rounded stones. Another pot hole of less depth exists upon Pot Island, about a mile to the southeast of Smith's Island. It is like a bread-trough in shape, and is 4 and 2 feet in its diameters, and 1½ feet deep. Still another, as I am informed, occurs on Rogers' Island, one of the westernmost of the same group. It is within reach of the tides and is 4 feet deep and 2 in width. These pot holes must have been made by torrents from the land. For the existence of such torrents the land should have been above its present elevation. We cannot fix positively the era of this higher level, but it may have been that of the great glacier, and the torrents, sub-glacier streams then existing.

c. The valleys of the streams of Connecticut and even those of the north side of Long Island are in general continued over the bottom of the Sound beneath its waters, apparently excavated for the most part out of the sand and mud deposits which constitute it; and this fact appears to indicate that the Sound was once dry land—a great east-and-west depression of the surface—into which the streams of the adjoining country flowed, and there concentrated their waters in a grand central river which received the existing Connecticut a few miles before entering the Atlantic. The admirable chart of the Sound by the U. S. Coast Survey, which is covered with figures indicating the soundings, enables any one interested in the subject to draw the lines of equal depth, and verify this statement.* There is nothing in the depth of the Sound to render the above supposition incredible. An elevation of 100 feet would now lay bare all but a fifth of its bottom across from New Haven, and one of 140 feet the whole breadth; and one of 200, would dry it up all the way to the line of New London, 50 miles east of New Haven. Further, a rise of even 50 feet would wholly separate the narrow western portion of the Sound from the more eastern by a bare area in the meridian of Mamaroneck and Rye, or 50 miles west of New Haven. Only the broader depressions corresponding to the courses of streams are to be looked for over the bottom, even with the fullest possible series of sound-

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* It is best, in order to exhibit well on the map the curve of the deeper and shallower parts of the Sound, to draw the lines for each fathom of depth up to 8 fathoms, and then for every two fathoms, that is for 10, 12, 14 and so on; and in addition, to make the lines for 7, 18 and 24 fathoms much heavier than the others; and to use differently colored inks for the lines 4 to 8 fathoms, 10 to 22, and 24 and beyond; or else give the areas 3 to 8 fathoms, 8 to 24, and over 24, different shades of color.

ings. For like all New England, the Sound received vast deposits of gravel and sand in the Champlain era from the depositions of the great glacier; and ever since these depositions were made, the rivers have been carrying in detritus, each year making its large contributions; the estimate, therefore, that the original surface, as it was before the Glacial era, had been covered by all these deposits to an average depth of 50 feet, cannot be excessive. After such a process tending to obliterate all depressions, especially over the northern half of the Sound which has received the most of the detritus, it is certainly obvious that better defined river channels than exist are not to be expected.

But the conclusion from the existing channels above suggested has at least three sources of doubt—*one* arising from the present action of tidal currents; a *second*, from outflowing under currents which occur at times in connection with large bays; and a *third*, from the configuration of the rocky basement beneath the mud and sand of the bottom of the Sound.

(1.) Jutting capes, especially if prolonged far out beneath the water, as well as obstructing shoals or reefs, inasmuch as they narrow the Sound, give increased velocity to the tidal currents passing by them. This cause is sufficient to account for the large deep holes—30 to 33 fathoms—opposite Norwalk, where "Eaton's Neck" on the Long Island side makes a long projection into the Sound beneath its waters, which projection at its extremity, three miles out (and hence nearly half across this part of the Sound), close along side of the deep holes, is within 6 fathoms of the surface. Again, near the "Middle Ground," south of the mouth of the Housatonic, or of Stratford, a large shoal but 2 feet deep in one part, there are deep holes both off its northern and southern extremities, the former of 20 to $21\frac{1}{4}$ fathoms, and the latter of 20 to $27\frac{1}{2}$ fathoms; and they are in part at least an obvious consequence of the tidal currents sweeping by.

Ten miles west of the mouth of the Connecticut, the Sound commences to narrow toward its eastern termination, its southern side here bending up to the northeastward; moreover shoals made from Connecticut river detritus, contract the breadth on the north. Consequently, here begin two depressions, and half a dozen miles east, a third on the north, which three unite in one broad range of deeper water, 18 to 32 fathoms in depth, that continues eastward, and finally increases to 50 fathoms as the waters approach the channel, called "The Race," by which they leave the Sound and enter the Atlantic.

(2.) The *outflowing under-currents* of bays are produced, especially when the broad opening has a comparatively narrow principal channel with other passages, among or over reefs; and they are strongest when the waves and currents occasioned by a storm drive heavily toward and into the bay; and still more so if a river add its floods to the waters which the storm waves and currents pile up within the bay. I do not know of any observations about the bays on the Sound tending to show where such under-currents exist, or what in any particular bay is their force or direction; and we are at a loss as to the effects to be attributed to this cause.

(3.) The actual configuration of the rocky substratum of the great basin in which the waters of the Sound rest is also little understood. Long Island has no rocks at surface, or about its points; and the Sound east of Hurl Gate, except quite near its shores, is also without any projecting rocks. Some of the prominent sand-spits of the shores, as those of New Haven and Stratford Point, may be traced far southward by means of the soundings. But it is not always easy to decide whether they have resulted solely from the detritus of the rivers to the west of whose mouths they lie, or whether a rocky basement has determined the form of the projecting spits. On the sand bed off the west point of New Haven harbor there are surfaces of bare rock, giving evidence of a rocky basement. Off Stratford Point, west of the mouth of the Housatonic, soundings have discovered no such rocks; and yet it is probable that the form of the bottom is here determined by the rocks underneath. On Eaton's Point the map says "rocky" at one spot; and the existence of this spit may also have been determined by the rocky basement below. But even when the spits or projecting sand-bars are proved to cover a ridge of rocks, it is not certain that this ridge may not have been a result of the excavations of the glacier, and of sub-glacier streams.

The shoals and deep holes in the vicinity of "Eaton's Neck" are directly south of the mouth of Norwalk river, and those about "Middle Ground" are south of the mouth of the Housatonic; and the question arises: Were they partly made by the rivers when the land was more elevated, or may they have been determined solely by the rocky configuration beneath and existing currents? It is apparent that without some direct investigations our conclusions can only be uncertain probabilities.

Yet notwithstanding all the doubts from the above mentioned sources, there are so many examples of depressions leading from the bays at the mouths of rivers over the bottom of the Sound, so many in which the outflowing under-currents of bays appear to be insufficient to account for the facts, either because the bay is not of the shape to produce appreciably such an effect, or there is not in the currents the proper accordance with the ebb in direction, that we think the facts afford strong evidence in favor of a former elevation of the region—an elevation probably not less than 150 feet. In such a case Long Island would have been literally the southern border of New England, and the universal glacier would have had no great basin of salt water to span in order to reach what is now the Island, and deposit there the boulders of Connecticut rocks, some of which, according to Prof. Mather, are from 500 to 1000 tons in weight.*

* It is difficult to explain the facts in detail with regard to the Sound without a map at hand. The following observations on the subject are however here added.

The main course of deep water through the Sound west of the meridian of Guilford commences near the northern shore of the Sound, off Coscob harbor and Greenwich Cove, (near the boundary between Connecticut and New York), and just here enter Byram, Mianus and Turn rivers. From this region it stretches eastward, passes the north point of the Eaton Neck spit, leaves "Middle Ground" to the north (and consequently in this part is south of the middle of the Sound), and then continues directly eastward till it almost touches the north coast of Long Island (being less than a mile off) in the line of Guilford. At the very end of the deep water channel the depth is 18¾ fathoms; just east of it, the depth is only 11½, then 10 and 9 fathoms. But about 6½ miles a little to the north of east, about two from the shore of Long Island there is an oblong deep hole, 18 to 19 fathoms in depth; and 2½ miles beyond, in the same direction, commences the southern arm of the great central range of deep water which continues eastward out of the Sound. The great range of deep water, seventy miles long, that commences in the west near Greenwich, must, as already observed, owe something of its depth, in its eastern portion at least, to its distance from the northern shore of the Sound or the region of rivers and detritus; and, again, it may have had its course determined originally by an east-and-west depression in the configuration of the basement rocks of the Sound. Still it affords some reason for believing that it once contained the channel of a great river. It begins against the north shore near Greenwich, just where three streams enter the Sound, as if a continuation of their united channels. Its depth at its eastern extremity, and its abrupt termination there, are reasons for inferring that it once continued still farther east, and was probably kept open by a flow of water through it. If the land were formerly higher by 150 feet, as has been supposed, the required conditions would have existed for making it a river course. But the query comes up, where in that case would have been the discharge? Its abrupt eastern termination takes place right opposite the large and broad Peconic bay which divides the eastern end of Long Island for a distance of nearly 20 miles, making the Island in form like the profile of an alligator, with its long mouth (Peconic bay) wide open; and the interval of dry land between the Sound and this bay is hardly three miles wide. Moreover, directly in the line of the depression, the land is low, and is intersected by Matituck lake, and also by various channels on the Peconic side. These facts lead to the supposition that this Sound stream of the Glacial era, whose tributaries included

5. Events and Results of the Champlain era.

The Glacial era closed in a subsidence of the land over a large part of the continent, the initiatory event of the next or Champlain era.

1. *Amount of Subsidence.*—The amount of the subsidence about New Haven is uncertain, because the actual height of the land in the Glacial era is not yet satisfactorily determined. It was so great as to carry the land considerably below its present level, as evinced by the height of the New Haven plain, this plain having been made and leveled off in the waters of the era. Taking the level of this plain as marking the water level, we learn that about the College square and for some distance to the north, and either side of this region on the same east-and-west line, the depression was near 40 feet. Farther to the north it increased gradually to 70 feet and more in Hamden; while

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the Housatonic and other rivers to the west, may have discharged through an opening into Peconic bay, and that this opening was filled up by sands during the following era of submergence (the Champlain era), and cotemporaneously the adjoining southern portion of the Sound was made shallow by the same means. The form of the bottom in this part of the Sound favors the idea that the sands for filling it came from the direction of the Peconic bay.

But the existence of the oblong deep hole in the course of a direct line to the southern arm of the great eastern deep water region of the Sound hardly nine miles distant, brings up the enquiry whether the river channel may not after all have been over this route *within* the Sound. The submergence of the Champlain era would have afforded the same means as stated above for filling up with sands this part of the Sound and for stopping off abruptly not only the channel of the Sound river, but the great depression in which the channel lay; for the waves of that era must have swept across the land in one or more places from the Peconic bay into the Sound.

If this latter view is the right one, the great Sound river, commencing in the rivers of the vicinity of Greenwich and taking into itself the waters of other rivers eastward to the Housatonic, and still others from Long Island, would, after receiving the Housatonic, have derived little else directly from the north until reaching what is now the eastern deep-water region; and this it would enter by the southern arm of that region. The rivers of the New Haven coast and other small streams between it and Sachem's Head, would have taken an intermediate course over the Sound to the same meridian, and then entered the middle arm. The rivers from Guilford to Killingworth harbor would have flowed eastward to the commencement of the northern of the three arms. And then a few miles beyond this, the northern arm would have received the Connecticut river, the great tributary, and from this point all the fresh waters of the various rivers would have been combined in one grand flow on their way to the ocean. From the depth of water and the character of the *deep holes* over the deep-water region south of the Connecticut, it may be inferred that here was actually the great bay of the Sound river into which the ocean waves set as they do now into the mouth of the present Connecticut. The latter has its deep holes inside of its bar; for the depth within the channel of the present river at low tide is 6 to 7 fathoms, while there are but 10 feet of water over the bar.

to the south it diminished in height, being but 30 feet in the latitude of Halleck's place on the bay. The facts on this point are given beyond (p. 88). North of Connecticut, over New England, the amount of depression below the present level was still greater, and increasingly so with increase of latitude, it having been 200 to 250 feet at least in central New Hampshire, 400 about Lake Champlain, and 500 feet on the St. Lawrence.

2. *General consequences of the Subsidence.*—As the writer has remarked upon elsewhere, an immediate consequence of a subsidence of the land, and especially of one which was greatest as a general thing to the north, would have been the bringing on of a warmer climate, and thence, the commencement of melting in the glacier.

As another result we note that the slope of the great valley of the Connecticut would have become less than it is now. Consequently the motion of the Connecticut valley glacier would have been greatly retarded, if not rendered altogether null. Moreover the rivers would have had a diminished rate of flow, and would therefore have spread in wider floods than ever before, becoming in some parts a series of lakes; and the lakes also would have had an unwonted expansion. The great flow of waters from the melting ice would have immensely augmented the floods in all directions.

Such an extended change of climate over the glacier area was equivalent in effect to a transfer of the great glacier from a cold icy region to that of a temperate climate and melting sun. The melting would therefore have gone forward over vast surfaces at once, wide in latitude as well as longitude, and not merely along a southern edge with slow creeping progress northward. Hence, as another result, the depositions of sand, gravel and stones from the glacier, would have taken place almost simultaneously over regions scores of miles wide in latitude, and in general without special accumulations along a southern border like what is called the *terminal moraines* in the Alps. They would have descended alike over the hills, plains, and valleys, lake regions, flooded rivers and sea-shore bays; but not with like results over these various regions, for wherever there was water in motion beneath, the water would have worked over the pebbles and sand and produced some stratification of the material, or at least have leveled all off at top. Thus unstratified and stratified drift (the latter including the so-called modified drift, as well as a large part of the "alluvium" of river valleys) were formed simultaneously, and both in the Champlain era.

The *depositions* made directly from the glacier as a consequence of its melting, and which belong to the opening part of the Champlain era may be first considered; and afterward the secondary and later results.

1. Events and results of the Opening Champlain era.

1. *Depositions over the hills.*—The deposits over the hills in the New Haven region, consist, like those of the rest of New England, of sand, stones, and large boulders, mingled pell-mell, or without stratification, except where they fell into lakes and rivers.

This unstratified drift is found wherever the land rises above the level of the stratified "alluvium" of the New Haven plain, except along the upland valleys. In some places it appears to be more or less stratified, as near the Seymour turnpike (running west from Westville) after passing the first hill (that of the Edgewood line); but in this and other similar cases the stratification is owing to the fact that the region in the time of the melting glacier was the course of a flooded stream. The boulders and stones are not to be looked upon as lying just where they were dropped in all cases, nor as being formerly in the same large numbers as now over given areas; for the sands and smaller stones that fell with the larger masses have to a great extent been washed away to lower levels, and carried off by streamlets to rivers, and by rivers seaward, and thus the large stones that crowd the surface in some regions may when first dropped, have been many feet apart, or even scores of feet away from the spot where they now lie.

The character of the stones and the size of the boulders over the hills show what is the nature of much of the material which fell into the waters, and which now lies over what was the bottom of the bay in the Glacial era.

The larger boulders of the New Haven region consist mostly of trap and sandstone; and next to these in size and numbers are those of gneiss and quartz. Those of trap, sandstone and gneiss are quite numerous over the western border of the region, especially along the eastern margin of the Woodbridge plateau; those of quartz rock have a very wide distribution. Only a few of gneiss have been observed as far east as Sachem's ridge.

Some of the largest of the trap boulders are as follows:

One 2½ m. north of Westville, on Boulder Hill, measuring along its diameters 29, 14 and 12 ft. and weighing at least 400 tons.

The boulder in pieces making the Judges' cave (the place of concealment of the *regicide* judges for a while in 1661), 1¾ m. east of south of the preceding, on the top of the West Rock ridge, the masses when together having weighed at least 1000 tons.

One on the Woodbridge heights, $1\frac{1}{2}$ m. southwest, about 10 feet in its diameters, but now in halves.

One in the northern part of the Edgewood grounds, a mile southeast of the last, and 2 m. a little west of south from the Judges' cave, about 8 feet cube.

Three others, half a mile south of the last, in the same grounds, measuring 25, $18\frac{1}{2}$ and $8\frac{1}{2}$ feet, 14, $8\frac{1}{2}$ and 7 feet, 8, 5 and 4 feet.

One near the Derby turnpike, $\frac{1}{2}$ m. E. of S. of the last, of 14, 6 and 5 feet in its diameters.

One in the woods north of the Stoeckel farm, $\frac{1}{2}$ m. S.W. of the last, and in the same line nearly with the Judges' cave and the Edgewood boulders.

On the Milford turnpike nearly a mile east of south of the latter, $\frac{3}{4}$ m. west from Allingtown, measuring 15, 8 and 5 feet.

One at Savin Rock, farther south, 8, 6 and 4 feet.

These masses are all on the *western* border of the New Haven region. The height given in each case is the height above ground, the depth to which the boulder extends below the surface being uncertain. Many of those that formerly lay over these heights have been broken up for use in house-building.

Over the same region sandstone boulders are numerous, but they are seldom very large, owing to the nature of the rock. One of tabular form on Boulder Hill measures 21, 15 and 5 feet.

There are also large trap boulders more to the eastward. One on Sachem's ridge measures 16 feet in length and $8\frac{1}{2}$ in greatest breadth; and one in East Haven, back of Mr. Woodward's, of 11, 9 and 6 feet.

There are also occasional masses of native copper derived from the copper mines of the Connecticut trap and sandstone region. A mass from the vicinity of East Rock, given to the Yale Cabinet by Mr. Eli W. Blake is probably of this kind. Another weighing 90 lbs. was found early in the century on the Hamden Hills.

2. *Depositions over the waters.*—The New Haven bay in the Champlain era covered the whole breadth of the New Haven region, from the Woodbridge range on the west to the sandstone ridges of East Haven and North Haven on the east, and spread northward into Hamden. East and West Rocks, Pine Rock and Mill Rock were cliffs within its area, or on its borders. Sachem's ridge was a long north-and-south peninsula south of Mill rock: and the Beaver Hills, another south of Pine Rock. The Beaver Pond region was, for a while at least, the deep central portion of the New Haven bay; it lay in the interval between Mill Rock and Sachem's Ridge on one side, and Pine

Rock and the Beaver Hills on the other, close alongside of the latter. Mill River entered a narrow arm of the bay between East Rock and Sachem's ridge, and the waves widened its head and battered Mill Rock for some distance west of Whitneyville. This Mill River arm was encumbered by two or three low sandstone islands, the northernmost of which is now the site of the residence of Stephen Whitney. West River opened into another arm which lay between the eastern of the Woodbridge heights (or the Edgewood range of hills) and the Beaver Hills, and West Rock Cliff and Pine Rock overlooked it on the north. Up the Quinnipiac valley, beyond East Rock, stretched a long and broad arm of the bay, which was the great inner harbor.

We come now to the consideration of the action of the waters of the bay in arranging the material dropped into them by the melting glacier. The large boulders were evidently the first to fall; for none were found on the plain when it was first taken possession of by the colonists, although such masses were then very numerous over the low Beaver Hills and Sachem's ridge, and are somewhat so still notwithstanding man's free use of them. Further, in no excavations into the alluvium of the plain for cellars, wells, or other purposes, (as we are informed by Messrs. Perkins & Chatfield, Mr. Isaac Thomson and Mr. D. W. Buckingham, who have superintended such work for years past) have *boulders* anywhere been found, with only two exceptions; and these are really no exceptions, since the boulders in each case lay on the foot slopes of sandstone ridges. One occurred at a depth of 10 feet beneath the gravel of the alluvium, and was found while making a pit in Trumbull St., near the house of Prof. Fisher; it was of trap and about two feet across. In the other case a number of large stones were met with in digging a well on Whalley Avenue near Blake Street; Mr. Buckingham, who reported the fact to me, attributes their occurrence there to the nearness of the place to the Beaver Hills.

As the melting went forward, the sand, pebbles and cobble stones were thrown down together; but they underwent as they fell an arrangement which varied according to the movements in the waters beneath. The bay had its tidal currents, as now; its areas of comparatively still waters; and besides, certain channels along which the flow of the rivers increased greatly the force of the ebbing tide. The stratification of the deposits varied accordingly. Where the currents were strong, they washed away the sand from the stones, or if very strong, the sand and smaller pebbles, and thus layers of coarse gravel were made—gravel beds being always deposits from which the sand has been sifted out by moving or flowing water. Along the main river courses there ought to be found, consequently, long *gravel courses*, marking the direction of the strongest currents, and these gravel courses should be not far below the surface unless the depth of water in which they were deposited were too great for this. Accordingly, we find that the valley of West River, near West Rock is a pebbly and stony region.

Another more remarkable gravel course extends from the head of the harbor between Meadow and Franklin streets over State and Orange streets, toward and beyond Whitneyville, and this was evidently the course of the *Mill River channel.* It follows (see map) the west side of Mill River from Whitneyville down to Grand street, then diverges a little westward, the region between Mill River and Franklin Street, as I am informed by Mr. Chatfield, being less stoney than that to the west. Franklin street is about 500 yards from the river. At Neck Bridge, below the East Rock range, the "alluvium" on the *west* side of Mill River is four-fifths stones; and on the *east* it is very pebbly, but the proportion of stones to sand is not more than 1½ to 5; and farther east the proportion of pebbles becomes quite small. The gravel is in all parts exceedingly coarse, and consists largely of cobble stones. This gravel course extends far up Mill River, and is as coarse in its stones nèar Ives' Station 4½ miles to the north, as it is over the New Haven region. Just south of the Mt. Carmel gap, the stoney character is still more remarkable.

Another gravel course, but coalescent with the preceding as it approaches the bay, passes northward along the Canal railroad to the *west* of Sachem's ridge (*Sm*), instead of to the east of it. It has the course of the *East Creek* valley. The pebbley deposits or gravel underlie the surface from the head of the bay, northward across State street; its western border follows approximately (as I learn from Messrs. Perkins & Chatfield) a line along State street to Crown, across from this point to the corner of Chapel and Church; along Church from the corner of Church and Wall to the corner of Grove and Temple; and thence along the east side of the cemetery.

The extent of the region shows that the flow producing it had the breadth and character of a tidal flow. This East Creek *tidal channel* was connected directly with the central interior basin of the harbor, the Beaver Pond depression, as the channels in the surface along Webster and Munson Streets demonstrate (p. 53, 54).

The Mill River and East Creek tidal courses were branches of the great central tidal flow up the bay.

The gravel-course of the Quinnipiac is not in sight. This inner harbor of the bay was deep, and swallowed a vast amount of great stones, gravel and sand, without being filled to the surface.

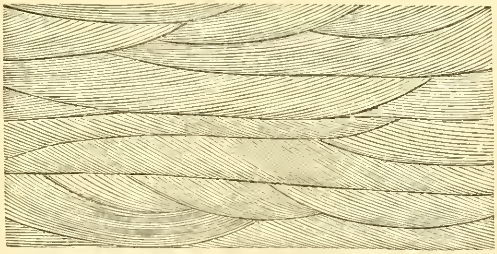
The courses of the tidal currents of the bay are also apparent in the less height of the drift formation wherever they swept along. Thus, within the range of the Mill River tidal course, at Neck Bridge, the height of the terrace on the *west* side of the river is but 32 feet, while it is 42 feet on the *east* side. This Mill River tidal current, although strongest, perhaps, to the west of Franklin street, had a wide spread to the eastward. For the area over which the terrace formation is below its normal height includes not only a region west of Franklin street, but all east of it to the river, and even a large part of Grape Vine Point (the wide point of land between Mill River and the Quinnipiac). Near the bridge at the foot of Chapel street on this Point the height of the drift or terrace formation is only 12 feet, and between this and the southern extremity of the Point, it is still less; half across the Point in the same line, it is only 21 feet: and half a mile to the north, near the Barnesville or Grand street bridge (the second bridge over Mill River), the height is only 29 feet. On the Quinnipiac side of Grape Vine Point, on the contrary, the plain has its full height, being 34 feet in the same east-and-west line with the Chapel street bridge, and 40 feet in that with the Grand street bridge. It is evident therefore that the central part of the great tidal wave up the bay in the Champlain era swept northward between Meadow street on the west and Ferry street in Fair Haven (on Grape Vine Point) on the east, an area over $1\frac{1}{2}$ miles wide; that it continued to be felt on the east side of the river to the north of Barnesville bridge; but at Neck bridge, approaching the south point of the East Rock range, it was pushed more to the *westward*, the terrace on the *east* bank at this point having a height of 42 feet, or the full normal elevation. An *eastern* branch of the tidal wave entered the Quinnipiac basin through the broad channel which forms the lower part of this river. Owing to the bend to the westward in the lower part of this channel, the wave was thrown against the *eastern* shore, so that the terrace formation on that side is mostly wanting while built up nearly to its full height apparently on the western side of the channel even quite to its mouth.

By closely studying the nature of the stratification of these deposits beneath the New Haven plain, the particular character of the action of the waters may generally be made out, even, in some cases, to distinguishing the effects of individual waves and changes in the action of tidal or river currents. A good example of this is afforded in the region south of the East Rock range (or of Snake Rock, its southern termination) between Mill River and the Quinnipiac, where sections of the deposits have been made in grading for the Hartford and Air-Line railroads (see the course of these railroads between Mill River and the Quinnipiac on the map). The whole height of the alluvium above mean tide is in this region from 42 to 45 feet. The cut through it for the railroads extends nearly southwest and northeast, and is about two-thirds of a mile, or 1200 yards, long. After the first 700 yards, the railroads pass under a bridge, and just beyond, the separate cut for the Air-Line railroad commences. The depth of the section is about 16 feet at its Mill River end, 20 at the bridge, and 26 toward the upper or Quinnipiac end. A number of interesting facts are to be observed in the sections:

a. The diminution in the proportion of pebbles on passing east from the Mill River valley is well seen. Along the Air-Line road they constitute hardly a fifteenth of the whole mass, although in an occasional small layer they are of large size, even like cobble stones.

Toward the more northern or Quinnipiac end of the cut, the layers are not only less pebbly but the lower part of the section contains two to four irregular layers of exceedingly fine clayey sand (M, fig. 2). The material adheres rather firmly, holds water well, and is so damp at all times that the exposed surface has in part become green from a covering of moss. The clayey layers are separated by others of sand, and an occasional one of pebbles.

1.



b. The alluvium is in nearly horizontal layers, just as it was originally laid down. But these layers are quite irregular, often of small lateral extent, and where composed of sand are very commonly made up of wave-like parts, from two to many yards long, as in the annexed figure—which represents a part of the surface six feet in height, about half way from top to bottom in the Air-line railroad cut.

c. A marked variation from horizontality occurs at the northern or Quinnipiac end of the cut, where the layers, as shown very distinctly in the firmer beds of clayey sand (fig. 2), dip downward four feet in a length of 30 feet, or from $7\frac{1}{2}$ to $3\frac{1}{2}$ feet above the railroad. This dip is toward the Quinnipiac river, or toward the old harbor, and may have some relation to the original bottom of the basin.

d. The sand of the sandy layers is *obliquely laminated* (not an uncommon fact in such deposits), as shown in the above figure. This division into thin oblique layers is not apparent when a cut is first made through it with the spade, but appears often on a surface of natural fracture, and very distinctly after exposure for a while to the winds. It shows that the sands were deposited in these delicate oblique layers while they were being accummulated in the long or horizontal beds which consist of these.

e. Throughout the upper part of the section, (above the line N S fig. 1), the inclination in the oblique lamination is mostly to the northward: while in the lower part (below N S) it is as generally to the southward. Layers containing both slopes may be observed in each, but the above are the prevalent courses. The formation is thus made up of an *upper* and *lower* division; and in many parts the two are separated by a thin band of large and small pebbles. Near the junction of the Air-line and Hartford tracks, the dividing plain is but two feet above the level of the railroad; to the eastward it retains nearly the same level (about 22 feet above meantide), but it is higher above the track, there being here a descending grade in the road. Below this bridge, or toward Mill river, the upper division is the only one in sight; the level of the dividing plain passes beneath the surface of the railroad excavation, and for this reason cannot be traced. For the first two hundred yards on the way toward Mill river, the slope of the oblique lamination rises quite uniformly to the southward as in the *upper* division above the bridge; through the next one hundred yards, this is still the prevalent direction; but farther toward the Mill river end of the cut both slopes occur, and that of the *lower* division finally becomes the most common.

f. In the upper part, the sands, through the cut for the Air-line road, have the ordinary dirt-brown color; in the lower part they are *brownish-red.* Thus there is a marked distinction between the two divisions in *color*, as well as in lamination. This color is of course not observable in the pebbly layers. It is owing mostly to the fact that the grains of quartz are tinged outside by red oxyd of iron, like those of the red sandstone.

The following conclusions flow from the facts here noted.

(1.) It has already been observed that Mill river valley, especially its west side, was the course of a powerful tidal current which set in and out over what is the head of the present harbor, whose ebb was increased by the flow of the river. From the diminution in the amount of pebbles to the eastward of the river (§ *a*), it appears that the tidal flow, as it spread in that direction around what was Snake Rock headland, rapidly lost its force; and finally, when fairly in the Quinnipiac basin, as the beds of fine clayey sand show, there were intervals of comparative quiet or of only gentle movements. The fact of these gentle movements is proved not merely by the fineness of these beds, but also by a very delicate contorted lamination in them, which in some places looks as if due to the smallest of eddyings in the water at the time of deposition; and also by successions of obliquely-laminated layers of sand only one or two inches thick, constituting here and there an overlying bed. Where layers of stones, or thick obliquely-laminated sand-beds, exist between these clayey beds, they indicate that a time of rougher movements intervened.

(2.) Since the slope in the oblique lamination throughout the *lower* division of the alluvium dips to the southward, or rises to the northward (§ *e*), the deposition of these beds took place under the action of a tidal current flowing northward, that is, *into* the old Quinnipiac harbor; and the reverse direction of the lamination in the *upper* division implies a current during its formation to the southward, *away from* the old harbor, or *toward the present bay.*

Such a change of current (A) would have attended the flow and ebb of each tide. But this cause of the transition in the beds would make the whole deposition a twelve-hour operation; which, even with a melting glacier above to supply material, would have been incredibly quick work. It might (B) have proceeded from a change in the place of discharge of the Quinnipiac waters, such as would have added the river current to the ebbing tide. But there is no evidence in favor of this in the existence of an old channel, and much against it, in the character of the layers along the present channel north of Fair Haven. It might (C) have resulted from the setting in of an extraordinary river flood, giving great force and volume to the outflowing tide, and not only along the proper channel of the stream, but far and wide over the low lands adjoining. Through such means the action of the incoming tide would have been as much weakened as that of the ebb enhanced; and, as a consequence, the oblique lamination of the sands would have been produced by the *outflowing* flood The special influence of the Quinnipiac flood would have diminished westward, where finally it would have encountered a similar, though smaller, Mill river flood; and hence it is natural that the alluvium should here lose its Quinnipiac characteristic and take that of the other stream, as stated in the closing part of (§ *e*). It might (D), if a flood were in progress, have been due to the fact that the depositions had reached such a level as to impede the inflowing tide, and thereby give the ascendancy to the river current; this being favored by the height of the land at the time.

Of the causes suggested above for the difference between the lower and upper divisions in the sections, C and D are the only ones that can be entertained; and such a flood would have been sooner or later a natural consequence of the melting of the glacier in progress. It would have been a flood enormous in extent and vast in effects; it may have been not merely an overflow of a few months, but of a period of years.

(3.) The subdivisions of the layers into subordinate wave-like parts may have resulted from the plunge of the waves that accompanied the tidal or current movements of the waters. Each of these subordinate parts is not the whole that was formed by the plunge and flow of a wave, but this *minus* what it lost by the succeeding plunge or plunges—as a little study of figure 1 will make apparent. In these wave-like parts of a bed, the oblique layers usually diverge as they rise upward, as shown in figure 1. The wave struck at the end from which the lines diverge, and as it pushed forward with slackening force, it dropped more and more of the the sands taken up, and so the little layers formed by it were made gradually thicker. So much material deposited with one fling of a wave would seem to indicate rapid work in the deposition of the beds.

The reasons for regarding these and other like beds as depositions directly from the glacier are the following. (1.) Stratified deposits were thus made by the glacier and the waters beneath somewhere about the New Haven region; and no others exist that can be such. (2.) These beds, consisting largely of interstratified sand and gravel, and in part of layers of cobble stones, have characters according precisely with the supposed mode of origin. It will be noticed that the layers of cobble stones have not required for their formation, on this view, streams of tremendous magnitude and violence, beyond all physical probability, in order to transport the stones from their place of origin, 50 or 100 miles or more to the north; the work of transportation was done quietly by the glacier, and they were simply dropped to their places; much more moderate streams served to sift out the finer material so as to leave the larger stones alone. (3.) These sand and gravel beds could not have been formed like ordinary sand-banks on a sea-shore or in a bay. For the waves and currents, which are the means of piling up such banks, could not have introduced the layers of gravel or cobble stones except they had been furnished by some other agency; and the amount of sand that the waves move in a stroke is but little, and this is spread widely. (4.) Again, they could not have been formed as sea-beach deposits. They have not the structure of such deposits. Moreover, if the beds of the New Haven plain had been produced by the gradual growth of a beach seaward, the harbor would have also existed somewhere, in narrow areas at least, among the encroaching beaches, and remains of the cotemporaneous mud-flats of the harbor should occur to mark its position. But no such clay or mud deposits have in fact any where been found, except in the Quinnipiac valley (upon which we remark beyond); none along the courses of Mill and West rivers, where we should naturally look for clayey interpolations among the sands, if not thick beds. The work of filling up the bay was evidently too rapidly done for the accumulation of mud or clay from the contributions of rivers.

3. *Filling of depressions with the drift.*—The depositions from the glacier filled up the greater part of the New Haven bay nearly or quite to the sea limit, as is shown by the even surface of the plain, the whole having been leveled off by the waters. The rivers, where not too deep to be filled, had currents to sweep out the sand and keep them clear.

The Beaver Pond depression, the great central basin of the bay, was one of the unfilled channels; and unfilled, in all probability, because of its depth. The drift was dropped over it as over the rest of the bay; but its depth saved it from obliteration; it still remained the open central basin of the bay. Its original communication with the wider outer portion of the bay was probably, as has been shown (p. 53), through the *West Creek* channel, whose extent, north-and-south course, and approximate conformity in direction and line with the Beaver Pond basin, accord with this view. During the melting of the glacier there would have been an abundant flow of waters from the northward through it; and these currents, together with the inward setting of the tidal flow, would have made the steep terrace-slopes that form its boundary, and those also of West Creek valley, which resemble in all respects the terrace-slopes along the rivers.

But while not filled by the depositing drift, the Beaver Pond depression appears to have lost much in breadth; for in the surface of the adjoining plain, especially along Crescent street, there are several large isolated basin-like depressions—deep holes, as they are often called, although sometimes 100 yards or more across—which must have been cut off by the depositions made by the glacier. The east and west Goffe street ponds occupy such exscinded depressions. The valley of West Creek appears to have been dissevered from the Beaver Pond basin by the same means; having no river (p. 52) to perform the office of sweeper, it would have been unable to resist the encroaching sands.

But while the Beaver Pond depression was thus closed in the direction of *West* Creek, a tidal communication appears to have been kept open between it and the deep parts of the bay, through the wide valley-like depressions near Webster and Munson streets, and thence through *East* Creek. The gently sloping sides of the East Creek valley along the course of Chapel and Elm streets below Temple, as well as near Webster and Munson streets, and other facts already mentioned (p. 54) correspond with the view, as just stated, that this channel was originally a depression in the sandy bottom made by the sweep of the tides. Accepting these views, the channels of East and West Creeks, which diverge at the bay, make together the circuit of the original New Haven square, and converge toward the southern extremity of the Beaver Pond depression, were both, though at different times, outlets of this great central basin.

The valley of Pine-Marsh Creek was another of the deeper glacier excavations, as already explained; and one too deep to be filled with the droppings of the glacier. This is proved by the remarkable breadth of the valley, and the fact that it is bordered by a steep terrace-slope, although no large stream but that made by the melting of the glacier ever flowed through it. There are deep holes or basins in the plain along its borders which may be explained in the same way as those adjoining the Beaver Pond depression; that is, they are spots that were unfilled by the sand and gravel of the glacier, because of their depth.

The Quinnipiac valley was far the largest and deepest of the deep basins of the New Haven bay; for while in one part a mile in width, the terraces on its eastern and western sides are very narrow. Moreover they are mostly below the usual height; and in some places so poorly defined as to be apparently altogether wanting. But to the south, between the basin and the bay, there is a great development of the drift or terrace formation, indicating that over this wide area the material was dropped by the glacier in shallow water. Red sandstone, the basement rock, outcrops from beneath the sands of the formation south of East Rock and in Fair Haven, opposite borders of the plain. The fact that the tidal flow in the bay during the Champlain era was not over this area but either side of it (along Mill River and the Quinnipiac channel), is other proof that the region was originally shallow; for the course of the tidal wave is along the deeper parts of a bay.

In contrast with the basin, the Quinnipiac valley near the village of North Haven and north of it has its lower flats exceedingly narrow and the upper plain of great extent; and here, concordantly, the red sandstone is but a little way beneath the surface, for it outcrops along the river, and, as I am informed by Mr. D. H. Pierpont, is the bottom of all wells in the village. But the poor condition of the terraces in the Quinnipiac basin cannot be attributed solely to its extent and depth; it must be owing partly to the currents that swept through the basin in the era of the melting glacier; for the upper plain or terrace, evidently for the same cause, has in general been left remarkably low, often not half its normal height, about North Haven and to the north. It is to be noted also that the drift formation or plain south of the basin may owe something of its extent and height to the diminished velocity which the waters would have had after passing East Rock, as they there escaped the bounds of the Quinnipiac valley, and were free to spread widely to the westward.

4. *Origin of the material of the drift.*—The sand, gravel and stones of the drift-deposit of the plain came largely from the Red sandstone formation; (1) the pulverized sandstone affording sand; (2) the associated conglomerate yielding pebbles and stones; (3) the wear of fragments from the harder varieties of sandstone and conglomerate making other stones or pebbles. There are some pebbles of trap, but they are very few in comparison with what the preceding source supplied. The rest came from the region of crystalline rocks to the northwest and northeast.

The great trap boulders may have been derived from any of the trap mountains to the north. Those of the western border of the New Haven region, which are often tabular in form and sometimes thick-laminated in structure, were probably carried off from the heights between the western of the Hanging Hills of Meriden and Mt. Tom, though possibly in part from the West Rock ridge more to the south. The great fallen masses in some of the valleys of the Meriden mountains resemble many of these boulders in form, in fine-grained texture, and in laminated or jointed structure. The masses of the Judges' Cave are probably from these more northern trap ridges which, as already mentioned, are the highest of the valley. This view of their origin accords with the fact that the gneiss boulders so common along with them are probably from the adjoining region of the town of Granby, or from Massachusetts, farther north, as stated by Percival after a comparison of the rocks. The quartz and quartzite boulders may be from the adjoining region in Massachusetts. But they are widely spread over the New Haven region, and they may have come from Vermont or New Hampshire, where such rocks occur.*

5. *Rapidity of deposition.*—The wasting of the glacier, beginning as the warm Champlain era opened, (p. 66) would at first have been slow, and mainly above. But after a while, the glacier would have been reduced to a comparatively thin sheet of ice, and then, through the heat conveyed into it in all directions by means of waters from above, and that received through flowing waters and air below, the rotting of the mass would have become general, and the unloading of the glacier would have gone rapidly forward. The period of years occupied by the deposition of the sand and boulders may therefore have been short. It may be queried, considering how much appears to have been done by a single wave, whether one year, or even less, would not have sufficed for the *upper* division, or the upper twenty feet, in the part of the formation represented in figure 1, on page 73.

With so quick a way of dumping the load of the great glacier it is nothing incredible that the channel of West Creek should have been cut off from its northern continuation, the Beaver Pond basin; nor is it impossible that, by like means, Mill River should have had its course through the same basin and channel intercepted by half a mile of sand and gravel, and have been forced to open a new way for itself by Whitneyville, although deemed improbable for the reasons stated on page 55. Even the floods of Niagara were thus stopped short; the old gorge, as long since made known, was filled to the brim for miles by the drift, and the river was turned off to work out another passage through the rocks.† The accumulations of a "ter-

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* Besides the boulders described on page 68, there are the following in more remote localities. One, of trap, 6 miles in an air-line north of the city, 1½ m. west of Ives' Station, fifty rods west of W. Fenn's, south and east of a bend in the road, is 88 feet in girt and 17 feet high, and must weigh over 600 tons. Less than half a mile south of this spot, near, and east of, the "West Woods" road, a little south of R. Warner's house, there are four great trap boulders, nearly in a north-and-south line, the largest 50 feet in circuit. Half a mile north of the Mt. Carmel gap, a short distance west of the railroad track, (and in full sight from the cars when passing), there is a boulder of trap, somewhat house-like in shape, which is 25 feet long by 14 wide and 16 high, with a girt of 68 feet; and along side lies a slice from its broad face, averaging 4 feet in thickness, which when a part of the mass, would have made its diameters 25, 18 and 16 feet, and its original weight at least 450 tons. It shows traces of vertical lamination, like a trap dike, and was probably taken off from some trap-mountain before it had fallen from its place.

† Dr. Newberry in his memoir on Surface Geology, already referred to (p. 49), mentions the Ohio river as another that was diverted by the filling up of the old channel

minal moraine" in the ordinary slow way would never have stopped the course of a Niagara. But before a sudden down-throw of sand and gravel from a freighted glacier, no stream is too large or rapid to hold its place.

Although the accumulation of freight by the old glacier must have required a very long period, even that of the whole Glacial era, the deposition of a large part of the older "alluvium," if the above view is right, was a rapid work—much more rapid than has hitherto been suspected. Any attempt to measure the interval of time between the depositing of the top and bottom layers by comparing the thickness of the formation at New Haven with the accumulations now going forward along the shores would lead only to great error. This conclusion holds not merely with reference to all similar formations made by direct deposition from the glacier, but also to others accumulated by the action of moving or running waters immediately afterward, inas-

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in the Champlain era, and states that its present course along the falls or rapids near Louisville was thus determined. Other cases also are referred to.

It is possible that in Mill River we find an example of such a change of course, as I have stated above. But the facts with regard to the Mill River gravel-course (p. 71) are another argument against it. It will be understood that this gravel is not that of the bed of the stream, but the material of the terrace or drift formation standing high along the border of the river; and that it is similar in character above and below the Whitneyville dam. It seems to be good evidence that the river occupied its present channel throughout the period of the deposition of the drift.

A change of course in the Quinnipiac through the cause alluded to is quite probable. The river at the bridge flows in a sandstone trough, the rock rising above the river 10 feet on the western side and over 20 on the eastern. Along the road running thence eastward to the depot (50 to 60 rods distant) which rises from 15 to 25 feet in level, there is no sandstone, and instead a deep bed of the sand of the stratified drift. The wells at three of the houses west of the depot go down 2 to 4 feet below high-water mark in the river, without reaching the "red rock." Moreover the low flats of the river north of the bridge spread eastward and sweep around to within 40 yards of the depot; and in consequence, a brick house recently built opposite the depot (across the street), while it stands in front on the firm sands, rests its northern or back walls on piles which were driven down in the meadows 20 feet without finding for all of them a firm footing. That the river's bed was once here is the supposition of those on the spot who know the facts. But we may suspect further, that the river from this point flowed southward to join the present channel half a mile below, the low level of the bottom of sandstone over this region determining it; and that the sands and gravel derived directly from the glacier or indirectly through the river floods, during the submergence (45 to 50 feet in amount, as shown beyond) of the Champlain era, filled up the earlier channel, so that the stream, when the land was afterward elevated, was forced to open a new channel, in doing which it took a course over the rocks because compelled to it by the existing slope of the surface.

much as the hills and valleys were everywhere left by the glacier loaded with sand and gravel ready and convenient for transportation.

The evidences of rapid deposition are so many and obvious that they appear to set aside any theory of the glacial cold which demands a slow decline of the era.

2. Later events and results of the Champlain era.

1. *Continuation of the Drift formation.*—It has been stated that, during the progress of the depositions by the melting glacier in the bay, the lighter or finer portions would have been largely sifted out by the moving waters; and while part of the sands would have been eddied off to one side, a much larger part would have gone with the current and the ebbing tide down the bay to be distributed by the tides chiefly *at their influx* along its borders.

Over the whole of the wide western portion of the New Haven plain, and especially the southwestern, the terrace formation consists of sands. To the north, toward Westville, at the entrance to West River valley, there are pebbly layers; but, on passing southward, these rapidly lose most of their pebbly character, and increase in fineness; and between Congress Avenue and Oyster Point, the beds are almost solely sand. The detritus which is *now* borne by the rivers to the bay is distributed largely along its western side, and there, consequently, are the great sand flats; and this is so because the direction of the tidal current in the Sound on its influx is *to the west*, and as it enters the bay to the northwest; and the depositions of detritus take place mainly during the inflowing tide. The same would have been the action of the currents and tides in the Champlain era; and hence this western part of the New Haven region would have been, from the beginning of the depositions, an area of accumulating *sand* beds.

The part of these sand beds that were made during the progress of the melting, should be marked off, if they could be distinguished, as belonging to the first section of the Champlain era, and only the subsequent additions, as "later results;" but the progress of the beds through the two intervals was continuous, and it is probably impossible to ascertain the limit between them. The hills and valleys, after the melting was completed, would in many places have been left thickly covered with sand and gravel ready for transportation by every little rill the rains might make, and the rivers would for a considerable time have continued to transport an unwonted amount of sand. The depositions along the borders of the bay for a while would, therefore, have gone forward with a rapidity almost equalling that of the melting period itself; and the decrease of rate would have been quite gradual. On the west side of the bay near Halleck's place (where the present railroad grounds abut against it), a section of the terrace formation 25 feet in height (the upper twenty-five) is exposed to view, and throughout it, the beds have precisely the structure exhibited in fig. 1 (p. 73), and differ only in the paucity of pebbles; they evince the same free supply of material and rapid deposition under the action of the waves. Moreover, the slope of the oblique lamination is toward the south (as in the lower part of fig. 1), showing that the deposition was accomplished mainly during the *inflowing* tides.

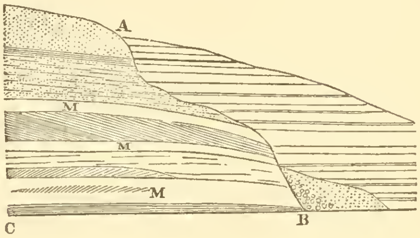
The result of all this transportation and deposition was an extension southward of the sand beds, as well as an increase in their height; and the terrace formation was thus completed to its outer limit. The plain stretching south to Oyster Point and over West Haven gives us some idea of its extension in that direction; but not necessarily its original extent, since the sea may have washed away much from its borders as well as from its upper surface.

Over the region toward Oyster Point, the beds are sandy throughout, and free from any upper layer of fine river or bay detritus, such as is deposited about existing mud-flats and sand-banks. On Grape Vine Point, between the mouths of Mill River and the Quinnipiac, there is the same absence of any thing like a layer of harbor mud over the sandy beds of the drift formation. The proof appears hence to be quite positive that *these sandy beds did not lie for a long period beneath the water, after the material was deposited.*

2. *Sand-formations on the borders of the Quinnipiac valley.*—The Quinnipiac valley was the site of the *inner harbor* of the bay, during the Champlain era—and a harbor of great extent and depth, as already stated. While the sand-formation was in progress down the bay, changes should have been going forward within its area. On its borders we naturally look for sand beds distinguishable from those that were made during the hurrying time of the melting by unconformability, and also by freedom from layers of coarse pebbles and cobble stones. One locality of such sand beds of considerable extent occurs on what was the southwestern border of the old harbor, at the northeastern end of the cut made through the terrace formation for the Airline railroad, south of the East Rock range. The character of the terrace formation along this cut has been described on pages 73, 74. The position and general character of these whitish sand beds are shown in the following cut. The part A B C is the terrace formation, consisting of beds of sand, some quite coarse pebbly, and below including

three layers (M) which are of clayey sand. A B is the plane of separation between this part and the layers of whitish sand. The latter

2



differ not only in their white color, but also in the absence of all pebbles, and in the much greater fineness of the sands. Through the washing of the waters against the shores, they were not only ground up, but they also lost almost entirely the oxyd of iron that tinges the quartz grains of the proper terrace formation. At the foot of the slope A B there is a collection of pebbles or stones, and for a short distance east of B, reddish sands; the pebbles and sand evidently fell down the bank from the layers above, when it existed as an exposed slope before the beds of whitish sand were deposited. These sands, moreover, were laid down in even layers, free from the oblique lamination that occurs in the terrace formation.

3. *Mud-formations in the Quinnipiac harbor.*—Besides these shore formations, the old harbor had its mud beds. They are the clay beds situated along the borders of the present river flats or meadows under 3 or 4 feet or less of sand: in these later times they have become the sites of numerous brick-yards. The clay beds vary in depth from 6 or 8 feet to over 25, the bottom in some places not having been reached at the latter level. Where penetrated they are found to rest on sand. The clay is very thinly and evenly laminated. The beds have been opened at several points near the outer borders of the meadows, on both their eastern and western sides, through a length on each of about three miles. The width of the border of clay is reported to be from 100 yards to a third of a mile. The two ranges converge toward North Haven, where the harbor had its head, and where, moreover, the terrace formation becomes wider and crowds upon the river. The clay continues north, between layers of sand, under the lower part of the village of North Haven. I learn from Mr. D. H. Pierpont, that in digging a well in the village of North Haven, after passing through 7½ feet of sand, a bed of clay 4 feet thick was met with, the bottom of which was 8½ feet above the level

of the Quinnipiac river. This $8\frac{1}{2}$ feet was made up of fine quicksand. The clay was a sandy clay, or what the brick-makers call "weak clay." This well is about 80 rods east of the depot. At two others, between the depot and the river, clay was found, and in one, there was at top 4 feet of sand; then 5 feet of "weak clay;" and below quick-sand, 3 feet of it above the level of high-water in the river.

The clay beds, according to Mr. I. L. Stiles, do not extend beneath the deep muck of the great meadows; on reaching the muck, instead of keeping at the same level, it *dips downward* with a rather large angle beneath the muck. What lies beneath the muck, whether clay or sand, has not been ascertained. In making the track for the Air-line railroad, which runs for nearly a mile and a half obliquely (north-eastwardly) across the flats, piles were driven to various depths, down to forty feet; solid bottom was reached, but the nature of its material is unknown.

Over the region north of North Haven village, the upper plain or terrace is very wide and the lower relatively narrow, the reverse of what is true to the south. Moreover, the country is remarkably sandy, large fields of loose moving sands making part of the surface. These sands are the present top of the upper plain or terrace. When this region, in the Champlain era, lay at the head of the great Quinnipiac harbor near high tide level, it was in a condition to be washed over by the running waters, and it is probable that the grinding and sifting then went on that robbed the sands of their feldspathic and other softer grains; and that what the sands lost the harbor received as a contribution to the mud of the harbor, now the clay beds.

The description of these beds of clay is here inserted under the head of the "Later events of the Champlain era." But it is not at present possible to decide whether part, or even all, of the deposition may not belong to the early part of the era. We need to know something more definitely with regard to the relative positions of these beds and the others of the drift-formation before a positive conclusion can be arrived at. The layers of sandy clay in the section at the cut for the Air-line railroad, represented in fig. 2 (p. 83), although 20 feet above the level of the meadows, may have some relation to the clay beds farther north. The fact that they have a dip toward the Quinnipiac basin is a significant one, as intimated on page 72.

What depositions were going forward at this time in the Beaver Pond basin, the central basin of the New Haven harbor, cannot be ascertained without an artesian boring. Such a boring would develop several facts of interest; for the depth to the sandstone bottom would give the depth of the original excavation; that of the beds of sand over it, the thickness of the drift derived from the glacier; that of any clay bed, or infusorial bed, or shell deposits, and of the peat, other important points in its history. The depth of the basin was small compared with that of the Quinnipiac harbor, as is evident from the present level of its meadows.

4. *Denudation.*—In this era of submergence, the sea breaking against the foot of East Rock and the other cliffs of the bay, must have worn away the sandstone along the base, and thus carried forward the degradation of the trap dikes and sandstone hills which had been begun by the glaciers. The waves acted upon the region in front of Pine Rock both from the direction of the Beaver Pond basin, and that of the broad West River channel. The part of the Beaver Hills occupying this position being thus attacked on both sides would have been soon swept away and a free passage made across for the waters. This spot is now occupied by a portion of the New Haven plain, directly proving that waters communicated across from the Beaver Pond basin to the West River channel, or the reverse, as just stated; and the degraded condition of the front of Pine Rock is further proof of the action of the sea here supposed. The sweep of the tides across this region, would have some where made a tidal channel; and this channel, as the high terraces either side show, was that which after a while became, and now is, the outlet to the Beaver Pond, along the north side of the Beaver Hills (see map). In like manner, a depression was made in front of the larger part of Mill Rock, by encroachments upon Sachem's ridge. The disjunction was not so complete as in the case of the Beaver Hills, because the central basin of the bay, the Beaver Pond, gave no aid through its currents and waves, since it was remote from Sachem's ridge, while close along side of the Beaver Hills. As already observed, the streamlets descending the front of the Rocks after rains would have aided in the process of denudation, and with much greater effect after the elevation of the land which closed the Champlain era.

3. Life of the Champlain Era.

More than a score of years since, according to Mr. I. Lorenzo Stiles, the antlers of a buck were dug up at a depth of 10 or 15 feet at the Stiles clay-bed near North Haven village. Mr. Stiles informs us that they were those of the common species of deer. The specimen was deposited in the New Haven Museum, an institution which years since came to its end, and it has been lost sight of, so that the fact with regard to its species cannot be verified. It is also stated by Mr. Stiles that impressions of leaves have been found in the clay. The muck at a depth of 6 to 12 feet has been found to contain at places great logs and stumps, nuts and leaves, accredited popularly (and probably rightly) to trees of existing species. But these are subsequent in age; for the muck beds of the interior of the basin could not have been begun until the salt-water harbor had been mostly obliterated by an elevation of the land.

The above is all we have yet gathered from the deposits of the New Haven region with regard to the life of this era. It is certain that there is much more to be learned; for there is good evidence of the existence of the Mastodon formerly in this part of Connecticut. While digging for the Farmington Canal in Cheshire, 13 miles north of New Haven, three or four teeth of a Mastodon were found, (Am. J. Sci., xiv, 187, 1828); and long before, remains of the same animal were obtained near Sharon. Also later, a vertebra of a Mastodon was brought to light in digging a canal for a manufactory in Berlin, the bone occurring in "a tufaceous lacustrine formation, containing bleached fresh-water shells of *Planorbis*, *Lymnæa*, *Cyclas*, etc., similar to those of the waters in the vicinity." (Am. J. Sci., xxvii, 165, 1835). This Berlin Mastodon existed as late as the Champlain era; for if of earlier time the lacustrine deposit would have been buried beneath drift, either the stratified or unstratified.

6. Terrace or Recent Era.

The work of the waves, tides and rivers went forward until the great drift formation of the bay and river valleys was completed. An elevation of the land then commenced which affected cotemporaneously all New England, and, it is believed, a large part of the continent, and bordered the rivers and lakes with terraces. This elevation marks the transition to the Terrace or Recent era.

1. Amount of Elevation.

In determining the amount of elevation of the land about the New Haven region, we have to take it for granted, not only that the plain was leveled off by the waters, but further, that a considerable part of its surface at the time nearly coincided with that of the water. The even character of the plain shows that this is not an improbable assumption.

The following are the results of the observations upon its level thus far made. The heights along the river valleys, the Beaver Pond basin, the valley of Pine-Marsh Creek and the borders of the bay are from approximate measurements, by means of a hand-level, by the author. The rest are from the large map of the city, published in 1858, from surveys and drawings by Mr. S. W. Searl. The distances from Oyster Point given are differences of latitude, or northings, in statute miles, and are derived from published maps. In reckoning the heights mean-tide level is taken as the base. The heights are not given of such parts of the terrace or plain as are obviously below the true or normal level (owing to river or tidal currents, or other causes), a fact generally made manifest by neighboring portions being at their full elevation.

I. Height of the surface along a nearly north-and-south course through the middle portion of the New Haven plain, from Oyster Point, by the College Square, to the Beaver Pond Meadows, and thence, half a mile to the eastward along the valley of Pine-Marsh Creek, (or as it is sometimes called Pine-Swamp brook).

	Northings from Oyster Point.		Height of Terrace.	
Oyster Point	0	miles	21½	feet
In line with id., w. of West R.	0	"	24½	"
N. of Oyster Point	0·50	"	27	"
Halleck's Place, S. side*	0·75	"	30	"
" " N. side	0·87	"	30	"
College st., front of S. College	1·85	"	38	"
York street, corner of Broadway	2·00	"	41½	"
Beaver Pond basin, S. end	2·70	"	43	"
Id., E. end of Munson street Creek	2·80	"	43	"
Id., W. end of Munson street	2·80	"	44	"
Id., outlet, W. side	3·40	"	53½	"
Id., opposite outlet, on E. side	3·40	"	53½	"
Id., farther north, E. side	3·65	"	55½	"
Id., farther north, at road crossing	3·80	"	56	"
P. M. Creek valley, at southwest point	3·80	"	56	"
Id. at road crossing, N. W. of W. end Mill Rock	4·20	"	62	"
Id., farther north	4·30	"	63	"
Id., S. E. of Hamden Church	4·55	"	66	"
Id., at mouth of Creek	5·15	"	72	"

* The reader is advised to put a letter H on the map (p. 44) three-sixteenths of an inch north of the letter O, west of the harbor, and the letters G P on the point of land between the mouths of Mill River and the Quinnipiac.

II. Up West River valley.

	North. from Oyster Pt.	Height of T. in feet.
	0·20	23
Crossing of N. Y. railroad	0·50	27
End of Washington street	0·62	29
Crossing of Milford turnpike, W. side	1·25	36
North of Id.	1·40	37½
Above crossing of Oak st., W. side	1·85	38½
Crossing of Derby turnpike, W. side	2·25	41
" " " E. side	2·15	40
Crossing at Westville, E. side	3·15	46–47
Crossing at Westville, W. side	3·15	45–46
Near Congregational Church, Westville	3·45	56–57

III. Up Mill River valley.

Near Neck Bridge, east side, to highest point	2·00	42
Suydam Grounds, Whitneyville, W. side	3·30	53
Above dam, below 1st bridge, W. side	3·90	63
Whitneyville Church	4·40	66
N. of the Church	4·55	69
Mouth of Pine-Marsh Creek	5·15	72
Above mouth of Id.	5·60	76

IV. Up the Quinnipiac valley.

Foot of Third st., Fair Haven, near mouth of river	1·33	34½
Crossing of Shore-line R. R., W. side of river	1·80	40
North of Id.	1·90	41
Crossing of Air-line R. R., W. side of river	2·50	45
At North Haven	7·00	46

V. South of the latitude of Oyster Point.

On the west coast of the bay, 0·33 m. south of Oyster Point, the terrace is 24 feet high; 0·43 m., 21 to 23 feet; 1·30 m., at the Savin Rock beach, only 8 feet, but about 300 yards north, 14 feet.

In the following table the results in the preceding four tables are brought together for comparison. The Roman numerals I, II, III, IV, indicate the table from which the numbers below are taken.

North. from Oyster Point.	I. Middle of plain.	II. West River.	III. Mill River.	IV. Quinnipiac.
0·	21½–24½	21½		
0·20		23		
0·50	27	27		
0·62		29		
0·75	30			
0·87	30			
1·25		36		
1·33				34½
1·40		37½		
1·80				40
1·85	38	38½		
1·90				41
2 00	41½		42	
2·25		41		
2·50				45
2·70	43			
2·80	43			
2·88	44			
3·15		46–47		
3·30			53	
3·40	53½	56–57		
3·45				
3·65	55½			
3·80	56			
3·90			62	
4·20	63			
4·30	64			
4·40			66	
4·55	66		69	
5·15	72		72	

The Beaver Pond Meadows and the valley of Pine-Marsh Creek are natural levels, the former over a mile long, the latter three-fourths of a mile, each containing a range of nearly still water along the bottom through this distance; and hence the height of the terraces on either side is ascertained with great facility. It has already been stated that in the latter this water level is determined by the Whitneyville dam, so that the height of the dam gives, after an allowance for the back-water rise, the height of the water above mean-tide level, even for that of the upper part of the valley west of Mill Rock. The edge of the dam over which the water falls is 34 feet 8 inches above the base of the dam, according to Mr. Eli Whitney; and the surface of the water a few yards back is 4 inches higher, making in all 35 feet for the whole height of the fall. The base of the dam is very near mean-tide level. The back water above the dam extends about 2½ miles, to within 300 feet of the dam at Augerville; the increase in the height of the surface along this distance has been estimated to be about 6 inches a mile; or 15 inches for the whole distance, and 8½ inches to the mouth of Pine-Marsh Creek.

The elevation above mean-tide level of the water-surface in the Beaver Pond Meadows near its outlet, is taken at 22 feet, in accordance with information received from Mr. Eli W. Blake as to the heights of the dams between the Beaver Pond meadows and West River. A few hundred feet above the outlet of the Beaver Pond basin, the meadows commence a rising grade northward, as is obvious in the rippled surface of the little streamlet which flows along it; the increase of height thereby at the crossing of the road to Pine Rock (3·80 from O. P., in Table I) is at least 3 feet; and beyond this to the north the slope of the meadows runs parallel closely with that of the terrace plain either side, the height of the plain, even to its northern extremity, above the meadows being quite uniformly 31 to 32 feet.

The observations show that the plain rises gradually to the northward. The average increase of elevation from Oyster Point to the mouth of Pine-Marsh Creek, a distance of five miles, is 10 feet per mile. From Oyster Point to York street, two miles, it is 8½ feet; and to College street nearly 7¼ feet; from College street to the west end of the Munson street crossing of the Beaver Pond meadows, one mile, it is only 6 feet; along the Beaver Pond basin, from its southern end to the road which crosses it a little south of the line of Pine Rock, a mile in distance, the rise is 13½ feet; along the valley of Pine-Marsh Creek, the average per mile is about 12 feet. The slope for a mile north of College street, that is, between 1·80 and 2·80 miles in latitude from Oyster Point, is more gradual than either to the north or south; and the same is true for a surface of like latitude near West river, on which the increase in elevation from Oak street (1·85) to Westville (3·15), 1·30 miles in distance, is only 8½ feet.

The fact that the increase of elevation northward is by *a gradual slope, and not through a succession of two or more abrupt terraces*, is manifest along Dixwell Avenue (the road to Hamden Plains). The Avenue lies to the east of the Beaver Pond Meadows, and to the west of Pine-Marsh Creek, and extends northward in a nearly straight line, beyond the mouth of Pine-Marsh Creek; and hence any terrace would be apparent along its course, or in the fields either side, if such existed.

The observations prove the fact of an elevation of the land along this part of Connecticut after the Champlain era, the era in which the drift formation was made. They also appear to prove that this elevation was greatest, by a nearly regular rate, to the north. But before arriving at any conclusions as to the amount of elevation, or its rate of increase northward, it is necessary to consider:

First, Whether part of the slope above pointed out did not exist in the surface before the elevation began.

Secondly, Whether part of the slope was not formed by the retreating waters during the progress of the elevation.

Thirdly, Whether part is not a result of a sinking of the more southern portion of the plain since the elevation.

(1.) Slope antedating the elevation.—There can be no doubt that part of the slope antedates the elevation. This may be true of each end of the slope, that is (A) the *southern* part adjoining the bay, and (*B*) the *northern* part.

A. *The Southern Part.*—A slope in the southern part may have arisen (*a*) from the tidal currents with or without the waves, aided by the river floods; (*b*) from the waves alone; or (*c*) from increasing depth in the bay outward, and decreasing supply of sand.

(*a.*) *From tidal currents.*—Oyster Point projects toward the Sound between West River and the bay, and in this exposed condition would in all probability have been swept by the tides in such a manner that it would have failed to be built up to the water's surface or to mean tide level. The *eastern* part of this Point for the last half mile is actually half lower than the western or that bordering West river, owing undoubtedly to the action of the cause here mentioned; and the western suffered also; for, *on the other side of West River the terrace is* 24 *to* 24½ *feet high.* Grape Vine Point, a mile and a quarter farther north in the bay, is another example of this effect, as observed on page 72, where the facts as to its little height over its middle, and the western or Mill River side, and the full height of the terrace on the Quinnipiac side, are stated. Had the Point been a little narrower, it might have been low all the way across, so that it would have remained doubtful whether this low level was due to tidal currents or not. But the heights on the Quinnipiac side are as great as those of the middle of the New Haven plain in the same east-and-west lines, so that they have nearly the normal elevation. They show, therefore, that the lower part of the Point is over 20 feet below the normal level, owing to the action of the great central tidal flow up the bay. Again, at the corner of State and Chapel streets, along side of the channel of the old East Creek, the present height is 15 feet, or about 22 feet below the full height for the latitude; and this influence of the sweep of the tides is felt all the way nearly to an east-and-west line through the corner of College and Chapel streets.

It is quite certain, in view of these facts, that Oyster Point was in no part built up to the water level. How much to allow for the deficiency, we have not facts to determine. An allowance of 10 feet could not be too great; and this would give 31 or 32 feet as the height which the Point would have had, if no such cause had operated.

If the surface of the plain at Oyster Point, corresponding to the original water level, is to be reckoned at 30 feet above the present mean tide, then the slope normal for the whole of the plain to the southern part of the Beaver Pond meadows, a distance of $2\frac{3}{4}$ miles, would not have been over *six* feet a mile.

b. From the waves alone.—The bay flats are a direct continuation of the flood-grounds or lower flats of the rivers entering the bay; and yet the former are leveled off at one-third tide, or lower, while the river flats and those of any sheltered coves may be very near high-tide level. The flats in the bay, like those outside, are washed by the waves and hence their lower level. If the surface is at one-third tide, as is the case with the flats off West Haven Point, there is then a difference of about 4 feet between their level and that of the flats or meadows along Mill river and the other rivers of the region. Consequently, *in a rise of the land the surface of the river flats would be* 3 or 4 *feet higher than that of the unprotected bay flats.*

When, however, the river flats are wet meadows, made of deep muck and oozy mud, they will dry and sink, and may thus lose all their excess of height, unless the flats are of so soft a mud as to settle equally. In the latter part of last century the tides were mainly shut out from the upper part of West River by a dam along the line of the bridge of the Milford Turnpike (see map) and, as a consequence, the meadow north of the dam is $1\frac{1}{2}$ feet lower than that to the south. Those who know the history of the changes there attribute the difference of level to a fall in the surface from loss of water beneath; and this was doubtless the true cause. But, in the case of the river flats of the Champlain era, there is no evidence that they were topped by muck meadows; for in all the sections exposed to view they carry their sandy layers quite to the top. We may therefore reasonably assume that 3 to 4 feet of the excess in the *height of the part of the plain leveled by the river floods* above that of those along the bay, are to be attributed to the cause here explained.

c. *Slope as a combined result of* (a) *the increasing depth of the waters southward over the shallow border of the bay region, and* (b) *a decrease southward in the supply of sand*—the deposits as they extend southward consequently rising to a less and less height beneath the water's surface. The waters dropping their sands as they flow on through the bay would necessarily have had less for deposition about its outer portion. Part of the diminishing elevation of the plain in West Haven toward the Sound (p. 89), and perhaps something of that of Oyster Point, may have this explanation; and the latter may have been the principal one of the two causes here included.

B. *The Northern part.*—Somewhere across the New Haven region there was the limit of proper tidal action, or of the salt water flood-grounds, an irregular line bending north along the river valleys. [The northward bend for the rivers is much less than what the rise of the tides in the streams would seem to indicate; since this rise is largely due to the fresh waters being dammed up by the incoming tide; and in case of river floods, the fresh waters, and also something of the river slopes, may force their way to the bay, and even into it, in spite of the tides.] Whatever the position of this line, the plain to the north of it was made and leveled off by the river floods, and not by the tides. The slope of the surface in this upper part should therefore correspond with that of the waters in the flooded streams of the Champlain era.

It would be a great convenience if the sea had left its mark well defined across the plain; for then the present height of the former sea-limit would be easily ascertained. But all traces of a line of beach, if such there were, appear to be obliterated. We are left, therefore, to approximations from uncertain data.

We safely conclude that the land now at 30 feet elevation was within the range of the sea, for this is the height *directly on the bay*, at Halleck's; and further, that of 35 feet, for this is the height on the bay at the mouth of the Quinnipiac; and, moreover, the whitish sands overlying the terrace formation on what was the shore of the Quinnipiac harbor (p. 84), have a height of 35 feet notwithstanding the denudation they have undergone at top since their deposition.

Again, the part of the plain between 38 and 44 feet in elevation above mean tide is that which has the least slope, or is the most nearly level: and above it, or to the north, the plain rises at the rate of 11 to 12 feet a mile. There appears to be reason in this fact for placing low-tide, or mean-tide, limit near the line of 44 or 45 feet. If 44 were the low-tide limit, then high tide would have reached to the present 50 feet level; and the terrace formation, in the Snydam grounds below the Whitneyville dam west of the river, 53 feet high above mean-tide level, might have been the work of the sea water alone. *Fifty feet* as the *high tide* limit, would correspond to a difference of level in this region between the Champlain and Terrace eras of 50 to 51 feet, since the surface of the present river flats at Whitneyville is at high tide level.

Along the Mill River valley, above Whitneyville, the rising grade of 11 to 12 feet a mile for the plain continues not only to the mouth of Pine-Marsh Creek, but also nearly to Ives' Station; beyond, the rate diminishes to 10 and 9 feet, the latter occurring just below Mt.

Carmel. The height of the terrace-plain along Mill river is approximately as follows:

	Above the river.	Above mean-tide level.
At Whitneyville dam, (by calc.) . .	55 feet.	55 feet.
1·40 m. N. of Wh., at mouth of P. M. Creek, (by calc.)	55 "	72 "
2·25 m. N. of W., at Augurville . .	50 "	86 "
4 m. " ½ m. S. of Ives's Station	43 "	103 "
4½ m. " at Ives' Station,	41 "	108½ "
5¼ m. " south of Mt. Carmel gap	36 "	115 "

The heights above mean-tide level are obtained by adding the known height of the river at the several places mentioned (see page 101) to the height of the terrace. The height corresponding to the position of the Whitneyville dam is deduced from that at the Suydam grounds, a sixth of a mile below. The slope of the terrace plain up to the station half a mile south of Ives's station, according to the above, is 12 feet a mile, the quotient from dividing the difference of 103 and 55 by 4 (the distance). For the whole distance to Mt. Carmel, the average is about 11 feet a mile.

When it is considered that the waters which leveled this plain were the same that distributed the sand and gravel of the drift formation—that, in other words, the plain is only the upper surface of the drift formation then deposited, it is obvious that the water, to have made such a slope over so wide a region, even to the shores of the bay, must have been those of a flood of no common magnitude. For the last mile, the flooded waters of Mill River were united in one great tumultuous sea with those of western Hamden, or those of the several tributaries of Wilmot Brook, for the plain in this part has one level all the way across, a distance of three miles. Such a flood could hardly have come from any source but a melting glacier, and must have been simultaneous with the deposition of the material arranged by the waters.

The evidence that the drift formation north of the line of Whitneyville is attributable to the action of river floods, and not simply to an elevation of the land greatest to the north, is proved by the very different level of the terrace formation in the same latitudes in the Quinnipiac and Mill River valleys.

In the village of North Haven the stratified drift, *east* of the river, has a height in St. John street (a road ascending the west slope of a hill) near the northeast angle of the cemetery, of 40 feet above the river at high tide, or 43 to 44 feet above mean-tide level in the bay. The terrace plain is however poorly defined, and the hill rises gradually eastward to 61½ feet above high tide in the river;* yet the limit of the stratified drift formation is well marked beneath the surface; for the material of the part of the hill above 44 feet is much more compact than that below, and abounds in boulders or large stones promiscuously distributed, (many of them over a foot in diameter, and some very distinctly marked with parallel grooves from abrasion while in the foot of the old glacier),† showing plainly that it is *unstratified* drift.

On the *west* side of the Quinnipiac, the terrace plain (also here not very well defined) has a height of about 46 feet above mean-tide level.

Now this height of 44 to 46 feet (or perhaps 50 normally), at North Haven village occurs on the same east-and-west line with that of 103 feet in the Mill River valley. *If an elevation of the land were the cause of the increase of height northward, the two should have been alike.* The difference must be owing to the peculiarities of the two river regions. The Quinnipiac valley is that of a much larger river, has a much greater width as well as length, and opens toward the bay with a breadth of more than a mile. Moreover it descends to within four feet of the level of the sea at North Haven, four miles farther north than Whitneyville, a condition owing to the deep excavation of the basin in earlier time. The waters over such a basin would have been nearly level throughout, with only a small rise if the floods descending it were very great. The terraces therefore should have been but little above those at the southern limit of the basin between East Rock and Fair Haven, which is the fact; and hence the wide difference in height above the sea from what is observed in the Mill River region.

The conclusion that the amount of elevation was near 50 feet is sustained by the fact that the terraces on Mill River are at least 50 feet in height above the level of the river even as far north as Augurville, 2¼ miles from Whitneyville. The height of the terrace depends on the depth of the excavation after the elevation; and if the slope of the river's bed after the excavation is just what it was before, (provided the slope of the land had not been changed by greater or less eleva-

* According to leveling by Mr. D. H. Pierpont. An average tide rises 3½ feet.

† The boulders lying on the surface in the southeast part of the Cemetery, (the part that is highest on the slope of the hill) were thrown out, as I learn from Mr. James H. Thorpe, in excavations for graves. On the *east* slope of this hill (or that away from the river), the stratified drift, judging from the loose sands of the surface, may extend a little higher than on the west side; but this point remains to be investigated.

tion to the north,) then the interval between the level of the terrace plain and that of the present flood-plain of the river (47 feet at Augurville) would just equal that of the amount of elevation. But in fact the river's bed at Augurville is 3 or 4 feet above what is required for a restoration of the earlier slope (p. 101), and not more than one foot of this 6 or 7 can be attributed to the rise of the land being greatest to the north; and hence 50 feet for the amount of elevation in the latitudes of Whitneyville and north to Augurville cannot be too great.

(2.) Slope made during the progress of the Elevation.—Since the sand-flats of a bay have their height determined by the tides and waves, and are thus kept, for the most part, below mean tide level, a rise of the region exceedingly slow in progress might result in a wearing away of the surface at the same rate of progress; and thus the height of the sand-flats would be lowered, as the rise went on. But the material washed off from the flats would be carried to the shore to extend the beach seaward. The relation of the beach to the sand-flats may be seen along the shores near Savin Rock. As the rise went forward, the beach would keep extending; and as the beach attains a height by the accumulations, of only a few feet (three or four at Savin Rock) above high tide (the height of wave action), the final result would be a gradual seaward slope in the surface of the land, and one made during the progress of the elevation. But in such a case beach accumulations would have been laid down over the land to a depth of six feet or more; which would evince their origin by a dip in the layers of the lower part corresponding with the slope of the original beach, and an irregular arrangement of layers in the upper; if not, also, in the presence of beach relics.

Now, over the New Haven plain, all the way to Oyster Point, the drift formation in the numerous sections has a uniform horizontal stratification to the very top. The sands of the upper foot or less are discolored by the growth of vegetation, yet they are in fact a part of the upper layer. An overlying beach formation is nowhere distinguishable. There is therefore no certain evidence that any of the seaward slope of the plain was produced by the method here explained.

The facts tend to show that the elevation that placed Oyster Point and the land farther north above the sea was not slow in progress.

(3.) Slope resulting from a later sinking of the sea-margin.—The evidences of a later sinking of the sea-margin to be looked for are the following: (1) Old stumps, in the position of growth imbedded in the flats or the shallow waters off the coast; (2) submerged remains of human structures; (3) submerged shell heaps bearing evidence of man's agency in their accumulation; or (4) if the sinking is one now in progress, it should be apparent in the fact that the waters have deepened in historic times over submerged rocks, or in harbors. No proofs of such a sinking have been observed, and no one among those who have had the most to do with the coasts has suspected that any is now in progress.

The fact that the plain extends quite to the western hills, without any higher margin or range of beaches along these hills, is the strongest argument for the supposed sinking, that is, a sinking greatest to the southward.

(4.) Slope resulting from an increase in the amount of elevation to the north.—The great differences in the height of the drift formation in the Quinnipiac and Mill River valleys have shown that the slope in the surface of the latter is not due solely, or mainly, to an elevation of the land that was greatest to the north. The facts in Mill River valley would require, if this were the cause, an average increase in the rise northward of 11 feet a mile between Whitneyville and Mount Carmel; and those of the Quinnipiac, even taking the normal height of the terrace of North Haven at 50 feet, of but a foot a mile. Still it is possible that some part of the slope of the land is attributable to this cause, and even probable in view of the fact that the rise affected cotemporaneously all New England, and resulted in raising its northern portions, especially the northwestern, the most—the increase from New Haven, by Lake Champlain, to Montreal averaging 1½ feet a mile. Judging from the increasing height of the terraces to the northward along the rivers of Connecticut and Massachusetts, it does not appear probable that the increase per mile in southern New England exceeded *one foot* a mile. Adopting this rate for the New Haven region, the average slope of the part of the plain along Mill River valley, south of Mt Carmel, would be reduced to 10 feet a mile, and that of the part of the Quinnipiac south of North Haven, nearly to a level surface.

(5.) Conclusions with regard to the Elevation.—The following are the conclusions to which we are led with regard to the amount and character of the elevation.

1. That it was rapid if not abrupt, at least for the first 25 feet. (Progress for a century or two would be geologically rapid.)

2. That it was 45 to 50 feet, probably 50, in amount.

3. That the formation of the northern part of the plain, beyond 50 feet in elevation is due mainly to the floods of fresh water filling the valleys and spreading widely over the plains during the melting of the great glacier of central New England.

4. That not more than 1 foot a mile of the increase in the angle of the slope is due to a northward increase in the amount of elevation.

5. That part of the rapidity of slope in the lower portion of the plain below 40 feet in height, after allowing for a descent of the one foot a mile of §4, is due to tidal, wave, and river action over the region of the bay; and part to increasing depth over the borders of the bay southward; part to a decrease southward in the amount of transported sand.

6. That part of the slope in the lower part of the plain may possibly be owing to a slow sinking of the land along the margin of the Sound; but that there is no evidence that such a sinking is now in progress.

7. That the level of the terrace along Mill River above Whitneyville, and along the Quinnipiac north of North Haven may owe 3 or 4 feet of its height, as compared with that more to the south, to the fact that the surface of the latter was subjected to wave action because within the range of the bay.

But *may not this rise of 50 feet be only the final condition after a series of oscillations of level?* May not the land, when in course of elevation, have risen beyond 50 feet, even to 100 feet or more, and afterward have subsided to the present level? It is possible; for such an oscillation as this, performed in a brief period of time, would have passed unregistered. That the land has not stood at a level of 100 feet or so for any great length of time in the Recent or Terrace era may be inferred from the fact that, both at the outlet of Saltonstall Lake, and at the passage of Mill River through the Whitneyville gap, the trap dike over which the waters flow has not been worn away *below high tide level.* The gap intersecting the trap dike, (in fact a trap ridge) was in each case worn down toward its present condition in the Glacial era, as already observed. It is not at all probable that an elevation of the land could have again exposed both these valleys through a long period to the wear of waters flowing along them in rapids and descending in cascades of 50 feet or more, without at least one of them being worn to a lower level. The trap at Saltonstall Lake is soft and easily decomposable.

The rapids on West River for a mile above the bridge at Westville, are evidence that the channel has not been excavated, since the Glacial era, to a depth much below the present bottom.

It has been already stated that large stumps and logs occur in the Quinnipiac meadows. I am informed that it is a common thing to see them projecting from the banks at the very lowest limit of low water, or 5 or 6 feet below the level of the meadows; and some have been taken out and sawed into good boards. The wet meadows along the rivers of Connecticut formerly were mostly under forests, and it is probable that this was true of those of the Quinnipiac. But stumps could not commence their growth at such a depth, and hence the position of the stumps and logs may seem to show that the level of the Quinnipiac meadows when these trees were flourishing, was a few feet at least above the present, and that consequently a slow sinking has taken place. The evidence appears to be sustained by the fact that the muck or peat in the meadows has great depth, for the lowest layer must have been near the present level of the meadows, when the plants of which it is made were growing. But the surface of a meadow may slowly subside, as growth goes on above, owing to the weight of the increasing accumulation of material; and large trees are known to sink in soft swampy soil as they attain large dimensions. The evidence therefore as to the fact of even the small elevation which is here suggested, is quite doubtful.

2. Results of the Elevation.

As a consequence of the rise, the rivers had at once a steeper slope than before to the sea; and hence, having new force for erosion and transportation, they set about deepening their beds, and the level also of the lower flats—making these lower flats mainly by encroachments on the terrace plain. They thus worked toward a restoration of the old slope at a lower level, or toward a slope still more gradual; and in the process, they made for themselves deep cuts through the drift formation and left the upper surface of the formation as a high upper plain or terrace. Until this change, the stratified drift formation was in no sense the *terrace formation.*

Along Mill River, between Mt. Carmel and the sea, the cut made was 35 to 55 feet or more in depth, as is indicated by the present height of the old flood grounds, that is, the terrace plain. The height of the terrace above the river's surface is—

A mile north of Whitneyville, (by calc.) - - -	51 feet.
At Augurville, 2¼ miles north of Whitneyville -	50 "
½ m. S. of Ives' Station, 4 m. N. of Whitneyville -	43 "
At Ives' Station, 4½ m. N. of Wh. - - - -	41 "
¼ m. S. of Mt. Carmel, 5¼ m. N. of Wh. - - -	36 "

The height of the surface of the river above tide level, as derived mostly from the height of the dams,* with an allowance of 6 inches

* I am indebted for information on this point to Mr. Charles Holt. The height of the successive falls of water, north of the 35-foot fall at Whitneyville, are (1) at Augurville, 8 feet; ½ mile above, Webbing Company's dam, 8½ feet; ⅛ m. above, Beers's Grist Mill, 8 feet; near Ives' Station, James Ives' dam, 10 feet; at the Mt. Carmel gap,

per mile for the rise in the back-water above the dams, and as much more for descent above Augurville not included in the falls of the dams, is as follows at the different points here mentioned:—

$2\frac{1}{4}$ m. north of Whitneyville, below the Augurville dam	36 feet.
4 m. N. of Whitneyville, $\frac{1}{2}$ m. S. of Ives's Station -	60 "
$5\frac{1}{2}$ m. N. of Whitneyville, below the Mt. Carmel dam	80 "
6 m. N. of Whitneyville, above the Mt. Carmel dam	92 "

It follows from the facts that the present slope of the bed of the river is about 15 feet a mile, while that of the terrace plain or old flood grounds varies from 13 to 9 feet a mile. The latter was the descent of the river in the Champlain era; and consequently the e -cavation which has taken place since the elevation closing that era has not wrought out as gradual a descent as the earlier, by *one to five feet a mile*, 1 foot a mile of the slope being taken as a result of an elevation of the land (p. 98, §4).

The height of the terrace corresponding to the line of the Whitneyville dam being 55 feet above mean-tide level (p. 95), its height *above the surface of the river* as it stood before the dam was built would be about 53 feet. Consequently, the amount of excavation that would be required at Augurville to restore the old slope would be 3 feet (50 feet being the height of the terrace above the river's surface) at Ives' Station, 12 feet; below the Mt. Carmel gap, $5\frac{1}{4}$ miles from Whitneyville, 17 feet; below the dam at the gap, $5\frac{1}{2}$ miles from Whitneyville (where the terrace as deduced from the average slope in this part of the valley has a height of about 34 feet above the river's surface, though now abnormally lower), 19 feet.

At the Mt. Carmel gap there is a descent of 12 feet in half a mile, owing to the hard trap rock lying in the way of the river; but the terrace plain above appears to correspond in level with that below, that is, it has nearly the same slope and is almost in the same continuous plain. For while the river here descends 12 feet in half a mile, the depth of the cut made by the river through the terrace or drift formation north of the gap is only 26 feet—this being the height of the terrace plain above the river. The amount of excavation in this part of the valley would therefore have to be 27 feet.

These numbers, as already observed, are only approximations. For exact results, the slope of the bed of the river and the heights and slope of the terrace plain should be ascertained by more accurate

F. Ives's dam, 12 feet; between the last two, 8 feet; in all 89 feet. The back-water of F. Ives's dam is less than a fourth of a mile in length, and its head about 6 miles in an air-line north of Whitneyville.

methods than by the use of a hand-level, ordinary measurements of the heights of dams, and estimates only of the slope of back water.

In the West River valley, the depth of the excavation made by the river is 45 to 48 feet in its lower part just above the limit reached by the tides, or near the Whalley Avenue bridge; but $1\frac{1}{4}$ miles (in an air-line) up the valley, near the Pond Lily Paper Mill and beyond, *it is only* 7 *or* 8 *feet.* The river therefore, to within $1\frac{1}{4}$ miles of the tidal limit, has a *level but* 7 *or* 8 *feet below that which it had in the Champlain era.* The plain spreads across this part of the valley and stretches far northward. But although showing so little elevation, it is actually *over* 70 *feet above mean-tide level.* The river has a descent of 72 or 73 feet from the head of back-water of the Pond Lily dam to the bridge, a distance of $1\frac{1}{2}$ miles, in an air-line, which is equivalent nearly to 54 feet a mile.* There is also an unusually high angle of slope in the terrace plain of the valley, its height a mile and a half (1·50 m.) up the valley, being about 82 feet above mean-tide level; at 1·15 m. (Pond Lily dam), 72 feet; at 0·62 miles (below Parker's Paper Mill), 62 feet; at 0·3 miles (near the Congregational church), 56 feet; or in all about 24 feet a mile. These striking peculiarities of West river, may come partly from the valley being comparatively narrow; but they arise mainly from the fact that the terminating ridge of the Edgewood line of hills crosses the course of the stream just below the Pond Lily Paper Mill, and the passage cut through it for the waters is shallow. The bed of the stream in this part, as through all the region of rapids below, is made up of large boulders, and none of the schistose rocks of the Edgewood range are in sight; but they must lie not far below. The terrace plain, standing

* The falls above the Whalley Avenue bridge are as follows: 1st dam, $4\frac{1}{2}$ feet; 2d or Beecher's dam, 8 feet; between 1st and 2d dams, 1 foot; 3d dam, or Mallory's, 9 feet; above Mallory's, (Parker's and the Pond Lily dams), 50 feet; in all, $72\frac{1}{2}$ feet. The terrace near Beecher's dam is 42 feet above the level of the pond, and the pond is at surface $13\frac{1}{2}$ or 14 feet above mean-tide level. The average course of the river from the bridge northward is about northeast, so that in $1\frac{1}{2}$ m. in its direction there is only about 1 m. of northing.

I may add here, as an addendum to page 76, that just west of the Whalley avenue bridge, the oblique lamination in some of the layers of the terrace formation indicates the existenoe of a great river flood, or current southward, during the deposition; like that which existed, according to similar evidence, in the Quinnipiac. But east of the bridge, the oblique lamination has the reverse dip, and thus shows that, throughout the progress of the deposition quite to its close, the sands were under the aetion of waves and tidel currents *from* the bay and not that of the river currents. This region east of the bridge, as the map shows, is outside of the Westville valley, the river bending in this part quite far to the eastward.

high near the Whalley Avenue bridge, extends northeastward to a short distance beyond Parker's Paper Mill, and then is interrupted by this Edgewood ridge, the level of the road rising from 62 feet, that of the terrace plain, to about 90 feet. The ridge consists, to a considerable depth, of drift, and many boulders lie over its surface. Descending to the north, the terrace plain is again reached near Harper's Mill, but instead of being 39 feet above the bed of the stream, as near Parkers' Mill, it has the low height of about 8 feet above mentioned.

After the excavations were completed to their modern limits, the movement of the tides ascended West River to Westville; West Creek to Broad street; East Creek to Elm street; Mill River to Whitneyville; and the Quinnipiac to two miles beyond North Haven. East and West Creeks were the drainage streams for the surface between Mill and West rivers; and considering their little length, they were remarkable for the distance to which the tides ascended, for it was nearly half their whole length. They are now almost obliterated through the progress which man's "improvements" have recently given to nature's grading processes.

The Beaver Pond depression even in the earlier Champlain era had become partly filled up (probably because originally rather shallow); and after the elevation of the land its bottom was, as now, above the sea-level. But the present height of the Meadows does not give us the original level; what this height was we shall not know until we have ascertained what part of the present 22 feet above the sea is occupied by peat or other formations of the Recent or Terrace era.

At the same time that the rivers were cutting down their valleys the tides and waves were making encroachments on the coast deposits about the New Haven bay, and carrying forward a new system of tide-flats, sand-banks, and sea-beaches: and at this they are still at work.

Moreover, over the land, lakes were made shallower, and many were reduced to swamps or wholly dried up. Some of the peat or muck bogs had their origin in these swamps, while others date from the commencement of the Champlain era, if not before. The muck or peat of the Quinnipiac meadows must be mainly of the former, since in the Champlain era the region was deep under salt water. Part of what was formed along the borders of the old Quinnipiac harbor, however, may have begun in that earlier era, and if so, this part ought to indicate it by the remains of salt water grasses and infusoria. This remark applies also to the Beaver Pond peat meadows.

Through this elevation of the Terrace era over New England and the continent, by which rivers, lakes, and seashores were every where bordered by terraces, millions of square miles of land were raised from the condition of low flood-grounds to that of elevated plains, fitted for fields, dwellings, and cities, for which purpose they were afterward to be used. The New Haven plain was thus made ready to become to man a means of happiness and improvement, and also a source of gratitude for so goodly a dwelling place, although its larger river is the Quinnipiac and not the Connecticut.*

3. *Life of the Terrace or Recent Era.*—Of the wild animals which once inhabited the region in this Terrace era, only a single relic has yet been found. A stick cut by a beaver, from the Beaver Pond Meadows, was formerly in the possession of Eli W. Blake, Esq., but it is now lost.

Aboriginal man has left his heaps of shells at various points along the coast. There is a layer of them beneath the turf, on the shore of the bay between Halleck's place and Oyster Point. Others occur at intervals in a similar situation at the top of the terrace bordering West River above Oyster Point, as far as the cut made for the New York railroad; in West Haven, along the terrace near the mouth of West River; also, on and near the bay south of the mouth of West River, where the fields for a considerable distance from the shore are underlaid by them, so that the surface is thickly sprinkled with fragments of shells after ploughing; on Grape Vine Point; at the top of the high terrace on the west side of the Quinnipiac north and south of Fair Haven; also on the east of the Quinnipiac at various points, one of them at the corner of Church and Prospect streets in Fair Haven, just east of the Episcopal church, where a bed of this kind was laid open in digging a cellar for the house recently built on the spot.

The shells are either those of oysters, or the round-clam, and not of the long clam. Below Halleck's, and on Grape Vine Point, they are mostly of the round-clam; and at one place in the former region, many of the shells appear to have been burnt, and occur with fragments of charcoal. On the east side of West River, near the New York railroad, and on the west side along the terrace at its mouth, and also just south of the West Haven ship yard, oyster shells are most abun-

* See page 47. Saybrook has the mouth of the Connecticut river to which New Haven had a Triassic title; and New Haven has Yale College which Saybrook lost, after 16 years of possession from its foundation. If New Haven bay were now the mouth of the Connecticut, the site of the New Haven plain would be part of the bottom of the bay.

dant; but farther south along the coast of West Haven clam shells prevail. At Fair Haven, the shells are mainly oyster shells.

I have looked among these heaps thus far in vain for flint arrow heads and other Indian relics.

Along the West Haven shore on the bay broken shells of the scallop (*Pecten irradians*) and of the large "winkle" (*Fulgur carica*), are occasionally met with. Two bones were found among the shells that had fallen from the edge of the terrace, which I have put into the hands of Professor Marsh, our palæontologist, for examination. One he reports is from the leg of a deer, and the other is probably from that of a wild goose. No distinct traces of charcoal or of burnt shells have been observed, except along the coast south of Halleck's place. The Indian evidently ate his clams as well as oysters in general without cooking. This is evident also from the broken condition of the clam shells. They look as if they had been treated like walnuts.

The shell beds often lie directly upon the brown or yellow sand or gravel of the drift formation, evincing that the Indian inhabited the plains before the alluvium had been covered with, or converted at top into, soil. But no instance is yet known of their occurrence beneath any of the beds of the stratified drift, or under the drift of the hills. They carry back the appearance of man in the region to the commencement of the Terrace or Recent era; and not beyond this.

7. Wells in the New Haven plain.—Hard-pan beneath the bay.

There are two series of facts bearing upon the geological structure of the New Haven region which should be here alluded to, although the subjects require farther investigation. One relates to the depth and source of the subterranean waters; and the other to the existence and nature of a compact layer, or hard-pan, beneath the muddy bottom of the bay and the beds of the adjoining parts of the rivers.

1. Wells.—The following facts with regard to the *subterranean waters of the plain*, as illustrated by its wells, I have from Mr. D. W. Buckingham, and Mr. Philo Chatfield, whose personal observations in this direction have been extensive.

(1.) The water is spread widely beneath the plain, and is not collected in local channels; this accords with the sandy nature and horizontality of the deposits that afford it.

(2.) The height of the water varies with the degree of humidity of the seasons, the extreme difference amounting to about two feet; it is ordinarily about three years in reaching its lowest level, and as many in regaining its highest.

(3.) In digging wells, water is not usually found until a firm gravelly layer is reached.

(4.) Over the central portion of the New Haven plain, about High street, back of the College grounds, and to the north, water is obtained wherever the height is near 40 feet, at a depth of about 26 feet—in other words, the upper limit of water, or the water-plain, is here about 14 feet above mean-tide level; and the height of any spot over this region being ascertained, the number of feet of excavation required to reach water is at once almost exactly known. To the southeastward the water-plain dips toward the bay; its height at the corner of Church and Chapel streets, one-fourth of a mile from High street, (where the height of the surface is 20 feet) is 6 feet, or 14 below the surface; and one-sixth of a mile farther southeastward, in State street near Chapel (where the height of the surface is 14 feet), it is about 3 feet, or 11 below the surface. Through Chapel street, between Church and State, and over the region either side, the depth to water is 12 to 14 feet, and in State street 11 to 12 feet. On the southwestern border of the High street region, along Oak street, the course of the old *West Creek* channel, water rises nearly to the surface, or to a level of 12 or 13 feet above the sea, the land here being low. Again in Grove street, on the other margin of the High street area, near the Cemetery, in the old *East Creek* channel, the water-plain is 20 feet above the sea; Sachem's ridge is near by.

In contrast with the above, we find that to the northwest of what we have called the High street region, beyond Dwight street, the water-plain dips toward West river, and falls even below the mean level of the water in the river, or that of the bay. Thus out West Chapel street, not far from its junction with the Derby Avenue, (where the plain has a height of 37 to 40 feet), wells are sunk to a depth of 50 feet before water is reached; the latter depth is 10 feet below the level of the sea and of the river. I learn from Mr. P. Chatfield that the excavation for the well at the house now occupied by Mr. G. H. Scranton, near the residence of Mr. E. Malley, was carried to a depth of 45 feet. Again, out Whalley Avenue, at Hamilton Park not far from West River, the depth to water is 45 feet. But on Hudson street, west of the jail, on Whalley Avenue, the wells are only 25 feet to water. Hudson street is therefore within the limits of the central *high-water* region of the city, while Norton street is beyond it.

In addition to these facts respecting subterranean waters derived from wells, there is another having an important bearing upon the subject connected with the great Beaver Pond depression. This basin, lying to the north of the High street region and but three-fourths of a mile from the College Square, is supplied through springs with an abundant and perpetual flow of water, making a stream of considerable size, which has its mill privileges like the rivers from the hills (p. 53.) *The level is constant at about 22 feet above the bay.* Formerly, before the deepening of its outlet, it stood at 24 feet, and 50 years since its ponds often afforded good skating in winter. To what height the springs would carry the water, if the outlet were dammed up to a higher level, is not known.

In this position of the Beaver Pond Meadows with reference to the plain, and in that of the adjoining Beaver Hills, we appear to have a partial explanation of the facts observed. The Beaver Ponds lie at the eastern foot of the Beaver Hills, and just southeast of the Pine Rock ridge. Now the dip of the sandstone in the New Haven region is almost uniformly either to the eastward or southeastward; it is southeastward, as observation shows, in the western part of Pine Rock; and probably south of east in the layers (now nowhere exposed to view) that underlie the Beaver Hills. There can hardly be a doubt that the Beaver Ponds owe their waters chiefly to the dip or inclination of the strata in these hills, this being just such as would throw the main part of the water that falls upon them in that direction. Further, the Beaver Hills extend southward and cross Whalley Avenue in the vicinity of North and Norton streets, and probably extend under ground much farther south. They consequently make a *western boundary* to the northern part of what we have called the High street area. Hudson street and the jail are *east* of the line of the Hills, and therefore, within the high-water area; while Hamilton Park is to the *west* and far outside of it. It would seem natural therefore that this area, having the water works of the Beaver Hills and Ponds on the north to aid the rains that fall over the surface in the wet season, should be supplied with water freely, and at a considerable height above the level of the sea; and at the same time that the region toward West River, to the west of the Hills, or of its line, failing of benefit from the dip of the rocks, or from the Beaver Ponds, (or deriving less benefit, if any) should require deeper excavation to reach water.

But the condition here explained can hardly be the sole cause of the difference between these regions; for the existence of so free a supply of water over the former would seem to require a partially hardened gravelly, or else a clayey, layer, ("hard-pan,") beneath to prevent waste; and the position of this layer would naturally affect the level of the water. But on this point we have no facts, since the wells over the plain have never been sunk so deep as to reach such a layer, nor even below a depth of forty feet. If the Beaver Pond depression was once, as supposed, a central basin of the harbor, it is likely that there is such a layer beneath.

Some facts respecting *Artesian Wells* are mentioned beyond.

2. Hard-pan of the harbor.—The following observations on the *hard-pan* beneath the harbor consist mostly of information obtained through the driving of piles, and the sinking of Artesian Wells. For the facts derived from pile-driving I am indebted mainly to Mr. C. R. Waterhouse, whose occupation has given him numberless opportunities for observation.

a. At the head of the bay, near the foot of Greene street, in preparing the foundations for the Gas Works, a *hard-pan* layer was found at a depth of 31 feet below the level of the sea; the overlying material being harbor mud. The layer was 3 feet thick. On driving through it, by way of experiment, the piles went down through 40 feet of mud or loose sand, without finding another hard layer.

b. In the construction of the Chapel street bridge across the mouth of Mill River to Grape Vine Point, a little south of the Gas Works, the piles, starting from mean-tide level, penetrated 33 feet of mud and struck the hard-pan. The layer was so hard that the piles made but an inch or two at a stroke, and with 54 strokes did not go through it.

c. At the steamboat dock, 120 rods farther south, the piles passed through 25 or 26 feet of mud before reaching the hard-pan.

At the end of Long Wharf, two-thirds of a mile outside of the old coast line, and near the deep-water channel of the bay, the hard-pan was reached at a depth of 45 feet below mean-tide level; 13 of the 45 feet being water, and 32 mud.

d. In the construction of the new Long Wharf for the Canal railroad, situated only twenty rods east of the old Long Wharf, and extending to the same deep-water channel of the bay, the piles, at the extremity, and for the greater part of its length, as I learn from Mr. Yeamans, the Vice-President, were driven down 43 to 45 feet below mean-tide level, the longest being those between its middle and the land. In driving other piles over the old Canal basin (which adjoins the wharf on the north) it was found that a region of very deep mud extended eastward not far outside of the present line of yards and buildings, which was evidently the former submarine bed of the old *East Creek* channel (whose waters it will be remembered, had their discharge into this Canal basin at its head, just east of the old Long Wharf, and close by the commencement of the new wharf). In the eastern corner of this basin, after crossing this mud-channel, a hard impenetrable bottom was found at 18 to 20 fathoms.

e. In driving piles for the bridge of the New York Railroad, across West River, toward its mouth, the hard-pan was found at a depth of 35 to 40 feet; and for the Derby Railroad crossing, a little farther north, at 25 to 30 feet; in one case 40 feet. In these, and other cases, the layer was not so thick but that the piles could be driven through it, and when thus passed, they descended many yards before finding good bottom again.

f. The piles for the Air-line railroad, over the Quinnipiac meadows, found a hard bottom at a maximum depth of 40 feet.

g. Last year piles were driven in the *West Creek* region, near the southeast corner of Congress Avenue and Oak street, which descended 20 feet before striking a hard bottom.

h. An artesian well sunk by the Messrs. Trowbridge on Long Wharf, about 350 yards outside of the old coast line, found a supply of fresh water, but slightly brackish, in a layer of gravelly hard-pan at a depth of 20 feet, or 14 feet below mean-tide level.

i. Another artesian well, on the same wharf, but 400 yards farther from the old coast line, made by Mr. Aaron Kilburn, under the direction of Capt. S. J. Clark, found water at a depth of 56 feet. The boring (6 inches in diameter) passed through 28 feet of mud; and then about the same thickness of earth resembling the ordinary sand beds of the plain, without any large stones; and the water at first rose to a height of 6 feet above the top of the wharf. Allowing for the height of the wharf, and the penetration of the hard-pan to a depth of 3 feet, the layer here lies 45 to 48 feet below mean-tide level. The depth consequently was very nearly the same with that ascertained by pile-driving at the end of the wharf.

j. At the Staples Block Factory, on Long Wharf, just north of the Messrs. Trowbridge, an artesian well was sunk by Mr. Kilburn to a depth of 45 feet below the surface of the wharf, or 39 feet below mean-tide level, and perfectly good fresh water obtained. The boring passed through 32 feet to the bottom of the mud, then through sand and gravel like that of the New Haven plain, in the course of which there were 2 feet of hard blue clay, a very hard hard-pan, as Mr. Kilburn describes it.

k. In another artesian boring, made by Mr. Kilburn, at the depot of the New York and New Haven railroad, east of the commencement of Long Wharf, good water, entirely free from brackishness, was obtained at a depth of 68 feet, or about 60 feet below mean-tide level. The boring passed through 36 *feet of harbor mud*, and, below this, through *sea-shore* or *worn sand*, which was coarser below. The great depth to water at a point so far inside of the Trowbridge and Staples wells, and also the thickness of the deposit of mud, are accounted for by the fact that the place was just within the mouth of the *East Creek* estuary.

[It may be added here, although not exactly relevant, that an artesian boring by Mr. Kilburn in Howard street, opposite McLagon & Stevens's factory, descended through 60 feet of quicksand, and struck the solid sandstone rock at a depth of 68 feet. The sandstone was that of the underground slopes of Sachem's ridge.]

l. In Greene street, at the India Rubber Works, about 50 rods above the Gas Works, an artesian well was sunk, under the direction of Mr. H. Hotchkiss, to a depth of 250 feet. But the existence of a hard layer was not noted, and is uncertain. The material passed through was mainly like that of the plain for 140 feet; then followed a bed of "splendid" clay, 14 feet thick; and below this the same essentially as above. At the bottom the tubing was badly bent by striking against something supposed to be rock, and the boring was consequently suspended. It is not known whether the rock was solid sandstone or a loose mass.

1. The facts show that a hard layer, called *hard-pan*, may be reached beneath the harbor, and the estuary part of the Quinnipiac and West Rivers, at depths mostly between 30 and 45 feet; that its depth along the north side of the deep-water channel of the bay is 40 to 45 feet; that this continues to be its depth through nearly two-thirds of the line of the Canal railroad wharf (which is much farther shoreward than along that of Long Wharf, owing to the fact that Long Wharf was built out as the extension of a sandy point between East and West Creeks, while the new wharf is situated off the mouth of East Creek); that toward the shore the depth of the hard-pan generally decreases.

2. That the hard-pan is one of the layers of the stratified drift, that is, of that portion of the drift which was deposited over the bottom of the bay and rivers.

3. That the layer varies in thickness; that it may generally be penetrated by a continued driving of a pile; and when passed, the pile goes easily through a great depth of material before another hard layer is found; and that this soft material beneath the first hard-pan

layer, although sometimes described as mud, is probably wet uncompacted sand or gravel.

4. That the hard-pan *may be* in most cases the *same* particular layer of the drift formation; but that we do not know facts enough to authorize the assertion that this is true; or enough to establish satisfactorily its probability.

5. That the hard-pan in some cases is probably a gravelly layer firmly compacted. The region north of the head of the harbor, in the direction of the Canal railroad and the Mill River valley, is underlaid, as has been shown (p. 71) by a very coarse gravel, as the result of the central tidal flow of the bay in connection with the currents of the streams; and it is probable that this gravel-course extends out beneath the harbor; and this may be the hard-pan layer that is reached by the piles. It would naturally have an inclination seaward, following the slope of the bottom of the bay. Along the valley of West River and that of the Quinnipiac, there were doubtless similar gravelly layers formed below, through like means, which may be the hard-pan encountered in the beds of these streams. Yet this is only a suggestion, to be tested by future examination. None of the hard-pan has ever been brought up to the surface, and nothing positive is known as to its nature or the cause of its hardness. It may owe its hard-pan quality to a partial cementing of the material by means of oxyd of iron, an ingredient always present in the sand and gravel and the source of the prevailing color, and often causing the waters that flow through them to become strongly chalybeate; besides being a common cement among rock strata. But the coarse gravel beneath State street and the Mill River region is in almost all parts very hard digging, owing to its firmness, and for thick beds perhaps nothing more in the way of firmness would be required than what here exists.

6. That the hard-pan layer is usually sufficiently water-tight, or close in texture, to carry fresh-water along it from the land, following its seaward slope, and thence to become a source of fresh-water for artesian wells in the harbor. The flow of fresh water in a layer beneath the bay is evidence that this layer probably continues inland, and is a seaward part of a sloping water-bearing layer beneath the plain. The fact that the wells of the central and lower part of the New Haven plain generally descend into a gravelly layer is favorable to the view that the hard-pan is gravelly. Yet a layer of clayey sand is equally retentive of water, and will as well hold up the fresh-waters flowing seaward from the land; and when the wells of the plain as

well as those of the harbor are farther investigated, it may be found that there is an impervious layer of this character beneath the water-bearing one.

We may add here one conclusion respecting East Creek. The facts teach that this estuary has a deep under-bay channel; and such a channel as could have been excavated only by fresh waters when the land was at a higher level than now. This era of higher level was probably that of the old glacier. The 36 feet that were occupied with mud in the artesian boring at the railroad depot (p. 109, § *k*) are only a part of the whole depth of the excavation; for the sands and gravel of the drift must lie beneath. The depth to which the mud extends here and over the harbor is probably an indication of the depth of water in the channel and bay, in the later Champlain or earlier part of the Terrace or Recent era; and when the mud deposit has been sounded throughout we shall have some idea of the topography characterizing the bottom of the New Haven bay at that time.

III.—Notes on American Crustacea. By Sidney I. Smith.

No. I. Ocypodoidea.

Read, December 15th, 1869.

This article, which is intended as one of a series, is chiefly made up of notes and descriptions resulting from the study of the higher American crustacea in the Museum of Yale College and the collection of the Peabody Academy of Science. Mention is made only of those species of which I have examined specimens and in regard to which there are some new or unpublished facts to offer, except where mention of such species seemed needful for the proper understanding of new or imperfectly described forms. In the genus *Gelasimus*, I have departed somewhat from this course and have given the principal facts known to me, whether published or not, in regard to all the American species. I have not attempted to arrange the groups according to any zoölogical system, but have merely taken up the families as convenience suggested.

All specimens referred to, unless otherwise stated, are in the collections of the Museum of Yale College.

Family, Ocypodidæ.

Gelasimus Latreille.

The species of this genus, like most terrestrial crabs, seem to have been neglected by collectors. This fact, together with the difficulty of distinguishing the species from females or young specimens, and the impossibility of determining, from the descriptions and figures alone, what species many of the older authors had in view, has led to much confusion in the synonymy. Even some of the modern authors have published very imperfect descriptions of numerous closely allied species, neglecting to mention the form and ornamentation of the carapax or ambulatory legs, which give some of the best characters for distinguishing the species.

The genus, as at present constituted, is chiefly characterized by the enormously unequal development of the chelipeds in the male. This unsymmetrical development is not however confined to the chelipeds, but extends to almost every part of the animal. The carapax, in every species which I have examined, is more or less one-sided, the antero-lateral angle being more developed on the side of the larger cheliped. The ocular peduncle also is usually longer on this side, and in some species is terminated by a slender stylet. This ocular stylet is quite remarkable, and appears to be a constant and important character of several species. Desmarest mentions it in a species which he describes under the much misapplied name of *vocans*, but his description would imply that it was found upon both sides. Edwards, in his description of *G. styliferus*, mentions it, and it is represented in his figures, but his words also imply that it was not confined to one side. In Edwards' Histoire naturelle des Crustacés, tome ii, p. 50, however, there is the following foot note:—"Au moment de mettre cette feuille sous presse; je reçois de M. T. Bell la communication d'un fait que je ne puis passer sous silence. Quelques Gélasimes présentent, à un certain âge, sinon toujours, un stylet à l'extrémité du pédoncule oculaire du côté de la grosse pince, tandis que l'œil du côté opposé conserve toujours la forme ordinaire." This observation of Bell agrees with my own on quite a number of specimens of two species described beyond, and it is quite probable that this is always the case.

The described species of *Gelasimus*, as limited by Edwards and other authors, form two very natural and distinct groups, which should perhaps be recognized as genera, but upon which, for the purposes of the present paper, it is not necessary to impose new names.

In the first group the front is contracted between the ocular peduncles so that their bases approach very closely, and the peduncles themselves are very long and slender. This includes Edwards' section A, in which the front is spatulate, and probably also, all of his section B, in which the front is very narrow between the eyes but not spatulate. In some of the species the meral segments of the ambulatory legs are armed with sharp spines, and with these species I have united the genus *Acanthoplax*.

In the second group, which corresponds with the section C of Edwards, the front is broad and evenly arcuate, and the bases of the ocular peduncles are thus separated by quite a broad space. The peduncles themselves are much shorter than in the species of the other section. The species are mostly small and exhibit a remarkable uniformity in general appearance, so that it is difficult to distinguish them without careful study.

A single species, described beyond, differs from both these groups, in having the male abdomen only five-jointed and not narrowed at the second segment. The carapax is transverse and very little contracted behind. This species is evidently the type of a third very distinct group.

The number of American species now known is quite large. Edwards, in his review of the Ocypodoidea in the Annales des Sciences naturelle for 1852, enumerates, including his *Acanthoplax insignis*, eight species as appertaining to America. In 1855 Major LeConte described another species (*G. minax*), and in 1859–60 Dr. Stimpson added three others. In the following pages nine more are described, making in all twenty-one species known in the American faunæ. Of the species which I have personally examined none are common to the east and the west coast. Edwards, however, mentions one species (*G. stenodactylus*) as occurring in Chili and Brazil, but even in this instance there may have been some mistake. The following list will illustrate the distribution of the species on the two coasts. The localities from which I have examined specimens are followed by an !.

SECTION A.

ATLANTIC COAST.	PACIFIC COAST.
	G. heterophthalmus, nov. Central America!
	G. styliferus Edwards. Ecuador.
	G. heteropleurus, nov. Central America!
G. platydactylus Edwards. Guiana.	*G. princeps*, nov. Central America!
G. maracoani Latreille. Guiana, Brazil.	*G. armatus*, nov. Central America!
	G. ornatus, nov. Central America!
	G. insignis (Edwards, sp.) Chili.

SECTION B.

ATLANTIC COAST.	PACIFIC COAST.
G. palustris Edwards. Antilles.	
G. minax LeConte. Long Island Sound to Florida!	*G. brevifrons* Stimpson. Cape St. Lucas!
G. pugnax, nov. Long Island Sound to the W. Indies!	*G. macrodactylus* Edw. et Lucas. Chili.
G. rapax, nov. Aspinwall!	
G. mordax, nov. Brazil!	
G. pugilator Latreille. Massachusetts to Florida!	*G. stenodactylus* Edw. et Lucas. Chili.
G. sub-cylindricus Stimpson. Matamoras on the Rio Grande!	*G. Panamensis* Stimpson. Panama!

SECTION C.

ATLANTIC COAST.	PACIFIC COAST.
	G. gibbosus, nov. Central America!

A.—*Species in which all the segments of the abdomen are separated by distinct articulations, and in which the front is very much contracted between the bases of the ocular peduncles and somewhat spatulate in form.*

Gelasimus heterophthalmus, sp. nov.

Plate II, figure 6, 6[a]. Plate III, figure 1–1[b].

Male. The carapax is somewhat quadrilateral in outline, but the antero-lateral angle on the side of the larger cheliped is much produced laterally, so that the orbit is much longer on that side than on the other and the lateral border strongly divergent. The dorsal surface is smooth and shining, and convex longitudinally but not at all laterally. The branchial regions are very slightly swollen, scarcely higher than the gastric and cardiac regions, and are separated from them by slightly marked sulci. The front is spatulate, contracted between the bases of the ocular peduncles and much expanded below. The superior border of the orbit is much excavated at the base of the ocular peduncle, and strongly arcuate in the middle, and has a very slightly upturned and entire margin. The antero-lateral angle on the side of the smaller cheliped, is angular but does not project either anteriorly or laterally, while on the side of the larger cheliped it is broad, obtuse and projects very much laterally, as described above. The lateral margin is obtuse and its posterior part only is indicated by a faint granulous line. The upper part of the inferior branchial region is oblique, flat and very smooth, and is separated from the lower portion by a slightly raised line running straight from the antero-lateral angle to the base of the third pair of ambulatory legs. The inferior border of the orbit is denticulate with minute, flattened and truncate teeth. The jugal regions are smooth and shining.

The ocular peduncles are rather slender, slightly enlarged at the cornea, and the one on the side of the larger cheliped is considerably the longer and is terminated beyond the cornea by a very slender filiform stylet, much longer than the peduncle itself, and slightly flattened and expanded at the tip. There is no trace of a terminal stylet on the peduncle of the other side.

In the larger cheliped, the anterior surface of the merus is smooth, narrowly triangular in outline and considerably convex, the inferior margin is sharp and denticulate, and the superior margin is armed with a slight crest which is very low and entire for most of its length but quite high, and in some specimens slightly dentate, at its distal extremity. The carpus is short and its upper surface is slightly verrucose. The basal portion of the propodus is rounded and coarsely and densely verrucose externally, the superior and inferior margins are thin and dentate, and the inner surface is nearly smooth, excepting three, high, tuberculose crests, of which one runs obliquely upward from the inferior margin, one from the base of the dactylus along the margin of the depression into which the carpus folds, meeting the first in nearly a right angle, and another along the margin next the base of the dactylus, leaving a rectangular, depressed area between it and the lower crest. Both the fingers are smooth on the inside, quite long, compressed and high, and the prehensile edges are evenly tuberculated and each armed with a single, stout, median tooth. The outer surface of the propodal finger is somewhat roughened with irregular, shallow punctures, the inferior edge is granulated and has a submarginal, granulous line on the outer side, and the prehensile edge is armed with a stout tooth considerably within the tooth on the dactylus; the edge beyond this tooth is straight and closes evenly against the dactylus, but between the tooth and the base it is deeply excavated, leaving a short and broad opening between the bases of the fingers. The dactylus is smooth on the outside, except a small space at the base, its superior edge is entire and smooth, and the prehensile edge is nearly straight, tuberculated and armed with a stout tooth a little beyond the middle.

In the smaller cheliped the merus is slender and somewhat triquetral, and the superior and exterior angles are sharp. The carpus is short, ovoid in form, and smooth and rounded externally. The hand is slender, and the fingers long, flattened at the tips, and the angles clothed with hairs.

The ambulatory legs are smooth and unarmed.

The abdomen is contracted at the articulation of the first with the second segment, and the edges are straight from the second segment to the terminal, which is broad and obtusely rounded at the extremity.

Four specimens gave the following measurements:—

	1.	2.	3.	4.
Length of carapax, - - - - - - -	18·7mm	18·5mm	18·2mm	16·9mm
Breadth of " - - - - - - -	32·2	32·3	30·0	27·2
Ratio of length to breadth, - - - -	1 : 1·72	1 : 1·75	1 : 1·65	1 : 1·61
Length of larger hand, - - - - - -	48·4	53·5	43·0	37·5
Length of ocular peduncle on side of smaller cheliped,	14·0	14·3	12·9	12·3
Length of ocular peduncle on side of larger cheliped, excluding stylet, - - - - - - -	16·2	16·3	15·0	13·8
Length of terminal stylet of ocular peduncle, -	19·4	20 0	----	10+

In numbers 3 and 4 the ocular stylets are broken and partly wanting.

Quite a number of specimens are in the collection of the Peabody

Academy of Science, all obtained at the Gulf of Fonseca, west coast of Central America, by J. A. McNiel.

This species is apparently closely allied to the *G. styliferus*, but the ocular stylets in that species are very short, and the hand, as figured by Edwards, is shorter and higher in proportion than in our species. The description of *G. styliferus* is, however, too short to permit of a detailed comparison of the species.

Gelasimus styliferus Edwards.

Gelasimus platydactylus Edwards, Règne animal de Cuvier, 3me édit., Crust., pl. 18, fig. 1 a, *non* Histoire naturelle des Crust., tome ii, p. 51, 1837, (*teste* Edwards).

Gelasimus styiferus Edwards, Annales des Sciences naturelle, 3me série, Zoologie, tome xviii, 1852, p. 145, pl. 3, fig. 3.

The following is the description given by Edwards:—"Espèce très voisine du *G. platydactylus*, mais ayant le crête marginale du bras moins développée et les podophthalmites terminés par un petit stylet comme chez les Ocypodes.—Guayaquil."

Gelasimus heteropleurus, sp. nov.

Plate II, figure 7. Plate III, figure 2–2b.

Male. The carapax is quadrilateral in outline, but the antero-lateral angle on one side is produced as in *G. heterophthalmus*. The dorsal surface is slightly granulous, quite flat anteriorly and only slightly convex posteriorly. The branchial regions are not at all swollen but are separated from the gastric and cardiac regions by deep sulci. The front is spatulate and expanded below the bases of the ocular peduncles. The superior border of the orbit is arcuate in the middle and has an upturned and slightly crenulated margin. The antero-lateral angle, on the side of the smaller cheliped, is acute and projects slightly forward, while on the side of the larger cheliped, it projects laterally as a very prominent obtuse tooth. The lateral margins are angular and armed with a very marked line of sharp granules. The upper part of the inferior branchial region is smooth and nearly perpendicular. The inferior border of the orbit is thin and denticulate with minute, flattened and truncate teeth. The jugal regions are granulous.

The ocular peduncles are slender, much enlarged at the cornea and the one on the side of the larger cheliped is much longer than the other and is terminated by a slender flattened stylet about as long as the cornea.

In the larger cheliped, the anterior surface of the merus is narrow, somewhat convex, and smooth, its margins are minutely denticulate, and the superior one is armed with a narrow crest-like process at the distal extremity. The superior surface of the carpus is flattened and granulous. The outer surface of the basal portion of the propodus is thickly verrucose, the verrucæ near the upper margin being coarse and tuberculiform, the inner surface is armed only with the oblique tubercular crest running from the inferior margin. Both fingers are smooth on the inside, compressed and short, being but little longer than the basal portion of the propodus; their prehensile edges are evenly tubercular, each armed with a tooth a little way from the tip, and nearly straight, but widely separated at base, leaving a broad, open space within the teeth, but beyond the teeth, the edges meet and the tips hook by each other. The outer surface of the propodal finger is granulous or minutely verrucose and the inferior edge is minutely tuberculated and has a submarginal crest on the outer side. The outer surface of the dectylus is granulous like the other finger and the superior edge is somewhat tuberculated or denticulate.

The smaller cheliped and the ambulatory legs are very much as in *G. heterophthalmus.*

The abdomen is quite similar to that of *G. heterophthalmus*, but is more narrowed toward the tip and the edges are slightly concave.

Length of carapax, - - - - -	15·8mm	15·2mm
Breadth of " - - - - -	25·0	25·6
Ratio of length to breadth, - - - -	1 : 1·58	1 : 1·68
Length of larger hand, - - - - -	32·0	36·0
Length of ocular peduncle on side of smaller cheliped,	10·1	---
Length of ocular peduncle on side of larger cheliped, excluding stylet, - - - - - - -	12·0	12·3
Length of terminal stylet of ocular peduncle, - -	2·5	2·8

I have seen but two specimens, both obtained, with the other species mentioned, by Mr. McNiel, at the Gulf of Fonseca (Collection Peabody Academy of Science).

In the length of the ocular stylet this species agrees with the *G. styliferus*, but the merus and hand in the larger cheliped are very different, and at once distinguish it from that species.

The *Gelasimus vocans* of Desmarest (Considérations générales sur la Class des Crustacés, p. 123) seems to be distinct from any of the species descibed by recent authors and apparently belongs in this section, as it is distinctly stated that the ocular peduncles are terminated by stylets. Edwards refers it to his *G. palustris*, to which it evidently cannot belong, but, as the character of the front is not stated, it may possibly belong in section B, forming in that case a subsection with ocular stylets.

Desmarest's description is as follows:—" Carapace unie, avec le bord antérieur sinueux; serre droite ordinairement plus grande que la gauche; toutes les deux étant finement chagrinées en dehors, avec une ligne enfoncée courte, près de leur extrémité, et ayant leurs doigts longs, étroits, très-écartés entre eux, unis, comprimés; pédoncules oculaires pourvus à leur extrémité d'une pointe aiguë. Des Antilles."

Gelasimus princeps, sp. nov.

Plate II, figure 10. Plate III, figure 3–3^{c}.

Male. The carapax is in the form of a trapezoid much contracted behind, and the dorsal surface is smooth and shining. The branchial regions are somewhat gibbous, are higher than the gastric and cardiac regions and are separated from them by deep sulci. The front is spatulate and much contracted between the bases of the ocular peduncles. The superior margin of the orbit is strongly curved, the posterior margin is slightly raised and minutely denticulated, and the outer angle projects laterally as a very prominent triangular tooth, which is considerably larger on the side of the greater cheliped than on the other side, so that the carapax is somewhat unsymmetrical. The lateral margins are marked by sharply granular lines which curve slightly inward and rapidly converge posteriorly. The upper portion of the inferior branchial region is quite oblique, flat and smooth, and is separated from the lower portion by a slight, granulated line. The inferior margin of the orbit is armed with about twenty-five small, compressed and truncate teeth.

The ocular peduncles are unequal in length, the one on the side of the larger cheliped being the longer, very slender but considerably enlarged at the the cornea and shorter than the broad, open orbits.

The larger cheliped is enormously developed, the hand being nearly three times as long as the carapax. The anterior surface of the merus is flat and smooth, and its superior margin projects into a thin, high, evenly arched and sharply dentate crest, and the inferior angle is armed with a line of small and closely set spines. The upper surface of the carpus is rounded and verrucose and the inner margin is angular and denticulate. The basal portion of the propodus is rounded and coarsely verrucose externally, the saperior margin projects as a thin crest beneath which the carpus closes, the inferior margin is dentate, and the inner surface is smooth, excepting two tuberculose crests, of which one runs obliquely upward, from the base of the dactylus, along the margin of the depression into which the carpus folds and meets the first crest in a right angle. The fingers are much compressed and very long, the inner surfaces are smooth, and the prehensile edges are very tuberculose and each is armed with a stout tooth near the middle, the tooth on the dactylus being a little nearer the base than the other; within these teeth the prehensile edges gape widely leaving an ovate space, while beyond the teeth, the edges meet and are nearly straight almost to the tips, which, however, are strongly curved. The outer surface of the digital portion of the propodus is nearly smooth but has a submarginal, crenulated crest below, and the inferior margin is denticulate. The outer surface of the dactylus is somewhat verrucose and the superior edge is denticulate and slightly margined toward the base.

In the smaller cheliped, the merus is slender and somewhat triquetral and the superior and exterior angles are sharp and granulated. The hand is very similar to that of *G. heterophthalmus.*

The ambulatory legs are stout and nearly naked and the meral segments are somewhat compressed and their edges sharp and minutely denticulate.

The abdomen is broad, the basal segment is considerably shorter than the second and third, the edges approach each other somewhat at the junction of fifth and sixth, and the terminal segment is nearly twice as broad as long and its extremity is rounded.

Five specimens give the following measurements :—

Length of carapax.	Breadth of carapax.	Ratio.	Length of larger hand.
24·1mm	41·1mm	1 : 1·71	64·0mm
24·0	39·8	1 : 1·66	70·0
23·4	39·8	1 : 1 70	71·4
22·0	36·4	1 : 1·65	64·4
21 3	36 0	1 : 1·69	60·4

I have examined a large number of specimens of this species collected at Corinto, on the west coast of Nicaragua, by J. A. McNiel, (Collection Peabody Academy of Science).

There are three female specimens of *Gelasimus* collected at the same locality by Mr. McNiel, which probably belong to this species although they differ quite remarkably from it. The carapax (Plate II, figure 8) is not so much narrowed behind as in the males, the dorsal surface is evenly convex and thickly covered with rounded granules, which are quite coarse along the lateral borders, and the branchial regions are not raised above the gastric and cordiac regions, and are separated from them only by slight sulci. The sides of the carapax are perfectly symmetrical, the anterior angles are prominent and sharp, and the lateral margins are marked by sharp crests of bead-like granules. The jugal regions are granulous. The chelipeds resemble very much the smaller cheliped of the males but are rather smaller in proportion. The abdomen is broadly elliptical and there is a line of granules on the basal segment.

Two of these specimens give the following measurements:

Length of carapax.	Breadth of carapax.	Ratio.
21·8mm	33·8	1 : 1·55
15·2	23·4	1 : 1·54

Under the name of *G. platydactylus*, Saussure* mentions a species from Mazatlan, Gulf of California, which I should refer to this species without hesitation, did he not state that the carpus was bituberculate, a character which does not apply to any species of *Gelasimus* which I have seen. Saussure's notice is as follows:

"*Gelasimus platydactylus*, Latr.—Presque entièrement semblable aux individus de Cayenne, si ce n'est que le carpe est bituberculé, et que la grande crête du bras est dentelée, non entière."

Gelasimus platydactylus Edwards.

? *Cancer vocans major* Herbst, Naturgeschichte der Krabben und Krebse, Band i, p. 83, Band iii, erstes Heft, p. 29, Tab. 1, fig. 11 (after Seba).

? *Ocypoda heterochelos* Bosc, Histoire naturelle des Crustacés, tome ii, p. 197, 1802.

? *Gelasimus maracoani* Desmarest, Considérations générales sur la Class des Crustacés, p. 123, 1825, (*non* Latreille).

Gelasimus platydctylus Edwards, Histoire naturelle des Crust., tome ii, p. 51, 1837; Annales des Sciences naturelle, 3me série, Zoologie, tome xviii, 1852, p. 144, pl. 3, fig. 2.

The synonymy of this species is in much confusion. Edwards quotes Herbst's and Seba's figures without query as belonging to his *G. platydactylus* and refers the *Ocypoda heterochelos* of Bosc to the *G. maracoani.* Bosc's description however appears to have been drawn up from Herbst's or Seba's figure, and if these figures really belong to Edwards' species, the name *heterochelos* should be restored and the species should stand as *Gelasimus heterochelos.* The roughened or verrucose character of the carapax in Herbst's figure is a marked feature which is not mentioned in either of Edwards' descriptions, so that it is quite likely that Bosc's *heterochelos* may be distinct from Edwards' species. Edwards gives Cayenne as the habitat of *G. platydactylus.*

As described and figured by Edwards, this species differs from *G. princeps* in having the superior crest of the merus of the larger

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* Description de quelques Crustacés nouveaux de la côte occidentale du Mexique. Revue et Magasin de Zoologie, 2e série, tome v, 1853, p. 362.

cheliped entire, the hand much shorter and the fingers gaping for the whole length, and wanting the stout tooth on the prehensile edge of the propodus.

Gelasimus maracoani Latreille.

Maracoani, Marcgrave de Liebstadt, Histoire rerum naturalium Brasiliæ, figure.
Ocypoda maracoani Latreille, Histoire des Crust. et Insectes, tome vi, p. 46, 1803.
Gonoplax maracoani Lamarck, Histoire naturelle des animaux sans vertèbres, 2e édit., tome v, p. 465.
Gelasimus maracoani Latreille, Nouveau Dictionnaire d'Histoire naturelle, 2e édit, tome xii, p. 517, 1817; Encyclopédie méthodique, pl. 296, fig. 1; Edwards, Histoire naturelle des Crust., tome ii, p. 51, 1837; Annales des Sciences naturelles, 3me série, Zoologie, tome xviii, 1852, p. 144, pl. 3, fig. 1; Dana, United States Exploring Expedition, Crust., p. 318, 1852.

Said to inhabit Cayenne and Brazil.

Very likely two or more species are still confounded under the name of *maracoani*. Neither Edwards nor Dana mention any spines on the meral segments of the ambulatory legs, while in Latreille's figure in the Encyclopédie méthodique there are short spines represented on the posterior legs.

Gelasimus armatus, sp. nov.

Plate II, figure 5. Plate III, figure 4–4d.

Male. The carapax is only slightly convex and very little narrowed posteriorly, and the dorsal surface is naked and deeply areolated. The gastric and cardiac regions are smooth and shining, and the cardiac is large and very prominent. The branchial regions are prominent and their surfaces smooth but covered by very distinct, raised, vein-like markings which branch off in an arborescent manner from a conspicuous central trunk. The front is small, spatulate, contracted between the bases of the ocular peduncles and expanded below. The superior border of the orbit has a strongly raised margin, its edge is slightly sinuous and the antero-lateral angle prominent, the one on the side of the smaller hand being directed forward and the one on the side of the larger hand being more prominent than the other and directed strongly outward. The anterior part of the lateral margin is longitudinal, so that the breadth of the carapax is scarcely more between the antero-lateral angles than a short distance posteriorly; at the posterior extremity of this longitudinal portion, there are two small, but prominent, marginal tubercles, from which a granulated line extends to the bases of the posterior legs, where there is another small rounded tubercle. The posterior margin is straight, smooth and unarmed. The inferior margin of the orbit is armed with fifteen to eighteen slender, compressed and truncated teeth. The jugal regions are swollen and smooth, but their surfaces are veined somewhat as the regions above.

The ocular peduncles are unequal in length, the one on the side of the larger cheliped being the longer, are very slender, but considerably enlarged at the corina, and shorter than the broad and open orbits which they only partially fill.

The larger cheliped is enormously developed, the hand being high and lamellar, and exceeding, in length, twice the length of the carapax. The ischium is armed above and below with a small, marginal tubercle. The merus is smooth and rounded posteriorly, the anterior surface is flat and smooth, the inferior angle is armed with scattered tubercles, and the superior angle rises into a low crest toward the distal portion, and is armed with slender tubercles. The carpus is smooth and rounded, but is armed with one or two small tubercles at the proximal extremity of the inner margin, and there are several low tubercles on the outer surface. The basal portion of the propodus is short; the inner surface is smooth and unarmed, except with a prominent tubercle near the middle, from which a line of obscure tubercles extends along the slight, oblique ridge to the inferior margin; the outer surface is covered with very large, depressed, smooth tubercles which are separated by considerable spaces; and the inferior margin is thin and armed with dentiform tubercles. The digital portion of the propodus is thin and very broad toward the base; the inner surface is smooth and somewhat concave; the outer surface is flat and very coarsely punctate; the inferior edge is denticulate and slightly margined on the outside; and the prehensile edge is straight, except a slight excavation at the base, is armed with very small marginal tubercles and a high, tubercular, median ridge, and at the extremity, with a slender tooth. The dactylus is broadest toward the extremity; the inner surface is concave and smooth; the outer surface is flat and nearly smooth; the superior edge is arcuate, thin and slightly denticulate; the prehensile edge is straight, closes closely against the propodal finger, except the slightly excavated portion at the base, and is armed with three lines of tubercles, like the propodal finger, except that the inner, marginal line is separated from the median line by quite a wide space toward the tip, and that one of the tubercles, about two-fifths of the way from the base to the tip, is much larger than the rest; and the tip is armed with a tooth projecting perpendicularly downward.

In the smaller cheliped, the merus is slender and its anterior edge is armed with three spinules. The hand is slender, and the fingers are long, flattened at the tips, and the angles clothed with long hairs.

The ambulatory legs are stout. The merus is smooth and unarmed in the first pair, but in the three last pairs, its posterior edge is armed with slender spines,—five in the second pair, six or seven in the third, and three short ones on the fourth or last.

The abdomen is quite similar to that of *G. princeps*.

Length of carapax, $25{\cdot}2^{mm}$; breadth of carapax, $35{\cdot}5^{mm}$; ratio of length to breadth, 1 : 1·41. Total length of propodus in larger cheliped, $60{\cdot}0^{mm}$. Length of dactylus, $45{\cdot}6^{mm}$; breadth of dactylus, $11{\cdot}8^{mm}$.

The only specimen of this species which I have seen is in the collection of the Peabody Academy of Science, and was obtained at the Gulf of Fonseca, West Coast of Central America, by J. A. McNiel.

The larger hand in this specimen resembles very much the figure of the hand of *G. maracoani* given by Edwards in the Annales des Sciences naturelles, 3me série, tome xviii, 1852, pl. 3, fig. 1b, but the carapax and ambulatory legs seem to be very different from that species, as neither Edwards nor Dana mention, in their descriptions of *G. maracoani*, the peculiar sculpturing of the branchial regions, the tubercles of the lateral margins or the spines of the ambulatory legs which are so conspicuous characters in *G. armatus*. In these characters it approaches the genus *Acanthoplax*, as described by Edwards.

Gelasimus ornatus, sp. nov.

Plate II, figure 9–9a. Plate III, figure 5–5c.

Female. The carapax is narrow and the greatest breadth is between the antero-lateral angles, it is convex longitudinally, but only slightly laterally, and the dorsal surface is verrucose, some of the verrucæ, especially on the branchial regions, being large and depressed. The regions are not swollen or protuberant, but the cervical and branchio-cardiac suture is very distinctly indicated. The front is narrow and spatulate, but only slightly expanded below the bases of the ocular peduncles. The superior border of the orbit is slightly and regularly arcuate, as seen from above, the margin is slightly raised and minutely denticulate, and the lateral angle projects forward and outward as a slender and prominent tooth. The antero-lateral margin is longitudinal for a short distance anteriorly, but the posterior portion curves inward to the base of the posterior leg, and is ornamented with eight to ten bead-like tubercles. The latero-inferior, branchial regions are nearly vertical, and are divided by a granulated crest which starts a little way from the antero-lateral angle and extends obliquely backward to the bases of the penultimate legs. The posterior margin is ornamented with a line of low tubercles. The inferior margin of the orbit is armed with about fifteen compressed and truncate teeth. The jugal regions are rough and sparsely clothed with short hairs.

The ocular peduncles are equal in length, slender, slightly enlarged at the cornea and very little shorter than the broad and very open orbits.

The chelipeds are like the smaller cheliped of *G. armatus*, except that the merus has but one spine and that the ischium has a slight tooth on the lower side next the articulation with the merus.

The ambulatory legs are quite similar to those of *G. armatus*, but all of them have a tooth or spine on the lower side of the ischium, and the merus is armed in the first pair with one or two spines, in the second with three, in the third with five, and in the last with two or three.

The abdomen is broadly elliptical, and the basal segment is ornamented with a line of small tubercles.

Length of carapax, 26·6^{mm}; breadth of carapax, 36·0^{mm}; ratio of length to breadth, 1 : 1·35.

The single specimen above described is in the collection of the Peabody Academy of Science, and was brought home, with the *G. armatus* and several of the foregoing species, by J. A. McNiel, but unfortunately has no label to indicate the exact locality from which it came. It is however undoubtedly from some part of the west coast of Central America.

This species is allied to the *Acanthoplax insignis* Edwards, but is at once distinguished from it by the verrucose dorsal surface of the carapax. It has also considerable affinity with *G. armatus*, and it is possible that it may be the female of that species, but this seems very improbable, when the great differences in the ornamentation of the carapax and in the armature of the chelipeds and ambulatory legs are considered.

Gelasimus insignis.

Acanthoplax insignis Edwards, Annales des Sciences naturelles, 3^{me} série, Zoologie, tome xviii, 1852, p. 151, pl. 4, fig. 23; Archives du Muséum d'Histoire naturelle, Paris, tome vii, p. 162, pl. 11, fig. 1, 1854.

Edwards states that this species was known to him only from a single, female specimen brought from Chili by M. Gay, but the figures which he has given in the Annales des Sciences and in the Archives du Muséum, differ so much that it would scarcely be supposed that they were intended to represent the same species, much less the same specimen.

The only generic characters which are given by Edwards to distinguish *Acanthoplax* from *Gelasimus*, the proportions of the carapax and the tuberculation of the branchial regions, appear to me to be of slight importance. In the proportions of the carapax, the difference between *Acanthoplax* as figured in the Annales des Sciences and the ordinary narrow fronted *Gelasimi* is scarcely, if any, greater than the difference between the two figures of *A. insignis*, for the figure of the carapax in the Annales is $19{\cdot}0^{mm}$ in length and $27{\cdot}5^{mm}$ in breadth, giving the ratio of length to breadth, 1 : 1·45, while the carapax in the figure in the Archives du Muséum is $25{\cdot}2^{mm}$ in length and $32{\cdot}0^{mm}$ in breadth, giving the ratio, 1 : 1·27, and this when both figures are stated to be of natural size. No measurements are given in the text in either place. The tuberculation of the branchial regions appears to be merely a character of ornamentation to which there is a considerable approach in the females of many of the large *Gelasimi*, and in the male *G. armatus* described in this article, there is a still closer approach to it.

The armature of the ambulatory legs, however, may prove to be a character of some importance, and would unite in one group with *A. insignis*, *G. ornatus* and *G. armatus*, and perhaps also *G. maracoani.*

B.—*Species in which all the segments of the abdomen are separated by distinct articulations, but in which the front is broad and evenly arcuate between the bases of the ocular peduncles.*

Gelasimus palustris Edwards.

(?) *Cancer vocator* Herbst, op. cit., Band iii, viertes Heft, p. 1, Tab. 59, fig. 1, 1804.
Gelasimus vocans Edwards, Histoire naturelle des Crust., tome ii, p. 54; et Règne animal de Cuvier, 3me édit., Crust., pl. 18, fig. 1 (*teste* Edwards).
Gelasimus palustris Edwards, Annales des Sciences naturelles, 3me série, Zoologie, tome xviii, 1852, p. 148, pl. 4, fig. 13.
(*Non Cancer vocans* Linné, Systema Naturæ, editio xii, tome i, p. 1041).

As figured in the Annales des Sciences naturelles, this species is quite different from any species which I have examined, and is distinguished by the form of the terminal segment of the male abdomen, which is as long as its breadth at base, with the sides straight and slightly divergent and the extremity broad and rounded, and by the anterior margin of the orbital border being symmetrical and not more rapidly curved above the base of the ocular peduncle than on the outside, as it is in most of the allied species. It is described in the following brief terms:—"Crête sourcilière postérieure presque droite, l'antérieure très courbe; crêtes marginales très marguées sur les lobes mésobranchiaux.—Antilles."

It is quite apparent that Edwards confounded at least two species under the name of *palustris*. The figure of *G. vocans*, which he has given in the Règne animal and which he refers to his *palustris*, evidently represents a different and distinct species, as the front is quite narrow, the basal portion of the propodus of the larger cheliped much longer in proportion and the terminal segment of the male abdomen entirely different in form. It is very likely the same as the *G. vocans* of his Histoire naturelle des Crustacés, which is said to inhabit Brazil.

Stimpson, in the Annales of the Lyceum of Natural History, New York, vol. vii, p. 62, refers the *G. vocans* of Dana and the *G. minax* of LeConte to the *palustris* of Edwards, and he evidently had more than one species before him, as he mentions that the tubercles on the outer surface of the larger cheliped were minute or obsolete in specimens from the Mexican and Central American shores.

Gelasimus macrodactylus Edwards et Lucas.

Voyage de d'Orbigny dans l'Amérique méridionale, Crust., p. 27, pl. 11, fig 3, 1843; Edwards, Annales des Sciences naturelles, 3me série, Zool., tome xviii, 1852, p. 149.

"Côtes du Valparaiso" (Edwards and Lucas).

Gelasimus minax LeConte.

Gelasimus minax John LeConte, On a new species of Gelasimus, Proceedings Academy Nat. Sci., Philadelphia, vol. vii, 1855, p. 403.

Gelasimus palustris (*pars*) Stimpson, Annals Lyceum Nat. Hist., New York, vol. vii, p. 62, 1859.

Plate II, figure 4. Plate IV, figure 1–1b.

Male. The carapax is quite convex longitudinally and slightly transversely, and in large specimens the branchial regions are somewhat gibbous above. The dorsal surface appears smooth, but is very minutely granulous, and there are a few small tubercles on the anterior part of the gastric region near the lateral margin. The front is broad and regularly arcuate. The posterior, or upper, edge of the superior orbital border is transverse and nearly straight, and has a smooth upturned margin. The anterior, or lower, edge is marked by a sharply raised and minutely denticulated margin which curves rapidly downward above the base of the ocular peduncle, then gradually upward and joins the posterior margin a little way from the antero-lateral angle, which is obtuse and not at all prominent. The lateral border is marked by a sharply upturned and finely denticulated margin, which is arcuate anteriorly so that the breadth of the carapax is considerably less between the antero-lateral angles than a little posteriorly, and the posterior portion is strongly incurved and terminates opposite the cardiac region. The postero-lateral border is crossed by an oblique raised line or plication. The inferior orbital margin is finely toothed and the jugal region is rough and hairy.

The larger cheliped is stout, and the length of the hand in large specimens is nearly or quite three times as great as the length of the carapax. The anterior surface of the merus is smooth, narrowly triangular in outline and its margins are nearly straight, the inferior armed with minute tubercles, and the superior with slender tubercles on the distal portion; the upper surface is roughened with short, irregular, transverse rows of small tubercles. The superior surface of the carpus is covered with depressed tubercles, the proximal portion of the inner edge is tubercular and the inner surface is crossed by an oblique ridge armed with tubercles. The basal portion of the propodus is much shorter than the digital portion, and its superior and exterior surface is covered with depressed tubercles, which are large and separated by smooth spaces on the upper portion, but below are smaller and crowded, and, along the inferior border, almost obsolete; the inner surface is armed, on the inferior border, with a ridge of large tubercles extending from the base of the propodal finger obliquely upward to the border of the deep depression into which the carpus folds, and there are also a few tubercles between this depression and the base of the dactylus, and a line of tubercles extending upward, from the inner edge of the propodal finger, parallel to the base of the dactylus; the superior edge is tuberculose and has a crenulated margin on the outside and the inner margin is curved downward at the extremity of the depression into which the carpus folds; and finally, the inferior edge is smooth and rounded, but with a slight margin on the outside. The propodal finger is nearly straight; the inferior edge is smoothly rounded, the prehensile edge is broad and armed with marginal lines of small tubercles, and a median one of irregular tubercles, of which one, about the middle of the finger, is very much larger than the rest; and the tip has an excavation into which the dactylus fits. The dactylus is much curved, especially toward the tip, which hooks considerably by the tip of the propodal finger, and the prehensile edge is much as in the other finger, but the tubercles of the median line are nearly obsolete, except two or three large ones near the base, and as many more between the middle and the tip.

The ambulatory legs are stout and very hairy along the edges, and the meral segments are quite broad, those of the posterior pair being nearly three times as long as broad.

The abdomen is slightly narrowed at the first segment and is broadest at the second and third. The distal margin of the penultimate segment is somewhat excavated for the reception of the terminal segment, which is much narrower than the penultimate and broadest at the base, from which the margin is regularly arcuate, forming scarcely more than a semicircle.

Both in alcoholic and dry specimens the points of the articulation of the merus with the carpus, the carpus with the propodus and the propodus with the dactylus, in the larger cheliped, are marked by red spots, and there are similar, but smaller, spots on the ambulatory legs, at the articulation of the meral with the carpal segments.

The females differ from the males in being narrower and more evenly convex above, and in having the branchial regions more swollen and thickly covered with rounded tubercles.

A number of specimens give the following measurements:—

Locality.	Sex.	Length of carapax.	Breadth of carapax.	Ratio.	Length of hand.	Breadth of hand.
New Haven, Ct.	Male.	26·5mm	38·1mm	1 : 1·44	75·0mm	23·0mm
" "	"	22·9	34·0	1 : 1·48	61·0	20·8
" "	"	22·9	32·8	1 : 1·43	——	——
" "	"	22·2	30·0	1 : 1·35	53·0	18·0
Bluffton, S. C.	"	19·0	28·2	1 : 1·48	45·0	15·8
" "	"	17·6	25·2	1 : 1·43	40·5	14·8
" "	"	17·2	24·5	1 : 1·43	40·0	14·2
New Haven, Ct.	Female.	24·9	34·3	1 : 1·37	——	——
" "	"	21·8	29·2	1 : 1·34	——	——

This species is found at New Haven, Conn., on salt-marshes. There are specimens in the collection of the Peabody Academy of Science from Bluffton, South Carolina, and also, from St. Augustine, Florida. LeConte's specimens were from New Jersey.

This is a very large species and I have not seen young specimens. It has perhaps been considered an adult form of *G. pugnax;* LeConte, however, recognized it as a distinct species and pointed out the differences, having very naturally mistaken the *pugnax* for *G. pugilator*. The tubercles on the anterior portion of the branchial region of the male are probably only an adult character, but the very coarse tuberculation of the basal portion of the propodus and the red markings on the larger cheliped of the male, and the tubercular branchial regions of the female, are quite enough to distinguish it from the allied species.

Gelasimus brevifrons Stimpson.

Annals Lyceum Nat. Hist., New York, vol. vii, p. 229, 1860.

Of this species, which was found in a lagoon at Todos Santos, near Cape St. Lucas, Lower California, I have seen only a single, female specimen, which was kindly loaned from the collection of the Chicago Academy by Dr. Stimpson.

As far as can be judged from the female alone, it is very distinct from any other species with which I am acquainted and seems to be most closely allied to *G. minax.* It differs from the female of *G. minax*, in having the carapax broader in proportion and not nearly so much narrowed behind, and the dorsal surface less convex; the carinæ of the lateral margins are more prominent and, from the form of the carapax, are not so much curved; the front is shorter and more perpendicular, and the anterior margin of the orbital border is more convex, leaving a broader space between it and the posterior margin; and finally, the meral segments of the ambulatory legs are much narrower in proportion, and are marked with conspicuous, transverse plications.

Length of carapax, $17{\cdot}5^{mm}$; breadth of carapax, $25{\cdot}0^{mm}$; ratio of length to breadth, 1 : 1·43.

Gelasimus pugnax, sp. nov.

Gelasimus vocans (*pars*) Gould, Report on the Invertebrata of Massachusetts, p. 325, 1841; *G. vocans*, var. A, DeKay, Natural History of New York, Crust., p. 14, pl. 6, fig. 10, 1844 (*non Cancer vocans* Linné).

Gelasimus pugilator LeConte, loc. cit., p. 403 (*non* Bosc).

(?) *Gelasimus palustris* (*pars*) Stimpson, Annals Lyceum Nat. Hist., New York, p. 62, 1859 (*non* Edwards).

Plate II, figure 1. Plate IV, figure $2–2^{d}$.

Male. The carapax is quite similar to that of *G. minax* but it is broader, the dorsal surface is smooth and there are no tubercles on the branchial regions, the front is narrower and projects farther downward, the antero-lateral angle is sharp and the anterior part of the lateral margin is not at all, or only very slightly, arcuate.

In the larger cheliped, the anterior surface of the merus is usually somewhat granular or finely tuberculose, especially along the inferior border, its outline is triangular and much broader toward the carpus than in *G. minax*, and the distal portion of the superior margin is high and arcuate and not tuberculated as in that species. The superior surface of the carpus is covered with small, rounded tubercles and the inner surface is crossed by an oblique, and more or less tuberculated, ridge. The basal portion of the propodus, even in quite small specimens, is shorter than the digital portion and its superior and exterior surface is covered with small, depressed tubercles of unequal sizes and so thickly crowded together that there are scarcely any spaces between them, the oblique ridge on the inferior border of the inside is armed with numerous very small tubercles, the whole space between the upper portion of this ridge and the base of the dactylus is finely tuberculose, and the inferior edge is very distinctly margined on the outside. Both the propodal finger and the dactylus are more slender than in *G. minax* but offer no distinctive characters.

The ambulatory legs are rather stout, very hairy along the edges of the carpal and propodal segments and the meral segments are broad, those of the posterior pair being about one and a half times as long as broad.

The abdomen is scarcely at all narrowed at the basal segments. The terminal segment is very much as in *G. minax* but slightly broader in proportion and very similar to that of *G. pugilator*, figured by Edwards in the Annales des Sciences naturelles, 3^me^ série, tome xviii, 1852, pl. 4, fig. 14^b^, and not at all like his figure of *G. palustris*, fig. 13^b^ on the same plate.

The females differ from the males in being slightly narrower in proportion and in having the dorsal surface of the carapax more convex and minutely granulous.

In life, the dorsal surface of the carapax of the male is very dark greenish olive, the middle and anterior portion, mottled with grayish white, the front, between and above the bases of the ocular peduncles, light blue varying somewhat in intensity in different specimens, and the anterior margin tinged with brown. The larger cheliped is lighter than the carapax, is marked with pale brownish yellow at the articulations and along the upper edge of the dactylus, and both fingers are nearly white along the prehensile edges. The exposed portions of the the ocular peduncles and the eyes are like the dorsal surface of the carapax. The smaller cheliped and the ambulatory legs are somewhat translucent and thickly mottled and specked with dark grayish olive. The sternum and abdomen are mottled ashy gray. The females differ from the males in having the dorsal surface of the carapax less distinctly mottled with whitish and in wanting the blue on the front. This description of the colors was taken, in November, from about a dozen specimens from New Haven.

A series of specimens give the following measurements:—

Locality.	Sex.	Length of carapax.	Breadth of carapax.	Ratio.	Length of hand.	Breadth of hand.
New Haven, Conn.	Male.	15·3mm	23·2mm	1 : 1·52	——mm	——mm
" "	"	14·8	22·6	1 : 1·51	40·5	13·8
" "	"	14·4	21·9	1 : 1·52	41·0	13·5
Bahamas.	"	14·3	22·0	1 : 1·54	39·5	13·4
New Haven, Conn.	"	13·8	20·7	1 : 1·50	40·0	13·0
" "	"	13·7	20·3	1 : 1·48	37·0	12·4
" "	"	12·8	19·3	1 : 1·51	34·5	12·2
" "	"	12·1	18·1	1 : 1·49	32·2	11·0
East Florida.	"	10·6	16·6	1 : 1·57	26·0	8·8
New Haven, Conn.	"	10·4	15·5	1 : 1·49	22·0	8·5
East Florida.	"	10·3	15·7	1 : 1·52	24·5	8·6
"	"	8·8	13·2	1 : 1·50	15·2	6·5
Bahamas.	"	8·7	12·8	1 : 1·47	21·0	6·8
"	"	7·4	11·0	1 : 1·48	16·4	5·5
New Haven, Conn.	Female.	12·8	18·6	1 : 1·45		
" "	"	12·5	17·8	1 : 1·42		
" "	"	12·0	17·1	1 : 1·42		
" "	"	9·6	13·7	1 : 1·43		
" "	"	8·6	12·4	1 : 1·44		
Bahamas.	"	7·3	10·2	1 : 1·40		
New Haven, Conn.	"	7·0	10·0	1 : 1·43		

This species is common upon the salt-marshes about New Haven, Conn., and there are specimens in the Museum of Yale College from St. Augustine, Florida (Col. W. E. Foster). In the collection of the Boston Society of Natural History there are specimens from Bahamas (Dr. Henry Bryant), and in the collection of the Peabody Academy of Science, from Hayti (Dr. D. F. Weinland).

At first sight this species might be mistaken for the young of *G. minax*, but when specimens of each, of nearly equal size, are compared there is no danger of confounding them. *G. pugnax* is much smaller than *G. minax*, the carapax is considerably broader, is not so much contracted at the antero-lateral angles and is perfectly smooth, the tubercles of the outer surface of the larger cheliped are very much smaller and more crowded together, and the coloration is quite different, the red on the chelipeds and ambulatory legs being entirely wanting.

A male of this species, collected at New Haven by W. C. Beecher, presents a remarkable anomaly in having the chelipeds nearly equal in size, while in other respects it is exactly like ordinary individuals. This specimen is briefly noticed in the American Naturalist, vol. iii, p. 557, under the name of *G. palustris.* The left cheliped is exactly like the larger cheliped of ordinary specimens, and the right one differs only in being somewhat smaller and in having the fingers slightly more incurved at the tips so as to fit nicely the buccal area. Length of carapax, 11·2^{mm}; breadth of carapax, 16·4^{mm}; rato, 1 : 1·46. Length of left cheliped, 25·0^{mm}. Length of right cheliped, 21·0^{mm}. The specimen, which was examined while alive, was very active and used both hands with equal facility.

With this single remarkable exception, I have found only the slightest variations in examining carefully more than a hundred specimens.

Gelasimus rapax, sp. nov.

Plate II, figure 2. Plate IV, figure 3.

Male. The carapax is very much like that of *G. pugnax*, but the front is narrower, the upper edge of the superior orbital border is sinuous and not so transverse as in that species, being directed somewhat backward, the border itself is wider and its lower edge is not so abruptly curved above the base of the ocular peduncle.

In the larger cheliped, the anterior surface of the merus is smooth. The superior surface of the carpus is minutely tuberculose and the inner surface is crossed by a slight, oblique ridge which is nearly smooth. The basal portion of the propodus is much stouter than in *G. pugnax* and considerably longer than the digital portion, the superior and exterior surface is thickly covered with small tubercles and the inner surface is much as in *G. pugnax*, but the superior margin is curved more abruptly, and farther downward at the extremity of the depression into which the carpus folds, and there is a line of bead-like tubercles, along the border next the base of the dactylus, which are very much larger than in *G. pugnax.* The propodal finger is short and stout and considerably curved upward, the inferior edge is smooth and rounded, and the prehensile edge is much as in *G. pugnax*, but the tubercles are larger. The dactylus is stout, curved toward the extremity and the tip hooked by the end of the other finger, the superior margin is tuberculose toward the base and margined on the outside for nearly half its length, and the prehensile edge is as in *G. pugnax* but there are four or five large tubercles close together near the base.

The ambulatory legs are quite similar to those of *G. pugnax* but seem to be much less hairy.

The abdomen is as in *G. pugnax.*

Length of carapax, 12·6^{mm}; breadth of carapax, 19·0^{mm}; ratio, 1 : 1·51. Length of hand, 28·2^{mm}; breadth of hand, 10·8^{mm}.

I have seen but a single specimen, which was collected at Aspinwall by F. H. Bradley. Although closely allied to *G. minax* and *pugnax*, it is very different from any specimens which I have seen, of either of those species, and is readily distinguished from them by the very short and stout fingers, the tubercles on the basal portion of the upper margin of the dactylus, the long basal portion of the propodus and the line of bead-like tubercles along its border next the base of the dactylus. The differences in the carapax are however very slight, and it may possibly prove to be a variety of *G. pugnax.*

Gelasimus mordax, sp. nov.

Plate II, figure 3. Plate IV, figure 4, 4[a].

Male. The carapax is convex both transversely and longitudinally The dorsal surface is punctate and the space between the puncta is smooth and naked, but the puncta themselves give rise to short hairs which are very easily removed. The front is much less deflexed than in the allied species, its dorsal surface is divided by a distinct median sulcus and its inferior surface, between the margin and the epistome, is quite high. The upper edge of the superior orbital border is directed somewhat backward as in *G. rapax*, but is straight and not sinuous; the border itself is much more oblique than in the allied species, so that it appears very large as seen from above. The anterior part of the lateral margin is thin and projects somewhat laterally.

In the larger cheliped, all the segments are more elongated than in the allied species. The anterior surface of the merus is smooth, narrow in outline and its margins are tuberculose. The superior and exterior surface of the carpus is obscurely tuberculose, and its inner surface is crossed by an oblique ridge which is nearly smooth. The basal portion of the propodus, as seen in front, is narrowed toward the articulation of the carpus and is very much shorter than the digital portion; the superior, and the upper part of the exterior, surface is obscurely tuberculose while the lower portion is smooth; the oblique ridge on the inferior border of the inside, is much higher and extends farther back toward the articulation of the carpus than in the allied species, and is thickly covered with very large, rounded tubercles, and all the space between its upper portion and the base of the dactylus is covered with depressed tubercles; the superior edge is somewhat carinated, slightly tuberculose and margined on the outside, and the inner margin is turned abruptly downward at the extremity of the depression into which the carpus folds; and finally, between this abruptly curved portion and the base of the dactylus and just below the superior margin, there is an oblong, depressed space which is very conspicuous as seen from above. This depression exists in *G. minax* but is not at all conspicuous. The propodal finger is very long and slender, curved upward at the extremity, and the prehensile edge armed with a large tubercle near the middle and another near the tip, which is deeply excavated for the reception of the dactylus. The dactylus is very slender, the basal portion nearly straight, the extremity strongly hooked downward and inward, the superior edge smooth, and the prehensile edge armed with several large tubercles.

The ambulatory legs are long and much more slender than in the allied species, the meral segments being quite narrow.

The abdomen is quite similar to the abdomen of *G. pugnax*, but is somewhat narrower.

The females differ from the males in having the carapax narrower and more convex, and in the branchial regions being tuberculose along the lateral margins.

Several specimens give the following measurements:—

Sex.	Length of carapax.	Breadth of carapax.	Ratio.	Length of hand.	Breadth of hand.
Male.	16·9mm	25·5mm	1 : 1·51	45·0mm	12·5mm
"	15·4	23·2	1 : 1·51	45·0	13·0
"	15·3	23·0	1 : 1·50	46·5	13·0
"	14·5	21·5	1 : 1·48	42·0	12·6
"	10·6	15·5	1 : 1·46	20·5	7·0
Female.	12·9	18·1	1 : 1·40		
"	12·5	16·7	1 : 1·34		
"	10·8	14·3	1 : 1·32		

"Canals at Pará, South America, October or November, 1858; Caleb Cooke" (Collection Peabody Academy of Science).

Gelasimus pugilator Latreille.

Ocypoda pugilator Bosc, Histoire naturelle des Crust., tome i, p. 197, 1802; (*pars*) Say, Journal Academy Nat. Sci, Philadelphia, vol. i, p. 71, 1817, p. 443, 1818.

Gelasimus pugilator Latreille, Nouveau Dictionnaire d'Histoire naturelle, 2e édit, tome xii, p. 520, 1817; Desmarest, op. cit., p. 123; Edwards, Annales des Sciences naturelles, 3me série, Zoologie, tome xviii, 1852, p. 14, pl. 4, fig. 149; Stimpson, Annals Lyceum Nat. Hist., New York, vol. vii, p. 62.

Gelasimus vocans, DeKay, Natural History of New York, Crust., p. 14, pl. 6, fig. 9; (*pars*) Gould, Report on the Invertebrata of Massachusetts, p. 325 (*non Cancer vocans* Linné).

Plate IV, figure 7.

This is at once distinguished from any of the east coast species, except *G. subcylindricus*, by the rectangular outline, swollen and highly polished, dorsal surface of the carapax, and by the inner surface of the basal portion of the propodus of the larger cheliped being evenly rounded and beset with small scattered tubercles, but with no indication of an oblique tuberculose ridge. From *G. subcylindricus*, it is readily distinguished by the carapax being narrower and its posterior margin straight, by the hand in the larger cheliped of the male being margined with a slight crest on the outside of the superior edge, and by the narrow male abdomen.

It seems to be abundant from the Gulf States to Massachusetts. At New Haven, Conn., it is very common upon muddy beaches, but is not usually associated with *G. pugnax*, which prefers salt-marshes. There are specimens in the Museum of Yale College, collected at Egmont Key, West Florida, by Col. E. Jewett, and at St. Augustine, by Col. W. E. Foster and H. S. Williams; and in the collection of the Peabody Academy of Science, there are specimens from Savannah, Georgia, from Bluffton, South Carolina, and from Nantucket, Massachusetts, those from the last locality collected by Dr. A. S. Packard, Jr.

A series of specimens give the following measurements:—

Locality.	Sex.	Length of carapax.	Breadth of carapax.	Ratio.	Length of hand.	Breadth of hand.
West Florida.	Male.	15·0mm	21·6mm	1 : 1·44	38·0mm	12·5mm
"	"	14·7	21·0	1 : 1·43	33·0	10·5
New Haven, Conn.	"	14·2	20·6	1 : 1·44	36·5	11·8
" "	"	13·6	19 4	1 : 1·43	34·0	11·0
" "	"	13·4	18·8	1 : 1·40	30·2	11·4
" "	"	12·5	17·4	1 : 1·39	27·0	10·6
" "	"	11·7	16·2	1 : 1·38	23·8	9.6
" "	"	7·6	10·2	1 : 1·33	9·5	4·8
West Florida.	Female.	14·6	20·4	1 : 1·40		
New Haven, Conn.	"	12·5	16·4	1 : 1·31		
" "	"	10·8	14·3	1 : 1·32		
" "	"	9·1	12·0	1 : 1·32		

Gelasimus subcylindricus Stimpson.

Annals Lyceum Nat. Hist., New York, vol. vii, p. 63, 1859.

Plate IV, figure 6–6b.

This species has a general resemblance to *G. pugilator*, but the body is much broader, not so much narrowed behind and very convex, being in fact much like *G. gibbosus*. The male abdomen and its appendages are, moreover, very unlike any other species which is known to me.

Male. The dorsal surface of the carapax is minutely granulous, very convex longitudinally and swollen along the branchial regions, which, however, do not project above the middle of the carapax, and the regions are not separated by distinct sulci. The front is evenly rounded and strongly deflexed. The superior border of the orbit is nearly perpendicular, and its posterior, or upper, margin is sinuous, curving forward in a slight prominence in the middle. The antero-lateral angle is obtuse and not at all prominent. The lateral margins converge slightly anteriorly and are only faintly indicated on the postero-lateral border. The posterior margin is divided into two broad lobes by a very marked median immargination. The inferior border of the orbit is slightly curved and finely denticulate.

The external maxillipeds are proportionately smaller than in the allied species, the ischium is only very slightly wider than the merus and its outer margin is nearly straight. Corresponding with the form of the external maxillipeds, the buccal opening is smaller and more rectangular than in the other species.

In the larger cheliped, the angles of the merus are obtuse and granulous and the anterior surface is slightly convex. The outer surface of the carpus is slightly granulous. The basal portion of the propodus is nearly as long as the digital portion; the inner surface is not armed with a tuberculose ridge along the inferior margin, that portion being rounded and only obscurely tuberculose, but on the border next the base of the dactylus, there are two, sharp, tubercular, parallel ridges, the inner one highest and separated from the other by a deep, narrow groove; the outer surface is densely covered with small, depressed tubercles which are more uniform in size and more prominent than in *G. pugnax*, or *G. pugilator;* the superior edge is tuberculose but not distinctly margined on the outside as in *G. minax*, *pugnax*, and *pugilator;* the inferior edge is armed with a prominent, tubercular margin on the outside, and the flat, oblique space between the inner and outer margins is smooth and shining, while in *G. pugilator* it is covered with rounded granules. The propodal finger is considerably curved upward, its outer surface is armed, on the basal portion, with a distinct, median ridge, the inferior margin is smooth, and the prehensile edge tubercular and armed with a single, large tooth near the middle. The dactylus is strongly and evenly curved, the superior margin is smooth and the prehensile edge is tubercular and armed with several larger tubercles toward the base. The smaller cheliped and the ambulatory legs do not differ notably from those of the allied species.

The abdomen is very broad, its breadth being fully equal to two-thirds its length, while, in *G. pugilator* and allied species, the breadth is not equal to more than half the length. The terminal segment is very small, being rather less than half as broad as the penultimate and very much shorter than broad. The appendages of the first segment are very stout and nearly straight organs, reaching to the middle of the penultimate segment, and the tips are horny and slightly hairy, while in *G. pugilator* these organs are longer, very slender, and strongly curved outward at the tips.

The female differs from the male in having the posterior margin of the carapax only slightly immarginate in the middle.

Sex.	Length of carapax.	Breadth of carapax.	Ratio.	Length of hand.	Breadth of hand.
Male.	12·1mm	18·5mm	1 : 1·53	25·0mm	11·0mm
"	10 5	16·0	1 : 1·52	20·5	9·0
Female.	10·0	15·5	1 : 1·55		

The above description and measurements were made from three of the original specimens, collected at Matamoras on the Rio Grande, by M. Berlandier, and loaned by Dr. Stimpson.

Gelasimus stenodacylus Edwards et Lucas.

Voyage de d'Orbigny dans l'Amérique méridionale, Crust., p. 26, p. 11, fig. 2, 1843; Edwards, Annales des Sciences naturelles, 3me série, Zool., tome xviii, 1852, p. 149.

"Trouvé sur les côtes du Valparaiso par M. d'Orbigny," (Edwards and Lucas). In the Annales des Sciences naturelles, Edwards gives the habitat as, "Chili, Brésil," but there is very likely some mistake in regard to the latter locality for very few, if any, species of crustacea are common to Chili and Brazil.

Gelasimus Panamensis Stimpson.

Annals Lyceum Nat. Hist., New York, vol. vii, p. 63, 1859.

Plate IV, figure 5.

Stimpson had only the young of this species and did not give the characters of the larger cheliped of the male, but a good series of specimens collected at Panama by Mr. Bradley, shows that it is very different from any of the east coast species and is not allied to any from the west coast, unless it be to *G. stenodcatylus* which I have not seen.

Male. The carapax is broadest between the antero-lateral angles and is much less convex than usual. The dorsal surface is very minutely granulose, and there are a few coarse granules or small tubercles on the front and on the anterior part of the branchial region near the lateral margin. The upper edge of the superior orbital border is sinuous and the border itself is quite narrow. The antero-lateral angles are sharp and project prominently forward. The inferior orbital margin is thin and sharply dentate and its outer angle is prominent and angular, and is separated from the superior margin by a deep and broadly rounded sinus.

In the larger cheliped, the merus is slender, and its anterior surface is narrow and smooth and the margins are unarmed and rounded. The carpus is evenly rounded and nearly smooth externally. The basal portion of the propodus is smooth or microscopically granulose and flat and entirely unarmed within; the depression into which the carpus folds is very short, not extending half way to the base of the dactylus; and the superior and inferior margins are evenly rounded. The propodal finger is slightly upturned at the tip, the inferior edge is perfectly smooth and evenly rounded, and the tubercles of the prehensile edge are nearly obsolete except a large depressed one near the middle. The dactylus is strongly curved downward at tip, the superior edge is smooth and rounded and the prehensile edge is obscurely tubercular In very young specimens the hand is quite granulose above but becomes smooth with age.

In the smaller cheliped the tips of the fingers are densely clothed with soft hair.

The ambulatory legs are slender, smooth and almost entirely naked.

The females differ from the males in the carapax being a little narrower in proportion, and in the branchial regions being slightly inflated and more granular or even tuberculose.

Several specimens give the following measurements :—

Locality.	Sex.	Length of carapax.	Breadth of carapax.	Ratio.	Length of hand.	Breadth of hand.
Panama.	Male.	12·5mm	18·0mm	1 : 1·44	27·5mm	9·4mm
"	"	12 1	18·0	1 : 1·49	32·0	11·0
"	"	8·3	11·1	1 : 1·34	9·4	4·8
"	Female.	13·6	18·5	1 : 1·36		
"	"	12·2	17·0	1 : 1·39		
"	"	11·5	16·0	1 : 1·39		
"	"	9·7	13·8	1 : 1·42		

C.—*Species in which the fourth, fifth and sixth segments of the male abdomen completely anchylose, and in which the carapax is very transverse, and the branchial regions are gibbous.*

Gelasimus gibbosus, sp. nov.

Plate II, figure 11. Plate IV, figure 8.

Male. This is a small species quite different in general appearance from any of the foregoing. The body is very short and broad, very little contracted behind, and, in general form, a short cylinder truncated at each end. The chelipeds and ambulatory legs are slender and elongated.

The dorsal surface of the carapax is naked, smooth and shining, convex longitudinally, deeply areolated and nearly symmetrical. The cervical suture is slightly curved and very distinctly marked by a deep sulcus. The median portion of the gastric region is triangular, and is separated from the antero-lateral lobes by very distinct but shallow sulci, which meet in an acute angle on the front. The cardiac region is large, quite prominent and distinctly separated from the gastric. The branchial regions are very prominent and swollen, projecting much above the median regions, and a narrow portion next the cervical suture is cut off by a straight and sharp sulcus. The front projects well forward and is quite narrow, but not contracted between the bases of the ocular peduncles. The superior border of the orbit is nearly on a plain with the anterior part of the carapax, its anterior edge is strongly arcuate and is marked by a very slight, but sharply raised and continuous margin, and the posterior edge is marked by a faintly raised line, which is transverse and nearly straight toward the front, but, toward the side of the carapax, falls off posteriorly, so that the antero-lateral angle, which is right-angular, but not at all prominent, is considerably posterior to the rest of the anterior margin. The faintly margined lateral borders are parallel anteriorly but approach slightly posteriorly. The inferior border of the orbit is denticulate, the teeth being very minute on the portion toward the front but much larger, and very slender on the outer portion, and round into the external hiatus. The jugal regions are much swollen and are separated from the buccal area by a deep depression.

The ocular peduncles are quite stout and as long as the orbits, which they nearly fill.

The ischial segments of the external maxillipeds are very broad and the outer edges are arcuate to fit the expanded buccal area, and thus resemble the species of section A.

The larger cheliped is remarkably developed for so small a species, the merus being as long as the carapax, while the hand is almost three times as long, and nearly twice as long as the breadth of the carapax. The anterior surface of the merus is smooth, flat and quite narrow, and its angles are smooth and unarmed. The superior and exterior surface of the carpus is evenly rounded and very slightly granulous, and the inner margin is sharp and dentate. The basal portion of the propodus is short and compressed, the outer surface is flat and granulous, the inferior edge is angular and has a very slight, granular margin on the outside, the superior edge is rounded and granulated, and the inner surface is armed with a slight, oblique, tuberculose ridge extending from the inferior edge to the short depression into which the carpus folds. The digital portion of the propodus is much compressed, straight and very slender, the inferior edge is nearly smooth, the prehensile edge is only very obscurely tuberculate and has a single, very slight tooth near the middle, and the tip is slender, acute and slightly upturned. The dactylus is compressed, very slender, straight for two-thirds its length and the terminal portion regularly curved downward, the superior edge is rounded and slightly granulous toward the base, and the prehensile edge is as in the other finger, except that the tooth is smaller and nearer the base.

The smaller cheliped is smooth and unarmed, the merus is slender and triquetral, the carpus is short and rounded, the basal portion of the propodus is quite short and thick, and the fingers are slender.

The ambulatory legs are long, very slender and nearly naked, and the meral segments are very narrow.

The sternum is very broad and very convex. The abdomen is scarcely at all contracted at the second segment, and it tapers slightly to the extremity of the sixth; the first and second are very short, the the third is about twice as broad as long, the fourth, fifth and sixth are completely anchylosed into one piece, and the seventh, or last, forms very nearly a semicircle.

Length of carapax, $8·5^{mm}$; breadth of carapax, $14·4^{mm}$; ratio, 1 : 1·79. Length of hand, $24·8^{mm}$; breadth of hand, $8·2^{mm}$.

I have seen only one specimen, which was collected at the Gulf of Fonseca, west coast of Central America, by J. A. McNiel (Collection Peabody Academy of Science).

Family, Gecarcinidæ.

Cardiosoma Latreille.

In this genus the abdominal appendages of the male present, in some cases at least, good specific characters. In all the species which I have examined, the appendages of the first segment are very stout and nearly straight organs reaching beyond the middle of the abdomen, articulated at their bases with a large and hard semicircular plate, which arches round the intestinal canal and joins the abdomen on each side, and armed at their extremities with slender, horny tips.

The appendages of the second segment are small and inconspicuous, and their slender tips are flexible and folded within a little groove on the inside of the bases of the appendages of the first segment.

Cardiosoma guanhumi Latreille.

Cardisoma guanhumi Latreille, Encyclopedie méthodique, tome x, p. 685, 1824, (*teste* Edwards); Edwards, Histoire naturelle des Crust., tome ii, p. 24, 1837; Règne animal de Cuvier, 3me édit., pl. 20, fig. 1; Annales des Sciences naturelles, 3me série, Zoologie, tome xx, 1853, p. 204, pl. 9, fig. 1; Gibbes, On the Carcinological Collections of the United States, Proceedings American Association, 3d Meeting, p. 179, 1850; Stimpson, Proceedings Academy Nat. Sci., Philadelphia, 1858, p. 100; Saussure, Crustacés nouveaux des Antilles et du Mexique, p. 21, 1858.

Ocypode (*Cardisoma*) *cordata* DeHaan, Fauna Japonica, Crustacea, p. 27, 1835 (*non Cancer cordatus* Linné).

Ocypoda ruricola Freminville, Annales des Sciences naturelles, 2e série, Zoologie, tome iii, 1835, p. 217 (*non Cancer ruricola* Linné).

Ocypoda gigantea Freminville, loc. cit., p. 221, 1835.

Plate V, figure 3.

The abdomen of the male is broadest at the third segment, from which the margins converge rapidly to the sixth, which is considerably longer than broad. The terminal segment is narrow and its extremity is rounded. The first pair of abdominal appendages reach to the middle of the sixth segment, are triquetral, straight and stout, and their tips are rounded and slightly flattened laterally, and each is armed with a very small, scale-like appendage directed obliquely outward, and on the upper edge, just above this appendages, there is a small process which is straight and does not reach beyond the rounded extremity of the thickened portion of the organ.

A male from the Florida Keys gives, length of carapax, 65mm; breadth of carapax, 78mm; ratio of length to breadth, 1:1·20. Length of merus in right cheliped, 31mm; in left cheliped, 49mm. Length of right hand, 45mm; breadth, 19. Length of left hand, 88mm; breadth, 44.

Cardiosoma quadratum Saussure.

See these Transactions, vol. ii, p. 16.

Plate V, figure 4.

In this species the male abdomen and its appendages are almost exactly like those of *C. guanhumi* except that the horny extremities of the appendages of the first segment are a little longer and more slender. There is a remarkable difference between the male abdominal appendages of this species and the species from the west coast of

Africa, with which it is compared on page 16 of this volume. In the African species the first pair of these appendages are very much like those of the following species, the horny tips being long, slender and somewhat spiral, and the process on the upper edge extending much beyond the thickened portion of the organ.

Cardiosoma crassum, sp nov.

Plate V, figure 5.

In general appearance this species is closely allied to *C. quadratum*. The carina of the lateral margin of the carapax is, however, much more strongly marked and the ambulatory legs are clothed with long hair, while in *C. quadratum* they are nearly naked. The male abdominal appendages are entirely unlike in the two species.

The dorsal surface of the carapax is naked, very minutely granulous, regularly and strongly convex longitudinally, but only slightly transversely, and the areolation is not strongly marked, the cardiac region and the median portion of the gastric alone being indicated; the anterior extremity of the mesogastric lobe, however, is distinct, long and slender and reaches nearly to the front. The front is broad and high and the epigastric lobes protuberant, leaving, between them and the front, a depressed space which is thickly covered with coarse granules. The superior margin of the orbit is slightly sinuous, as seen from above, and the lateral angle projects forward as an angular tooth. Just back of this tooth the antero-lateral margin is broken by a sharp notch, above which the carina of the lateral margin begins in a sharp prominence. This carina through its entire length is very high and distinct, being much more strongly marked than in *C. quadratum*. The epistome and nasal lobe are very much as in *C. quadratum*, but the labial border of the epistome is armed with a line of granules which is more sharply raised and composed of smaller granules than in that species. The jugal regions are densely clothed with short, soft hair. The inferior branchial regions are naked, but are roughened with numerous, short, sharp rugæ.

The chelipeds are very unequal in both sexes, and the ischial segments are armed, on the anterior side, with a few small tubercles. In the larger cheliped, the merus is triquetral, very stout and reaches slightly beyond the lateral margin of the carapax, the anterior surface is flat and both its margins are armed with very large and prominent tubercles directed forward, and on the outer surface and the posterior angle, which is obtuse, there are short granulous rugæ which are very conspicuous on the angle. The larger hand is very short and stout, the breadth being about equal to four-sevenths of the length; the outer surface of the propodus is flattened and smooth; the inner surface, in the middle and toward the base of the dactylus, and the margins, are armed with scattered tubercles; and finally, the fingers are very stout, the outer edges are armed with small horny tubercles, and the prehensile edges gape but slightly, and are armed with large, irregular teeth. In the smaller cheliped, the merus is more slender and does not quite reach the lateral margin of the carapax, and the hand is very much smaller and more slender.

The ambulatory legs are stout and the carpal and propodal segments, and the meral on the angles below, are clothed with long black hairs, which are very conspicuous and fasciculated on the carpal and propodal segments of the first and second anterior pairs.

In the male, the abdomen is broadest at the third segment, from which the margins converge regularly to the sixth, which is nearly or quite as broad as long and only slightly narrowed for most of its length, but sharply contracted just before the articulation with the small and narrow terminal segment. In the female, the abdomen is broadest near the articulation of the fifth with the sixth segment, and the margins of the sixth segment are arcuate and converge rapidly to the small, obtusely triangular terminal segment.

The first pair of male abdominal appendages reach to the middle of the penultimate segment of the abdomen, and their extremities are slightly flattened laterally, thickly clothed with hair on the outside and terminated by a long, slender, hard and horny tip, which curves outward for nearly half its length, then rapidly upward, and again outward at the end, forming thus about the third of a very elongated spiral. From the under edge, just below the base of this horny tip, there is a stout, straight process, which is soft and flexible, and clothed at the extremity with hair.

Four specimens give the following measurements:—

Sex.	Length of carapax.	Breadth of carapax.	Ratio.
Male. - - - -	50·7mm	62·0mm	1 : 1·22
" - - - -	54·0	66·3	1 : 1·23
" - - - - -	56·4	68·0	1 : 1·21
Female. - - -	53·0	64·5	1 : 1·22

I have examined a large number of specimens collected at the Gulf of Fonseca, west coast of Central America, by J. A. McNiel, and in the Museum of the Peabody Academy of Science.

Family, BOSCIADÆ.

Pseudothelphusa Saussure.

Potamia Latreille, Cours d'entomologie, p. 338, 1831 (*teste* Edwards); Edwards et Lucas, Voyage de d'Orbiguy dans l'Amérique méridionale, Crust., p. 22, 1843; White, List of the Crustacea in the British Museum, p. 30, 1847; Dana, United States Exploring Expedition, Crust., p. 293; Saussure, Crustacés noveaux des Antilles et du Mexique, p. 19, 1858 (*non* Robineau-Desvoidy).

Boscia Edwards, Histoire naturelle des Crust, tome ii, p. 14, 1837; Annales des Sciences naturelles, 3me série, Zoologie, tome xx, 1853, p. 207; A. Edwards, Annales de la Société entomologique de France, 4me serié, tome vi, 1866, p. 203.

Pseudothelphusa Saussure, Revue et Magasin de Zoologie, 1857, p. 305 (*teste* Saussure).

Latreille's name, *Potamia*, given in 1831, was properly rejected by Edwards on account of its previous use, in 1830, by Robineau-Desvoidy, for a genus of Diptera, but the name *Boscia*, proposed by Edwards in 1837, is quite as objectionable, having been used, according to Agassiz's Nomenclator Zoologicus, by Leach, in 1813, for a genus of Cirripedia, by Schweigger, in 1820, for a genus of Polyps, and by Leach again, in 1824, for a genus of Coleoptera. *Pseudothelphusa*, although at first proposed as a new genus, does not differ essentially from the species of Edwards' *Boscia* which have no superior frontal crest, and was finally united with *Potamia* by Saussure himself, so that it may properly be adopted for the genus as defined by Edwards.

Pseudothelphusa, as here limited, includes the following American species:—

P. Americana Saussure, from Hayti.

P. gracilipes (*Boscia gracilipes* A. Edwards, Annales de la Société entomologique de France, 4me série, tome vi, 1866, p. 204), from Haute Vera-Paz, Gautemala.

P. plana, sp. nov., from Peru.

P. macropa (*Boscia macropa* Edwards, Archives du Muséum d'Histoire naturelle, Paris, tome vii, p. 175, pl. 12, fig. 3), from Bolivia.

P. Chilensis (*Potamia Chilensis* Edwards et Lucas, Voyage de d'Orbigny dans l'Amérique méridionale, Crust., p. 22, pl. 10, fig. 1), from Lima, Peru.

P. denticulata (*Boscia denticulata* Edwards, Annales des Sciences naturelle, Zoologie, 3me série, tome xx, 1853, p. 208), from Guiana.

P. Bocourti, (*Boscia Bocourti* A. Edwards, loc. cit., p. 203), from the River Coban, Haute Vera-Paz, Gautemala.

P. dentata (*Boscia dentata* Edwards, Histoire naturelle des Crust., tome ii, p. 15, pl. 18, fig. 14–16), from the West Indies.

The only other described species is the *P. sinutifrons* (*Boscia sinutifrons* A. Edwards, loc. cit., p. 205), the habitat of which was not known.

Potamia latifrons Randall (Journal Academy Nat. Sci., Philadelphia, vol. viii, p. 120, 1839), supposed to have come from Surinam or the West Indies, probably belongs here, but the description is too indefinite to determine its affinities with any degree of certainty.

Pseudothelphusa plana, sp. nov.

Female. The carapax is very broad and its dorsal surface is flat in the middle and posteriorly, but convex along the anterior border, and is punctate, but the surface between the widely separated punctures is glabrous. The gastric region is undivided, except by a short and shallow median sulcus, which separates the slightly indicated anterior lobes and extends down the front. The anterior portion of the cervical suture, from the median lobes of the gastric region to the antero-lateral margin, is well indicated by a straight, broad and deep sulcus. There is no sulcus between the gastric and hepatic regions. The branchial regions are very prominent and undivided. The front is deflexed and the narrow inferior margin is perpendicular, and has a distinct submarginal groove. The orbits are well filled by the stout ocular peduncles. The antero-lateral margin is evenly and very strongly arcuate, and its edge is sharp and finely denticulated. The postero-lateral margin is concave in outline.

The external maxillipeds, as well as the sternum, are punctate like the carapax but the punctures are much larger.

A single cheliped is quite small; the merus scarcely reaches beyond the carapax, is triangular, the anterior angle slightly dentate, and the posterior angle rounded and granulated; the upper side of the carpus is punctate like the carapax, evenly rounded and armed with an angular tooth on the inner margin; the basal portion of the propodus is punctate, slender and evenly rounded; and finally the fingers are long, slender, cylindrical, nearly straight, and slightly toothed within.

The ambulatory legs are naked, slender and rounded, and the dactyli are nearly straight, cylindrical and sparsely spinulose.

The color of alcoholic specimens is uniform dark olive brown above and lighter beneath.

Sex.	Length of carapax.	Breadth of carapax.	Ratio.
Female.	13·6mm	22·4mm	1 : 1·65
"	16·5	27·7	1 : 1·67

There are two rather badly preserved specimens, collected at Paita, Peru, by Prof. James Orton, in the Museum of Yale College. The smaller specimen wants both chelipeds, and the larger specimen, one.

This species is closely allied to *P. macropa*, but is easily distinguished from it by the denticulated antero-lateral margin, by the short merus of the chelipeds, and by the flattened carapax—the carapax of *P. macropa* being represented in Edwards' figure as quite convex transversely, while in *P. plana* it is flat in that direction. Moreover the front seems to be much more deflexed in our species, the orbits are much smaller and are well filled by the eyes, and the antero-lateral margin is not "creusés en dessous d'un sillon bien marqué." In the depressed form of the carapax, it is apparently closely allied to *P. gracilipes*, but the ambulatory legs are not longer in proportion than in *P. macropa*, and the front is almost straight, as seen from above, and not lobed as in *P. Americana*, with which the front of *P. gracilipes* is compared. In the denticulated antero-lateral margin it resembles *P. Chilensis*, but in the form of the carapax, and in other characters it is much nearer to *P. macropa*.

Opisthocera,* gen. nov.

The carapax is much as in *Pseudothelphusa;* the dorsal surface is not distinctly areolated; the front is deflexed, smooth and unarmed, and the edge is not reflexed beneath a superior crest as in *Epilobocera* and *Potamocarcinus;* and the lateral margins are not armed with strong teeth or spines.

The epistome is deeply channeled transversely and the labial border is divided into three very prominent lobes projecting far forward, and of which the lateral ones are bilobed at tip and are separated from the antero-lateral angles of the buccal opening by broad and very deep efferent orifices.

The external maxillipeds are as in *Epilobocera*, the merus transverse, the anterior margin rounded, and the palpus goniarthroid.

In the single species upon which the genus is based, there is a long and slender spine projecting from the upper side of the expiratory canal near the external orifice.

In the character of the front, this genus agrees with the species of *Pseudothelphusa* which have no superior frontal crest and differs from *Epilobocera*, while, in the position of the antennæ, it agrees with *Epilobocera* and differs from *Pseudothelphusa*.

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* Ὄπισθε, *pone;* κέρας, *cornu.*

Opisthocera Gilmanii, sp. nov.

Plate V, figure 1.

Male. The dorsal surface of the carapax is evenly convex in two directions and nearly smooth, but very minutely granulated and conspicuously punctate with widely scattered punctures. There is no indication of areolation except two minute lunate impressions in the middle. The front has a smooth, revolute margin, which is continuous with the upper margin of the orbits, and a distinct, submarginal groove, which extends slightly along the inner portion of the superior orbital border. The orbits are large, open and shallow, only partially filled by the ocular peduncles, and the inferior margin is sharp and minutely denticulate. The antero-lateral margin is evenly convex in outline, is broken by a small, oblique groove near the angle of the orbit, and its edge is sharp and very slightly and obtusely denticulated anteriorly, but smooth posteriorly. The postero-lateral margin is concave in outline and rounded. The inferior lateral regions are naked and smooth. The labial border of the epistome is deeply divided; the lobes are very prominent, and nearly horizontally, the median lobe being longest and its extremity triangular.

The external maxillipeds are nearly smooth externally, but are marked with a few scattered punctations.

The chelipeds are very unequal; in both, the merus is triquetral, the inferior angle rounded, but armed with a few small tubercles toward the carpus, and the superior angles are obtuse and armed with numerous tubercles, which are somewhat spiniform on the anterior angle; the carpus is smooth and rounded externally and has a prominent spine on the inner margin. The basal portion of the propodus in the larger hand, is very stout, the superior margin is quite high, but rounded, and the inferior margin is armed with a few small tubercles near the base, the fingers are long, rather slender, and irregularly toothed within, and the dactylus is strongly curved so that the fingers gape very widely. The smaller hand is quite slender, the fingers are nearly cylindrical, very long, nearly straight, and but slightly gaping.

The ambulatory legs are slender, naked and nearly smooth, the meral segments are narrow, and the dactyli are armed with three rows of spines above and two below.

The abdomen is widest at the third segment, and the first and second segments are only slightly narrower; from the third segment, the margins converge quite rapidly to the sixth, which is nearly twice as broad as long and its lateral margins only slightly converging; the terminal segment is much broader than long and its extremity som what acutely arcuate. The appendages of the first segment are very stout and nearly straight organs reaching to the middle of the sixth segment, and articulated at their bases to a hard plate, which arches round the intestinal canal much as described under the genus *Cardiosoma.* A deep groove extends from the basal articulation along the inside of each of these organs, curving round to the outside and terminating at the tip, which is truncate, turned sharply outward and armed with sharp, hooked spinules, and, on the inferior edge, with a small, curved process. The appendages of the second segment are as long as those of the first, are widely separated at their bases, and the terminal portions, which are lodged in grooves in the appendages of the first segment, are long, very slender and taper to acute points.

The color, in alcohol, is uniform dirty yellowish brown, lighter beneath.

Length of carapax, 38·7^{mm}; breadth of carapax, 57·2^{mm}; ratio, 1:1·48. Length of larger hand, 61·0^{mm}; breadth, 24·5; length of dactylus, 37·0. Length of smaller hand, 41·0^{mm}; breadth, 12·8; length of dactylus, 24·5.

The single specimen, which furnishes the above description, is in the collection of the Boston Society of Natural History, and was collected in a small stream near the center of the Isle of Pines by S. H. Scudder and Winthrop S. Gilman, Jr. At the suggestion of Mr. Scudder, the species is named for his friend.

Epilobocera Stimpson.

Epilobocera Cubensis Stimpson.

Annals Lyceum Nat. Hist., New York, vol. vii, p. 234, 1860.

This species, discovered in fresh water streams on the Island of Cuba, near Santiago, has close generic relations with the last species, but the character of the front and of the epistome is very different.

I have seen only a single, imperfect, female specimen loaned by Dr. Stimpson. In this specimen, the dorsal surface of the carapax is armed, along the lateral border, with small, tuberculiform granules, and the inferior lateral regions are armed, toward the lateral margin, with similar granules which are conspicuous on the anterior part of the inferior branchial region. The superior frontal crest projects considerably beyond the inferior one and is divided into two, slightly convex lobes by a well marked, median sulcus which extends back upon the carapax to the mesogastric lobe. The inferior margin of the front is straight, as seen in a front view, and its edge is slightly crenulated.

The inferior margin of the orbit is finely crenulated, and the crenula tions cease near the external angle, but there is no hiatus.

The labial border of the epistome has a prominent, triangular tooth in the middle and smaller ones each side; they all project downward and very slightly forward, and the median one has one or two small denticles toward its base. There is a quite broad, but very short, process projecting from the upper side of the expiratory canal, nearly in the position of the slender spine in *Opisthocera.*

The abdomen is very similar to that of the male *Opisthocera* just described, except that the first and second segments are scarcely narrower than the third. It is remarkably narrow for a female, and the specimen is probably a sterile individual of that sex.

Epilobocera armata sp. nov.

Plate V, figure 2.

The carapax is flattened above and the dorsal surface is nearly smooth, but very minutely granulous and punctate with widely scattered punctures. The epigastric lobes are just indicated by slight elevations and are separated by a very distinct, broad and shallow median sulcus which extends forward and breaks through the superior frontal crest in a smooth sinus. There are no other marks of areolation except two minute lunate impressions in the middle of the carapax. The superior margin of the front projects slightly beyond the inferior one, is nearly straight, as seen from above, but curved downward in the middle, as seen in a front view, and is closely armed with conspicuous, rounded tubercles. The inferior margin of the front is straight and its edge is raised into a prominent crest and is distinctly crenulated. The superior margin of the orbit is continuous with the inferior margin of the front and is crenulated like it, and, at the outer angle is armed with one or two spiniform tubercles. The inferior margin of the orbit is finely dentate and is broken beneath the outer angle by a broad, smooth sinus. The antero-lateral margin is separated from the angle of the orbit by a slight hiatus and is armed with sharp, spiniform teeth, which are prominent and slender on the anterior portion, but decrease in size posteriorly and are quite small at the broadest portion of the carapax. The postero-lateral margin is concave in outline, as seen from above, smooth and rounded.

The labial border of the epistome is divided into three lobes as in the last species. The median lobe is very prominent, projects outward nearly as far as the superior crest of the front, is acutely triangular and armed with two or three spiniform tubercles on each side, of which the ones toward the base are very prominent. The lateral lobes are obtusely rounded, their outer margins are unarmed and the inner margins are armed somewhat as the median lobe, but the tubercles at the bases are slightly separated from the lobes, and stand partially between the lateral and median. There is a process projecting from the upper side of the expiratory canal, as in the last species.

The external maxillipeds, the chelipeds, and the ambulatory legs are very much as in *E. Cubensis.*

The abdomen is very broad, nearly covering the whole sternum, the greatest breadth being at the fifth segment, and the fourth and sixth but little narrower.

Sex.	Length of carapax.	Breadth of carapax.	Ratio.
Female.	43·8^{mm}	70·4	1: 1·61
"	47·2	77·5	1: 1·64

The two specimens from which this description was taken are in the collection of the Boston Society of Natural History, and without labels to indicate from whence they came, but they are probably from the Bahamas.

Although closely allied to *E. Cubensis*, it is readily distinguished from the only specimen of that species which I have seen, in wanting wholly any granulations or tubercles along the lateral margins of the carapax, either above or below, by the more tuberculose superior frontal crest, in having tubercles at the outer angles of the orbits and a marked hiatus beneath it in the inferior margin, by the much longer teeth of antero-lateral margin, and by the quite different labial border of the epistome.

Family, Trichodactylidæ.

Dilocarcinus Edwards.

Dilocarcinus pictus Edwards.

Annales des Sciences naturelles, 3^{me} série, Zoologie, tome xx. 1853, p. 216; Archives du Muséum d'Histoire naturelle, Paris, tome vii, p. 181, pl. 14, fig. 2, 1854.

There are specimens in the collection of the Peabody Academy of Science and of the Museum of Yale College, from the River Amazon, at Nauta, Peru, which I refer to this species, although they do not agree perfectly with Edwards' figures and description. The specimens from Nauta are alcoholic and both females, and are considerably larger than the figure given by Edwards, one of them giving the following measurements:—Length of carapax, 29·0^{mm}; breadth of carapax, including teeth, 34·6; ratio, 1 : 1·19. The carapax in our specimens is somewhat broader and the lobes of the front, as seen from above, are more prominent and their summits nearer together, leaving the orbit larger, than in the figure. The propodi and dactyli of the ambulatory legs are thickly ciliated along both edges, while Edwards' figures 2^c and 2^d represent only a few cilia on the posterior edges; in the text, however, the dactyli are said to be "à bords ciliés." The abdomen is quite remarkable for a female, the third and the three following segments being united into a single piece, as in the figure of the male abdomen, given by Edwards,* but, unlike the figure, it is broadest at the middle and the margins are convex in outline.

Family, Grapsidæ.

Glyptograpsus, gen. nov.

The carapax is much broader than long and the dorsal surface is distinctly areolated. The front is arched and nearly horizontal above the antennæ and antennulæ, but excavated and deflexed in the middle. The lateral margins are strongly arcuate and are dentate anteriorly.

The epistome is high and nearly perpendicular and is crossed transversely by a sharp groove, and the labial border is straight, as seen in a front view, but broken by a distinct notch in the middle, as seen from below. At the sides of the epistome, in the antero-lateral angle of the buccal area, there is a deep and narrow notch, which serves as an efferent orifice. There are no longitudinal ridges on the palate.

The basis of the antenna is movable and fills the whole space between the small, triangular, inner suborbital lobe and the front, and its summit is excavated on the inner side for the reception of the succeeding segments, which are within the orbit.

The external maxillipeds are not crested and their inner margins are closely approximated; the ischium and merus are of nearly equal length and are both very broad, the merus being broader than long, and its antero lateral angle not expanded.

The ambulatory legs are long and the dactyli are quadrangular and the angles armed with spines.

None of the segments of the male abdomen are anchylosed.

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* This figure is marked 3 on plate 14, as if it belonged with fig. 3, *D. spinifer*, and on p. 180 it is referred to under that species, but in the explanation of the plates on p. 192, no fig. 3^e is mentioned, while under *D. pictus* is placed, "Fig. 2^e. Abdomen du mâle," yet there is no fig. 2^e on the plate, and 3^e is the only abdomen there figured. The abdomen is not referred to in the description of *D. pictus*.

The aspect of the single species upon which this genus is founded is quite peculiar. The body is thick, the dorsal surface is uneven and the lateral margin is armed with five teeth (including the angle of the orbit), the last and smallest of which is on the postero-lateral margin. The form of the carapax, the arching of the front above the antennulæ, and the number of teeth on the lateral margin, recall the genus *Cryptograpsus*, from which, however, it is widely separated by the form of the external maxillipeds and of the epistome. In the form of the maxillipeds it is allied to *Heterograpsus*. The form of the epistome and the peculiar, deep efferent orifice are very marked and distinctive characters.

Glyptograpsus impressus, sp. nov.

Male. The dorsal surface of the carapax is uneven, with numerous, irregular, shallow punctures, and along the lateral borders, with small, tuberculose elevations. The cervical suture is indicated by a very distinct sulcus. The median portion of the gastric region is separated from the protogastric lobes by deep sulci, which unite between these lobes and extend down the front as a broad and deep depression. The epigastric lobes are very prominent and their anterior margins are transverse and precipitous. The protogastric lobes are well indicated, and an outer lobule is separated as a small, but very distinct, tuberculiform elevation opposite the inner angle of the orbit. The epibranchial lobes are uneven and partly separated from the mesobranchial by well marked, but short, depressions. The posterior portion of the branchial region is divided by a longitudinal ridge into a flat inner area and a broad precipitous portion between the ridge and the lateral margin. The front, as seen from before, is very sinuous, and broken in the middle by a broad, deep, rounded sinus; its outer angles, as seen from above, are obtusely rounded, and the margin is continuous to the inner angle of the orbit, where it passes abruptly downward beneath the ocular peduncle as a sharp ridge, leaving a distinct notch, above which the margin begins again and is continuous to the acutely triangular antero-lateral tooth, which is prominent and directed straight forward. The second tooth of the lateral margin is broad and obtusely rounded and situated above the plain of the anterior tooth; the third and the fourth are slender and acute; the last is on the postero-lateral margin and is small, acutely pointed and somewhat below the level of those just in front of it. The inferior margin of the orbit is straight and finely dentate. The inferior lateral regions are granulous and slightly hairy.

The chelipeds are short and very unequal; in both, the merus is short, not extending beyond the margin of the carapax, and triquetral, with the angles denticulate, and the carpus is small and its outer surface granulous and slightly margined on the inner edge. In the larger hand, the propodus is short and very stout, the outer surface is convex and finely granulous, and the digital portion is very short, and its prehensile edge directed obliquely downward; the dactylus is straight, rather slender, and granulous like the propodus; both fingers are obtusely tubercular on the prehensile edges and have horny, slightly excavated tips. The smaller hand is slender, somewhat cylindrical, the basal portion is granulous externally, and the fingers are very slender, with the prehensile edges minutely toothed and the tips as in the larger hand.

The ambulatory legs are nearly naked; the meral segments are flat and each is armed with a small spine on the anterior edge near the distal extremity; the carpi are slightly bicarinated along the anterior edges; the propodi are broad. somewhat expanded in the middle, the anterior edges carinated like the carpi, and the posterior edges spinulous. The dactyli are slender, slightly curved, somewhat flattened, and the angles armed with sharp spinules.

The abdomen is broadest at the base, from which it tapers to the last segment, which is longer than broad and rectangular, except that the extremity is slightly rounded.

Length of carapax, including lobes of frontal margin, $12{\cdot}4^{mm}$; breadth of carapax, including lateral teeth, $15{\cdot}0^{mm}$; ratio, $1:1{\cdot}21$. Breadth between antero-lateral angles, $11{\cdot}5^{mm}$. Length of ambulatory legs, first, 19^{mm}; second, 25; third, 25; fourth, 21.

I have seen only a single specimen, which was collected at Acajutla, west coast of Central America, by F. H. Bradley.

The appendages of the first abdominal segment in the male are widely separated at their bases, which are articulated to a slender plate arching round the intestinal canal, and converge toward their tips, but do not meet, although they extend to the middle of the sixth segment. Each of the organs is nearly straight and rather stout for two-thirds its length, and the terminal portion is suddenly constricted on the under side and curved outward and strongly downward to the tip. The appendages of the second segment are small and are lodged in grooves at the bases of the first pair.

Sesarma Say.

Sesarma reticulata Say.

Ocypode (*Sesarma*) *reticulatus* Say, Journal Academy Nat. Sci., Philadelphia, vol. i, p. 73, 76, pl. 4, fig. 6, 1817, and p. 442, 1818.

Sesarma reticulata Gibbes, Proceedings American Association, 3d meeting, p. 180, 1850; Edwards, Annales des Sciences naturelles, 3me série, Zoologie, tome xx, 1853, p. 182; Stimpson, Annals Lyceum Nat. Hist., New York, vol. vii, p. 66, 1859.

This species is found at New Haven, Conn., inhabiting salt-marshes and associated with *Gelasimus pugnax.*

Sex.	Length of carapax.	Breadth of carapax.	Ratio.	Breadth of front.
Male.	14·0mm	17·1mm	1 : 1·22	9·4mm
"	15·2	18·3	1 : 1·20	9·9
"	17·2	21·0	1 : 1·22	11·4
"	19·7	24·2	1 : 1·23	13·2
"	22·4	27·5	1 : 1·23	15·0
"	23·0	28·3	1 : 1·23	15·4
Female.	19·7	24·6	1 : 1·25	13·5

In this species, the first segment of the male abdomen projects laterally considerably beyond the second segment, and beyond the posterior margin of the carapax, and the third segment is as wide as the first and its lateral margins are strongly arcuate; at the fourth segment, the abdomen is suddenly contracted and the remaining portion is quite narrow and the margins are slightly concave to the sixth segment; the terminal segment is scarcely more than one half as wide as, but considerably longer than, the sixth, much longer than broad, and its extremity rounded. The appendages of the first segment extend nearly to the extremity of the sixth segment, are articulated at their bases to a slender, arched plate, much as in *Glyptograpsus impressus*, are triquetral, quite stout, nearly straight and widely separated even to their tips, which are slightly flattened and hairy. The appendages of the second segment are short and slender and are lodged in grooves at the bases of the appendages of the first segment.

Sesarma sulcata, sp. nov.

Female. The carapax is quadrilateral in outline and much broader than long. The dorsal surface is convex in both directions, but somewhat more so longitudinally than laterally, and is clothed anteriorly and along the sides with scattered fascicles of short hairs. The protogastric lobes are divided, for half their length anteriorly, into nearly equal lobules by well marked sulci, and are limited next the orbits by deep depressions which extend to the antero-lateral angle of the carapax. The median portion of the gastric region is surrounded by a broad depression and is somewhat separated from the rather broad mesogastric lobe, which extends forward, in the median sulcus between the protogastric lobes, nearly to the front. This median sulcus is broad and very deep, with precipitous sides and cuts through the whole height of the frontal crest. The branchial regions are traversed by sharp transverse plications. The front is perpendicular and low, and the inferior margin is broken by a broad excavation in the middle, where it scarcely projects beyond the epistome; above the antennulæ the edge projects, but toward the orbit slopes off again. The antero-lateral margin is armed with two stout teeth (including the angle of the orbit) and with the trace of a third. The first tooth is acute, directed forward and situated below the level of the rest of the margin, the second is prominent, acute, and projects forward partially over the deep, rounded incision which separates it from the first tooth, and the third is only indicated by a slight emargination.

The chelipeds are equal and rather small; the merus is rough externally, the angles are sharp and the anterior ones serrate; the carpus is very granulous externally; and the hand is slightly compressed, smooth externally, and the superior margin armed with a sharp crest.

The ambulatory legs are stout and much compressed, the meral segments are very broad, the breadth being equal to half the length, and rough with short transverse plications, the propodi and dactyli are hairy along the edges, and the dactyli are stout, curved and acuminate.

Length of carapax, $25{\cdot}0^{mm}$; greatest breadth of carapax, $31{\cdot}0^{mm}$; ratio of length to breadth, 1 : 1·24. Breadth of carapax between antero-lateral angles, $29{\cdot}5^{mm}$. Breadth of front, $16{\cdot}4^{mm}$; height of front, $3{\cdot}4^{mm}$.

The single specimen described was obtained at Corinto, west coast of Nicaragua, by J. A. McNeil, and is in the collection of the Peabody Academy of Science.

Sesarma cinerea Say.

Grapsus cinereus Bosc, Histoire naturelle des Crust., tome i, p. 204, pl. 5, fig. 1, 1802; Latreille, Histoire naturelle des Crust. et Insects, tome, vi, p. 72, 1803.

Grapsus (*Sesarma*) *cinereus* Say, Journal Academy Nat. Sci., Philadelphia, vol. i, p. 442, 1818 (*non Grapsus cinereus* Say, loc. cit.. p. 99, 1817).

Sesarma cinerea Edwards, Histoire naturelle des Crust., tome ii, p. 75, 1837; Annales des Sciences naturelle, 3me série, Zoologie, tome xx, 1853, p. 182; Gibbes, Proceedings American Association, 3d meeting, p. 180, 1850; Stimpson, Annals Lyceum Nat. Hist., New York, vol. vii, p. 65, 1859.

There are specimens before me collected at Egmont Key, west coast of Florida, by Col. E. Jewett; at Bluffton, South Carolina, by Dr. J. H. Mellichamp (collection Peabody Academy of Science), and at Fort Monroe, Virginia, by Dr. Kneeland.

Several specimens give the following measurements:—

Locality.	Sex.	Length of carapax.	Breadth of carapax.	Ratio.	Breadth at orbital angles.	Breadth of front.
Bluffton.	Male.	12·1mm	13·8mm	1:1·14	13·9mm	8·2mm
Ft. Monroe.	"	12·8	14·4	1:1·13	14·0	8·3
Bluffton.	"	15·2	17·4	1:1·13	17·0	10·0
Ft. Monroe.	"	16·4	18·6	1:1·13	17·8	10·8
Egmont Key.	Female.	11·0	12·8	1:1·16	12·6	7·2
"	"	12·8	15·0	1:1·17	14·5	8·7

The abdomen of the male is broadest at the third segment, the first and second are much narrower and of equal length; from the fourth to the sixth, the abdomen is broad and the lateral margins converge regularly; the terminal segment is scarcely a third as wide, but about as long, as the sixth, and very little longer than broad. The appendages are similar to the appendages of *S. reticulata*, but those of the first segment are a little shorter and much stouter.

Sesarma occidentalis, sp. nov.

A species closely allied to *S. cinerea* Say.

Male. The carapax is quadrilateral in outline and considerably broader than long. The dorsal surface is flat in the middle and posteriorly, but somewhat convex in front and along the sides. The protogastric lobes are convex and divided by slight depressions anteriorly, and the surface is rough with coarse, sharp granules arranged in very short, irregular, broken lines. The median portion of the gastric region is sparsely granulous, surrounded by a shallow sulcus, and the mesogastric lobe is very narrow and extends far forward in the well marked, median sulcus between the protogastric lobes. The branchial regions are traversed by indistinct transverse plications, and the posterior regions are punctate with indistinct, shallow puncta. The front is nearly perpendicular, quite high and slightly concave, the concave surface is irregularly and coarsely granulous, and the inferior margin is curved forward somewhat beyond the crest and its edge is nearly straight. The antero-lateral tooth is acute and projects well forward. The lateral margin is sharp, continuous, and nearly straight as seen from above.

The chelipeds are equal, short and stout; the anterior angle of the merus is sharp, dentate and raised into a thin crest at the end next the carpus; the carpus is thickly beset externally with sharp granules; the basal portion of the propodus is short, and the outer surface is evenly rounded and very granulous and the superior margin is armed with a sharp crest; and finally, the dactylus is granulous on the upper side at base.

The ambulatory legs are rather slender, the meral segments are sharply granulous above, and the propodi and dactyli are clothed with a few short, stiff hairs along the margins.

Two males give the following measurements:—

Length of carapax.	Breadth of carapax.	Ratio.	Breadth at orbital angles.	Breadth of front.	Height of front.
11·6mm	13·1mm	1:1·13	12·9mm	7·0mm	2·1mm
15·8	17·6	1:1·12	16·9	9·4	3·0

I have seen only two specimens, both males, which were collected at Acajutla, west coast of Central America, by F. H. Bradley.

Although closely allied to *S. cinerea*, it is very readily distinguished from all specimens of that species which I have seen, by the granulous anterior regions of the carapax, the coarsely granulous front, and by the crested and granulous hands. The carapax also is more convex anteriorly and along the branchial regions.

The male abdomen and its appendages are almost exactly as in *S. cinerea*, except that the last segment of the abdomen is somewhat larger in proportion.

Sesarma angustipes Dana.

United States Exploring Expedition, Crust., p. 353, pl. 22, fig. 7, 1852; Stimpson, Proceedings Academy Nat. Sci., Philadelphia, 1858, p. 106; Annals Lyceum Nat. Hist., New York, vol. vii, p. 66, 1859.

Six specimens give the following measurements:—

Locality.	Sex.	Length of carapax.	Breadth of carapax.	Ratio.	Breadth at orbital angles.	Breadth of front.
Aspinwall.	Male.	8·7mm	9·3mm	1:1·07	9·5mm	4·7mm
"	"	15·2	16·2	1:1·07	15·3	8·5
Florida.	"	17·0	18·2	1:1·07	17·0	10·2
"	"	18·9	20·2	1:1·07	18·4	10·6
"	Female.	11·2	12·0	1:1·07	11·5	6·8
"	"	16·6	18·2	1:1·10	16·8	9·5

Sesarma angusta, sp. nov.

Female. The carapax is quadrate, longer than broad and depressed. The protogastric lobes are very little convex, slightly divided anteriorly and their surfaces beset with sharp granules. The median portion of the gastric region is surrounded by a well marked sulcus, and the anterior portion of the meso-gastric lobe extends forward, almost to the line of the front, as a very narrow ridge in the deep sulcus between the protogastric lobes. The median and posterior regions are punctate with irregular, coarse punctations, and the branchial regions are slightly plicate transversely. The front is nearly perpendicular, but low and very concave, the superior crest projects almost as far forward as the inferior margin, and is divided into four equal lobules by a deep median groove and slight lateral ones, and the inferior margin is strongly reflexed, its edge sinuous, as seen from above, with a broad and shallow sinus in the middle, and a very slight one each side. The antero-lateral tooth is nearly right-angular, and projects but slightly forward. The lateral margin is straight and entire.

The chelipeds are equal and very small, the merus and carpus are sharply granulous externally, the hand is about half as long as the breadth of the front, slender, the inferior edge evenly rounded, and the superior edge more angular and sparsely granulous, but not crested, and the fingers are slender, nearly cylindrical, and very slightly toothed within.

The ambulatory legs are very long and slender, even longer than in *S. angustipes*, and the meri and propodi are rough above.

Length of carapax, from its posterior margin to superior lobes of the front, 14·1^{mm}; breadth of carapax, 13·8^{mm}; ratio, 1 : 0·98. Breadth of carapax between antero-lateral angles, 13·6^{mm}. Breadth of front, 7·2; height of front, 1·8. Length of ambulatory legs, first, 22·0; second, 28·4; third, 32·0; fourth, 25·0. Length of propodus in first pair of ambulatory legs, 5·6; second pair, 8·0; third pair, 9·0; fourth pair, 6·6.

I have seen only one specimen, a female, collected at the Pearl Islands, Bay of Panama, by F. H. Bradley.

It is readily distinguished from all the other described American species of the genus by the narrowness of the carapax, the low, perpendicular and excavated front, and the great length of the ambulatory legs.

GONOPLACIDÆ.

Prionoplax Edwards.

Prionoplax ciliatus, sp. nov.

A species similar to *P. spinicarpus* Edwards, Archives du Muséum d'Histoire naturelle, Paris, tome vii, p. 167, pl. 11, fig. 3.

Male. The carapax is very convex longitudinally, but scarcely at all transversely. The dorsal surface is thickly beset with small, tuberculiform granules, but the space between the granules is smooth and shining. The areolation is similar to that of *P. spinicarpus;* the cervical suture is indicated by a very distinct, smooth sulcus, which is sharp and deep in the longitudinal portions in the middle of the carapax; the mesogastric and the metagastric lobes are united; there are no distinct sulci between the protogastric lobes and the hepatic regions; the branchial regions are undivided and only indistinctly separated from the cardiac. The front is lamellar, very strongly deflexed and its edge divided into two prominent, rounded lobes, which, when seen in a front view, project below the inferior margins of the orbits. The antero-lateral margin is thin and is divided by deep rounded sinuses into four slightly upturned lobes or teeth, of which the anterior, the hepatic, and the epibranchial are broad and truncate and their truncated edges finely denticulated, while the posterior, or mesobranchial, is acutely pointed. The inferior lateral regions are granulous like the dorsal surface, and, along the lateral borders, are clothed with long cilia which project beyond the margins. There are also, some hairs along the lateral margins of the dorsal surface, but they are very easily removed.

The outer surface of the external maxillipeds is minutely granulous.

The chelipeds are stout and slightly unequal. The merus is triquetral and armed with a spine on the posterior angle near the distal extremity. The upper side of the carpus is flat, somewhat roughened, and armed on the middle of the inner side with a long spine. The hands are stout, slightly compressed laterally, and perfectly smooth; the upper edge is angular, but not crested, and the fingers are compressed, deflexed, somewhat incurved, coarsely and irregularly toothed within, and do not gape.

The ambulatory legs are slender and thickly hairy along the edges, especially on the dactyli, which are long, very slender, and cylindrical.

The sternum is granulous like the carapax, only more minutely. The abdomen is smooth; the first and third segments are very much wider than the second, and the penultimate is much broader than long and its lateral margins are deeply concave in outline. The appendages of the first segment are long, slender, triquetral, and nearly straight organs reaching almost to the extremity of the abdomen. The appendages of the second segment are short and inconspicuous.

I have seen only males.

Length of carapax, 15·2mm	Breadth of carapax, 22·9mm	Ratio, 1 : 1·44
" " " 15·5	" " " 23·9	" 1 : 1·47

Collected at Panama by F. H. Bradley.

This species is closely allied to *P. spinicarpus*, and it may possibly prove to be identical with the species from Panama mentioned under that name by Stimpson, Annals Lyceum Nat. Hist., New York, vol. vii, p. 59. Edwards states, however, that, in his species, the teeth of the antero-lateral margin are "aplaties et aiguës," and they are so figured on his plate, while in our species, all, except the posterior one, are broad, truncate and denticulated. The carapax in his figure is considerably broader, and the chelipeds seem to be much less robust, than in *P. ciliatus*. Moreover, there are no hairs or cilia indicated in the figure, on the carapax or the ambulatory legs, and they are not mentioned in the description.

The specimens, when received, were completely covered with ferruginous mud. Their cylindrical form is well adapted for living in holes, and this is quite probably the habit of the species, as it is of *Speocracinus*, according to Stimpson.

Euryplax Stimpson.

Euryplax nitidus Stimpson.

Annals Lyceum Nat. Hist., New York, vol. vii, p. 60, 1859.

Of this species, there is a specimen, in the Museum of Yale College, collected at Egmont Key, west coast of Florida, and there is another in the collection of the Peabody Academy labeled New Orleans, but probably from some part of the Gulf of Mexico.

Both these specimens are adult males and agree perfectly with Stimpson's description. The pit on the anterior surface of the merus is exactly alike in both chelipeds and in each specimen. The antero-lateral margins converge anteriorly so that the breadth of the carapax between the anterior angles, is very much less than between the posterior teeth. The anterior angle is obtuse, the second tooth is triangular, but blunt, and the last is slender and acutely pointed.

The male abdomen is broadest at the second segment, the sides of which extend in narrow projections quite to the coxæ of the posterior legs. The first segment is narrow and is only exposed in the broad excavation of the posterior margin of the carapax. The third segment is very broad and its sides project in acute angles, over the channel between the sixth and seventh segments of the sternum, nearly to the coxæ of the posterior legs. From the third segment, the abdomen is narrow and tapers to a very narrow terminal segment, which is two-thirds longer than broad, and obtuse at tip. The appendages of the first segment extend a little beyond the sixth segment. They are widely separated at base, strongly incurved till they meet a little way from the tips, which are again curved strongly outward. They are slender and taper to slender and acute tips, and the terminal third is shining black in color. The appendages of the second segment are situated within those of the first, are short, slender, straight, and white.

Alcoholic specimens are pale yellowish white, and the fingers white at tips.

Locality.	Sex.	Length of carapax.	Breadth of carapax.	Ratio.	Breadth of front.
Florida.	Male.	13·4mm	22·0mm	1 : 1·64	10·2mm
New Orleans?	"	14·6	24·0	1 : 1·65	10·4

Euryplax politus, sp. nov.

This species is allied to the last, but wants wholly the pits on the meral segments of the chelipeds, and the antero-lateral margins are parallel instead of converging anteriorly.

Male. The carapax is glabrous, convex longitudinally and very slightly transversely. The dorsal surface is not distinctly areolated, although the cervical suture can be traced by a slight depression. The front is nearly straight and has a distinct marginal groove upon the upper edge and is deeply notched each side at the insertion of the antennæ, as in *E. nitidus.* The antero-lateral margins are parallel, very short, and each is armed with three acute teeth. The postero-lateral margin is slightly incurved. The posterior margin is slightly concave in the middle.

The chelipeds are nearly equal, stout, smooth and glabrous. The merus is armed with a small spiniform tooth, as in *E. nitidus*, and the carpus, with a small tooth within. The hands are slightly swollen, the superior margins are quite high, but smooth and rounded, and the fingers are slender and slightly deflexed.

The ambulatory legs are smooth, nearly naked, and very slender.

The abdomen is quite similar in form to that of *E. nitidus*, and the appendages are very much as in that species, but those of the first segment are not as strongly curved at the tips, and the terminal portion is brown instead of black.

An alcoholic specimen is pale yellowish white, with the fingers brown at tip.

Sex	Length of carapax.	Breadth of carapax.	Ratio.	Breadth of front.
Male.	6·9mm	11·2mm	1 : 1·63	4·4mm

A single specimen was collected at Panama by F. H. Bradley.

This species agrees perfectly with all the characters assigned to the genus *Euryplax* by Stimpson, except in wanting wholly the pit on the front side of the merus of the chelipeds. This character might, perhaps, be considered generic, but, in the absence of any knowledge in regard to its functional importance, it seems best to refer this species to *Euryplax*, and especially, since it agrees so closely in most of its specific characters with the type of that genus.

Glyptoplax, gen. nov.

The carapax is cancroid in form and similar to *Eucratopsis*.* The dorsal surface is deeply areolated, the front is prominent and nearly horizontal, and the antero-lateral margin is dentate and about as long as the postero-lateral.

The basis of the antenna is long and joins a slight process from the side of the front.

The epistome is much as in *Panopeus*. There is a sharp carina on each side of the palate, along the efferent canal, but it is interrupted a little way from the border of the epistome.

The external maxillipeds are approximated along their inner margins. The ischium is longer than broad, and its anterior extremity projects farther forward on the inside than the outside. The merus is somewhat triangular, the antero-lateral angle is very prominent, the anterior margin is very short and nearly parallel with the inner margin, which slopes off rapidly toward the antero-lateral angle. The palpus is endarthroid.

The chelipeds are short, but the hands are very stout. The ambulatory legs are slender and smooth.

The seventh segment of the male sternum is exposed on each of the abdomen. The verges pass from the coxæ of the posterior legs to the abdomen, through canals beneath the sternum. The sides of the first segment of the abdomen extend in triangular projections to the coxæ of the posterior legs; the second segment is much narrower than either the first or the third; the sides of the third segment do not reach the margins of the sternum; and the third, fourth, and fifth segments are anchylosed.

This genus is allied to *Eucratopsis*, but differs very much from it in the form of the external maxillipeds, in the more prominent and horizontal front, and in the longer antero-lateral margins of the carapax. From *Speocarcinus* Stimpson (Annals Lyceum Nat. Hist., New York,

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* *Eucrate* Dana. See these Transactions, vol. ii, p. 35.

vol. vii, p. 58), it differs in the approximation of the external maxillipeds and in the form of the carapax.

Glyptoplax pugnax, sp. nov.

Male. The dorsal surface of the carapax is slightly convex longitudinally, but not at all transversely, and is thickly granulous. The mesogastric lobe is not distinct from the metagastric, but is well separated from the protogastric, and its anterior portion is narrow and extends well forward. The protogastric lobes are prominent and undivided, and are not distinctly separated from the epigastric, which are very slight elevations separated by a marked median sulcus. The hepatic region is prominent, undivided, and separated from the gastric and branchial regions by deep sulci. The mesobranchial and metabranchial lobes are separated by a very slight sulcus, and the anterior portion of the branchial region is divided into three lobules,—one at the base of the epibranchial tooth, a larger one just within this, and a small, indistinct one next the gastro-cardiac sulcus. The front is thin and horizontal, its edge is slightly convex, as seen from above, and divided by a very slight notch in the middle. At each side of the front, there is a deep antennal notch, above which, the inner angle of the superior orbital border projects as a prominent tooth. The superior margin of the orbit is divided by two deep notches. The antero-lateral margins are arcuate. The outer angle of the orbit projects only slightly beyond the second tooth and is separated from it by a slight sinus. The remaining portion of the margin is divided into three, prominent, triangular teeth, of which the middle one, or epibranchial, is most prominent.

The ocular peduncles are armed with a granulous tubercle on the anterior side near the cornea.

The chelipeds are slightly unequal and the hands are very large. The merus does not project beyond the lateral margin of the carapax. The carpus is short and the outer surface is granulous, has a slight groove along the margin next the propodus, a tooth upon the inner margin, and a small tubercle near the articulation of the propodus. The hand is compressed, very broad, and nearly smooth. The basal portion of the propodus is slightly convex on both sides, the lower edge is rounded, and the upper edge is slightly crested; the digital portion is very broad at base and very much deflexed, so that the prehensile edge is parallel with the margin at the base of the dactylus, the inferior edge is slightly margined on the outside, and the tip is slender and upturned. The dactylus is long and slender, the upper edge is slightly crested and the tip is hooked by the tip of the propodus. The prehensile edges of both fingers are sharp, very slightly dentate, and do not gape, or only very slightly.

The ambulatory legs are slender and minutely granulous; the propodi are slightly hairy on the posterior edges; and the dactyli are slender, slightly compressed, those of the posterior pair considerably shorter than the others, and all clothed with very short hair.

The sternum is minutely granulous. The terminal segment of the abdomen is about as broad as long, and the extremity is obtusely rounded. The appendages of the first abdominal segment are long, slender, nearly straight, and reach to the terminal segment. The appendages of the second segment are short and very small.

The females differ from the males in being more convex and in the front being less prominent and very slightly deflexed. The young males approach the females in these characters.

The fingers are black in both sexes.

No.	Sex.	Length of carapax.	Breadth of carapax.	Ratio.	Breadth of front.
1.	Male.	4·8mm	6·4mm	1 : 1·33	2·6mm
2.	"	5·7	7·8	1 : 1·37	2·8
3.	"	6·0	8·3	1 : 1·36	3·0
4.	"	6·8	9·4	1 : 1·38	3·5
5.	"	7·7	11·0	1 : 1·43	3·7
6.	"	8·6	12·1	1 : 1·41	4 1
7.	Female.	4·4	6·1	1 : 1·39	2·3
8.	"	4·8	6·7	1 : 1·40	2·6
9.	"	5·1	7·2	1 : 1·41	2·7

The chelipeds of numbers 2, 4, 6, and 9, give the following measurements:—

	Length of hand.		Breadth of hand.		Length of dactylus.	
No.	Right.	Left.	Right.	Left.	Right.	Left.
2.	6·7mm	6·2mm	4·7mm	3·8mm	5·1mm	4·6mm
4.	7·2	8·4	4·2	5·0	5·3	6·0
6.	10·2	11·0	5·8	6·2	8·0	8·4
9.	5 0	5·1	2·6	3·0	3·1	3·2

Collected at Panama by F. H. Bradley.

Family, PINNOTHERIDÆ.

Pinnotheres Latreille.

Pinnotheres margarita Smith.

I. Verrill, American Naturalist, vol. iii, p. 245, July, 1869.

This is a stout, thick species, with a firm integument, and every where covered, except the dactylus of the right ambulatory leg of the second pair in the female, and the tips of the others in both sexes, with a very short and close, clay-colored pubescence, looking much like a uniform coating of mud.

Female. The carapax is very strongly convex in all directions and the dorsal surface, beneath the pubescence, is smooth and shining. The cardiac region is protuberant and is separated from the gastric region by a conspicuous sulcus, and from the branchial regions, by very marked and deep depressions, which extend along the cervical suture to the hepatic region. The branchial regions are protuberant along their inner sides. The front is not protuberant, is strongly deflexed, and has a slight median depression.

The external maxillipeds are more longitudinal and of a firmer consistency than is usual in the genus. The merus is short and broad, and the inner margin is angulated in the middle, the portion toward the base fitting the anterior margin of the sternum and the distal portion being slightly concave and fitting closely the terminal segments of the palpus. The second segment of the palpus is large, broadest in the middle at the attachment of the terminal segment, and the outer surface is flattened. The terminal segment is slightly spatulate in form and reaches almost to the tip of the second segment.

The chelipeds are equal and very stout and the hands are long and nearly cylindrical. The fingers are somewhat cylindrical, nearly straight almost to the tips, which are hooked by one another, and the prehensile edge of the dactylus is armed, near the base, with a small tooth, which fits a slight excavation in the propodal finger.

The ambulatory legs are stout and all the ischial segments, and the posterior margins of the propodi and dactyli in the last pair, are clothed with a long, woolly pubescence. The dactyli in the three anterior pairs are short, curved, and pubescent nearly to the tips, except in the right leg of the second pair, where the propodus is considerably longer than in the corresponding leg on the other side, and the dactylus very long, almost straight, and entirely naked. In the posterior legs, the dactyli are long, straight, slender, and pubescent.

The anterior margin of the sternum is excavated into a broad, rounded sinus for the reception of the tips of the palpi of the external maxillipeds.

The abdomen is orbicular and completely covers the sternum.

Male. The only male which I have seen is much smaller than the females, and is not so thickly pubescent. The cardiac and branchial regions are less protuberant and are separated from the gastric by a slight depression only. The front projects slightly and is not so much deflexed as in the female.

The chelipeds and ambulatory legs are like those of the female, except that the ambulatory legs of the right side are like those of the left.

The abdomen is broadest at the third segment, from the third to the sixth, the margins are straight and converging, the sixth is abruptly contracted, and the terminal segment is nearly square. The appendages of the first segment are rather stout organs, somewhat hairy along the margins, and reach to the terminal segment. They curve inward for about two-thirds of their length and then outward again to the tips. The appendages of the second segment are short and are lodged in grooves at the bases of the first pair of appendages.

Locality.	Sex.	Length of carapax.	Breadth of carapax.	Ratio.
Pearl Islands.	Male.	5 5mm	6·1mm	1 : 1·11
La Paz.	Female.	8·1	8·9	1 : 1·10
Pearl Islands.	'	8·8	9·7	1 : 1·10
"	"	10·0	11·0	1 : 1·10
"	"	10·3	11·4	1 : 1·11
"	"	10·9	12 0	1 : 1·10
"	"	11·8	13·4	1 : 1·14

This species was found living in the Pearl Oyster (*Margaritophora fimbriata* Dunker), at the Pearl Islands, Bay of Panama, by F. H. Bradley. It has also been sent from La Paz, Lower California, by Capt. J. Pedersen.

A sterile female *Pinnotheres*, found in an alcoholic specimen of the Pearl Oyster collected at the Pearl Islands by Mr. Bradley, probably belongs to this species. It agrees closely with specimens of *P. margarita*, described above, in the form of the external maxillipeds and the firm integument.

The carapax is more like the male than the ordinary female, but is narrower and more depressed. The front is more prominent and scarcely at all deflexed. The dorsal surface is very slightly areolated, quite flat, and is clothed, except the cardiac region and a small space in the middle of the gastric, with a very dark, almost black, velvety pubescence.

A single cheliped is stouter in proportion than in the ordinary male and female, and the pubescence upon the upper surface of the carpus and a small space at the base of the hand, is black as on the dorsal surface of the carapax.

The ambulatory legs are less pubescent than in the male, while the propodus and dactylus of the right leg of the second pair are longer than in the corresponding leg of the left side, but are not as long as in the female.

The abdomen is not broader than in the male, but the margins are slightly convex, it is not contracted at the sixth segment, and the extremity is rounded.

Length of carapax, $5 \cdot 1^{mm}$; breadth of carapax, $5 \cdot 3^{mm}$; ratio, 1 : 1·04.

Pinnotheres Lithodomi, sp. nov.

Female. The carapax, in the single specimen examined, is much crushed out of shape, but the dorsal surface is smooth and naked.

The merus of the external maxilliped is broadest at the distal extremity, and both margins are nearly straight.

The chelipeds are equal, smooth, and naked. The hands are cylindrical, and the fingers are short, nearly straight, the tips are slightly hooked by each other, and the prehensile edge of the dactylus is armed, near the base, with a small tooth, which fits a slight excavation in the propodal finger.

The ambulatory legs are very slender and wholly naked, except the dactyli. In the first pair, the dactyli are very short and only slightly curved; in the second, they are considerably longer than in the first, and nearly straight; in the third, they are very long, being nearly as long as the propodi, slender, and slightly curved; and in the posterior pair, they are about as long as in the second and are ciliated along the posterior edges.

Breadth of carapax, about, 4^{mm}.

The only specimen seen, was found in a specimen of *Lithodomus aristatus* Forbes and Hanley which was in its excavation in the shell of a *Spondylus* collected at the Pearl Islands by F. H. Bradley. Although the specimen is very small, it has a large number of eggs beneath the abdomen.

Ostracotheres Edwards.

Ostracotheres politus, sp. nov.

Female. The carapax is depressed, naked, smooth, and shining. The dorsal surface is flat and the borders are smoothly rounded. There is a short median sulcus on the front, and a very slight U-shaped one extending from the orbits to the middle of the carapax. The front does not project beyond the anterior margins.

The external maxillipeds are smooth and almost entirely naked, and, in form, are considerably like the figure of *O. affinis* given by Edwards (Annales des Sciences naturelles, 3^{me} série, Zoologie, tome xx, 1853, pl. 11, fig. 11), but the merus is wider at the distal end and the outer margin is not so arcuate.

The chelipeds are equal and all the segments are rounded, smooth, and glabrous. The hands are small and much compressed. The fingers are shorter than the basal portion of the propodus, do not gape, and the dactylus is slightly curved and is armed, near the base, with a small tooth, which fits a slight excavation in the propodal finger.

The ambulatory legs are short, slender, cylindrical, and smooth. Those of the first pair are shorter than those of the second, and the dactyli, in both the first and second pairs, are very short and curved, and close against the expanded end of the propodus, which is clothed at that point with a little tuft of short, stiff hair. Those of the third pair are about the length of those of the second pair, and the dactyli are short and curved, but the distal ends of the propodi are not expanded for their reception. The posterior legs are shorter than those of the second or third pair, are much more slender than any of the others, and the dactyli are only slightly curved and are very long and slender, their length being about equal to that of the propodi.

The abdomen is very broad and covers the whole sternum.

Length of carapax,	$5{\cdot}4^{mm}$; breadth of carapax,	$7{\cdot}3^{mm}$; ratio,	1 : 1·35
" " "	6·3 " " "	8·3 "	1 : 1·32
" " "	6·4 " " "	8·5 "	1 : 1·33

Collected at Callao, Peru, by F. H. Bradley.

The integument is quite thin and yielding, and the species undoubtedly lives protected within some bivalve mollusk (probably *Mytilus algosus* Gould). It appears to differ remarkably from the other species of the genus in the depressed carapax and naked ambulatory legs, and I refer it to Edwards' genus with some doubt, although it agrees in the two-jointed palpus of the external maxillipeds.

The other described species of *Ostracotheres* are:—*O. Savignyi* Edwards (*Pinnotheres veterum* Savigny), from the Red Sea; *O. Tridacnæ* Edwards (Ruppell), also from the Red Sea; and *O. affinis* Edwards, from the Isle of France.

Pinnaxodes Heller.

Pinnaxodes Chilensis Smith.

Pinnotheres Chilensis Edwards, Histoire naturelle des Crust., tome ii, p. 33, 1837; Edwards et Lucas, Voyage de d'Orbigny dans l'Amérique méridionale, Crust., p. 23, pl. 10, fig. 2, 1843.

Fabia Chilensis Dana, United States Exploring Expedition, Crust., p. 383, 1852.

Pinnaxodes hirtipes Heller, Reise der österreichischen Fregatte Novara um die Erde, p. 68, pl. 6, fig. 2, 1865.

Pinnaxodes Chilensis Smith, in Verrill, American Naturalist, vol. iii, p. 245, 1869.

The parasitic habits of this species have been fully described by Prof. Verrill.* It inhabits *Euryechinus imbecillis* Verrill, living in a sac formed by the distention of the intestine near the anal orifice. The females, after they have arrived at any considerable size, must remain permanently within the same echinus, since the anal orifice is much smaller than the body of the crab.

I have examined quite a number of individuals obtained from specimens of the *Euryechinus* collected by Mr. Bradley at Paita and Callao, Peru, and by Prof. James Orton at Paita, and have little doubt that the species figured by Edwards and Lucas and by Heller are identical, although the figures given by these authors are quite different. The specimens before me agree very well with the figure in the work of Edwards and Lucas, except that the outer margin of the carpus of the external maxillipeds is not quite so much curved toward the distal extremity as in the figure. On account of the soft and yielding nature of the carapax, many of the specimens do not show distinctly the sulci in the dorsal surface. The figure given by Heller seems to have been drawn from such a specimen, for no sulci are represented. The carpus in the figure of the external maxilliped in Heller's work, is quite different from Edwards' and Lucas' figure; but the figure of the latter authors represents the whole maxilliped removed from the rest of the animal, while Heller's figure represents only the exposed portion, and was evidently drawn from the maxilliped while in place, and, if the carpus were seen in a slightly oblique position, it would account for its narrower form in his figure. The dactyli of the ambulatory legs, as represented in Heller's figure, are somewhat longer than in our specimens.

The peculiar habit is also a confirmation of the identity of the species. Heller's specimens were from Ecuador, and he says of them:—"Diese in zwei weiblichen Examplaren vorliegende Art soll nach Dr. Scherzer in einer Echinus-Art vorkommen." Neither Edwards nor Edwards and Lucas give anything in regard to the habits of the species, but merely state that it was found at Valparaiso. Dana, however, mentions it as "from an Echinus on the coast of Chili, near Valparaiso."

A single specimen of a male, which evidently belongs to this species, was found upon the outside of an echinus which contained within it a female. This male is very small, the carapax is rather narrower

* These Transactions, vol. i, p. 306, American Journal of Science, 2d series, vol. xliv, p. 126, 1867, and American Naturalist, vol. iii, p. 245, 1869.

than in the female, the chelipeds are stouter in proportion, and the ambulatory legs are somewhat less hairy. The carapax is of the same weak consistency, and the external maxillipeds of the same form, as in the female. The abdomen is quite narrow and all the segments are distinct. The margins are very straight to the sixth segment, which is slightly contracted, and the extremity is broadly rounded.

A number of specimens give the following measurements, which are only approximately correct, on account of the soft and flexible nature of the carapax.

Locality.	Sex.	Length of carapax.	Breadth of carapax.	Ratio.
Callao.	Male.	2·6mm	2·5mm	1 : 0·96
Paita.	Female.	7·2	7·8	1 : 1·08
Callao.	"	9·0	9·2	1 : 1·02
Paita.	"	12·2	12·7	1 : 1·04

The genus *Pinnaxodes* is quite distinct from the typical species of *Fabia* Dana, in the form of the external maxillipeds, which are nearly longitudinal and much as in *Pinnixa*, with which, in fact, Heller compares them, while in *Fabia subquadrata*, they are oblique and resemble those of *Pinnotheres*. The carapax also is quite different in form, and in *Fabia*, the sulci which extend back from the orbits are very deep and there is no median sulcus on the front, while in *Pinnaxodes*, the sulci from the orbits are very slight, not more distinct than the median.

Family, Dissodactylidæ.

This family, which is here established for the following genus, appears to be most nearly allied to the *Pinnotheridæ*, but differs from that family, and in fact from all other Ocypodoidea, in the structure of the palate, or endostome, which is not divided by a median ridge separating the efferent passages.

Dissodactylus,* gen. nov.

The carapax is depressed, the dorsal surface is smooth and not areolated, and the front is narrow and horizontal.

The eyes are very minute, being much smaller even than in the *Pinnotheridæ*.

The epistome is very short, so that the labial border approaches very near to the front, leaving only a narrow space which is nearly filled by the antennulæ. The labial border is regularly concave, as seen in a front view, is not interrupted in the middle by any projec-

* *Δισσὸς, duplex; δάκτυλος, digitus.*

tion or emargination, and is continuous with the lateral margin of the buccal area, which is broad behind as in the *Pinnotheridæ.* The palate is not divided longitudinally either by lateral ridges or even by a median one, so that the efferent passages are not distinctly separated at their external orifices.

In the external maxillipeds, the ischium is coalescent with the merus as in the *Pinnotheridæ*, and the palpus is composed of only two segments, of which the terminal one is large and spatulate.

The chelipeds are small and equal and the hands short and rounded.

The ambulatory legs are small and slender and the dactyli in the three anterior pairs are short and deeply bifurcate, while those of the posterior pair are simple and slender.

In the male, the sternum is flat and very broad, the breadth between the posterior legs being much more than twice as great as the breadth of the basal segments of the abdomen.

The male abdomen is narrow and only three-jointed, the first and second segments anchylosing into one piece, the third, fourth, fifth, and sixth into another, and the terminal being free. The verges are sternal and the appendages of the first segment are large and stout, while those of the second segment are very small.

Dissodactylus nitidus, sp. nov.

Male. The carapax is broad posteriorly, the breadth at the posterior margin being but little less than that between the lateral angles, and the postero-lateral margins are about as long as the antero-lateral. The dorsal surface is naked and polished, and is slightly convex in front and along the lateral margins, but flat in the middle and posteriorly. The antero-lateral border is slightly arcuate and is armed with an upturned margin which curves suddenly inward at the lateral angle, and extends a third of the way to the middle of the carapax. The postero-lateral border is nearly straight and is armed with a slight upturned margin.

The merus in the external maxillipeds is of about equal width at base and summit, the inner and outer margins are nearly straight, and the angles at the summit are rounded. The segments of the palpus are quite long, and, when folded down, the tip reaches to the anterior margin of the sternum; the terminal segment is spatulate and its distal end quite broad and squarely truncated.

In the chelipeds, the merus extends but little beyond the margin of the carapax; the carpus is short, smooth, and unarmed; the hands are smooth, rounded, somewhat swollen, and the fingers are slender, acutely pointed, slightly deflexed, and the prehensile edges minutely dentate. There is a small tuft of dense pubescence on the inferior edge of the propodal finger near the base.

The ambulatory legs are slightly hairy along the edges, and the meri, carpi, and propodi are somewhat compressed. In the first, second, and third pairs, the dactyli are smooth, naked, and divided halfway to the base; the divisions are cylindrical, acutely pointed, slightly curved, and the anterior one of each leg somewhat longer than the other. In the posterior pair, the dactyli are nearly straight, slightly compressed, sulcate above and below, and naked.

The first and second segments of the abdomen are narrower than the third and are completely anchylosed, but the suture which separates them is slightly shown for a little space in the middle and each side. The succeeding piece, composed of the third, fourth, fifth, and sixth normal segments, is slightly expanded at base, considerably contracted at the distal end, and does not show the slightest trace of any sutures. The terminal segment is small and forms a nearly equilateral triangle.

The appendages of the first segment reach almost to the terminal segment, they are straight for the basal two-thirds, and the terminal portion is turned sharply outward at an obtuse angle. The basal portion is hairy along the outer edge, and the terminal portion, on both edges.

The color, in alcohol, is dirty white, the carapax marked with irregular, transverse bands of purplish brown, and the divisions of the dactyli in the first and third pairs of ambulatory legs tipped with dark brown.

Length of carapax, $4{\cdot}7^{mm}$; breadth of carapax, $5{\cdot}1^{mm}$; ratio of length to breadth, 1 : 1·08.

Collected at Panama by F. H. Bradley.

Unfortunately only a single specimen was sent home by Mr. Bradley, and on this account, as well as from the minuteness of the species, the description is not so complete as might be wished. Although so small, the integument is firm and indurated, and the sexual organs are fully developed, so that it is evidently an adult. The structure of the endostome shows a very remarkable approach to the Oxystomata. The efferent canals do not, however, issue in a deep and narrow median opening as in that group, but seem to be spread out over the whole, broad, concave surface of the endostome, while the external maxillipeds retain the form peculiar to the Pinnotheridæ. The form of the carapax, the minute eyes, the peculiar, Ostracotheres-like, external maxillipeds, the broad male sternum with the verges arising from it, and the narrow male abdomen, show close affinity with the Pinnotheridæ, but the union of so many segments of the male abdomen separates it again from that family.

EXPLANATION OF PLATES.

Plate II.

All the figures are natural size, except 2, 11, and 11a, and all are copied from photographs, except 6a.

Figure 1.—*Gelasimus pugnax.* Carapax of a male, from New Haven.

Figure 2.—*G. rapax.* Anterior portion of the carapax of the male, seen partly in a front view and enlarged two diameters.

Figure 3.—*G. mordax.* Carapax of a male, from Pará.

Figure 4.—*G. minax.* Carapax of a male, from New Haven.

Figure 5.—*G. armatus.* Carapax of the male, from the Gulf of Fonseca.

Figure 6—*G. heterophthalmus.* 6, carapax of a male, from the Gulf of Fonseca. 6a, terminal portion of the ocular peduncle, on the side of the larger cheliped, with its stylet, seen in a front view.

Figure 7.—*G. heteropleurus.* Carapax of a male, from the Gulf of Fonseca.

Figure 8.—*G. princeps.* Carapax of a female, from Corinto.

Figure 9.—*G. ornatus.* 9, carapax of the female. 9a, facial region of the same specimen.

Figure 10.—*G. princeps.* Carapax of a male, from Corinto.

Figure 11.—*G. gibbosus.* 11, carapax of the male, enlarged two diameters. 11a, outline of the front of the same specimen, enlarged two diameters.

Plate III.

All the figures are natural size, and all from photographs, except 4d, 5, and 5b.

Figure 1.—*Gelasimus heterophthalmus.* 1, outer surface of the hand of the larger cheliped. 1a, inner surface of the hand of another specimen. 1b, anterior surface of the merus of the same cheliped as figure 1.

Figure 2.—*G. heteropleurus.* 2, outer surface of the hand of the larger cheliped. 2a, inner surface of the hand of another specimen. 2b, anterior surface of the merus of same cheliped as figure 2a.

Figure 3.—*G. princeps.* 3, outer surface of the hand of the larger cheliped. 3a, basal portion of the inner surface of the hand of another specimen. 3b, anterior surface of the merus of the same cheliped as figure 3a. 3c, external maxilliped.

Figure 4.—*G. armatus.* 4, outer surface of the hand of the larger cheliped. 4a, anterior surface of the merus of the same cheliped. 4b, 4c, 4d, ambulatory legs of the posterior, of the third, and of the second pair in the same specimen.

Figure 5.—*G. ornatus.* 5, outer surface of the hand of the female. 5a, 5b, 5c, ambulatory legs of the posterior, of the third, and of the second pair in the same specimen.

PLATE IV.

All the figures are natural size, and all from photographs, except 2d, 6b, 7a, 8a, and 9

Figure 1.—*Gelasimus minax.* 1, inner surface of the hand of the larger cheliped of a male, from Bluffton, S. C. 1a, anterior surface of the merus of the same cheliped. 1b, outer surface of the hand of the larger cheliped of a male, from New Haven, (from the same specimen as figure 4 on plate II).

Figure 2.—*G. pugnax.* 2, inner surface of the hand of the larger cheliped of a male. 2a and 2b, outer surface of the hand of the larger cheliped in two males. 2c, anterior surface of the merus of the larger cheliped of a male. 2d, abdomen of a male. All the specimens from New Haven.

Figure 3.—*G. rapax.* Inner surface of the hand of the larger cheliped of the male.

Figure 4.—*G. mordax.* 4, inner surface of the hand of the larger cheliped of a male. 4a, outer surface of the hand of the larger cheliped of a young male. Both specimens from Pará.

Figure 5.—*G. Panamensis.* 5, inner surface of the hand of the larger cheliped of a male, from Panama. 5a, anterior surface of the merus of the same specimen.

Figure 6.—*G. subcylindricus.* 6, outer surface of the hand of the larger cheliped of a male, from Matamoras. 6a, inner surface of the basal portion of the same hand. 6b, abdomen of the same specimen.

Figure 7.—*G. pugilator.* 7, outer surface of the hand of the larger cheliped of a male. 7a, abdomen of a male. Both specimens from New Haven.

Figure 8.—*G. gibbosus.* 8, outer surface of the hand of the larger cheliped of the male from the Gulf of Fonseca. 8a, abdomen of the same specimen.

Figure 9.—*G. princeps.* Abdomen of a male from Corinto.

PLATE V.

All the figures are natural size. Figures 1, 1a, 2, and 2a are copied from photographs, all the others from drawings.

Figure 1.—*Opisthocera Gilmanii.* 1, dorsal view of the whole animal. 1a, facial region. 1b, abdomen. 1c, one of the first pair of abdominal appendages. 1d, one of the second pair of abdominal appendages. All the figures from the male collected at the Isle of Pines.

Figure 2.—*Epilobocera armata.* 2, facial region of one of the female specimens in the collection of the Boston Society of Natural History. 2a, outline of the antero-lateral margin of the carapax of the same specimen. 2b, external maxilliped.

Figure 3.—*Cardiosoma guanhumi.* 3, one of the appendages of the first segment of the abdomen of a male, from the Florida Keys. 3a, side view of the same.

Figure 4.—*Cardiosoma quadratum.* 4, one of the appendages of the first segment of the abdomen of a male, from Pernambuco, Brazil. 4a, side view of the same.

Figure 5.—*Cardiosoma crassum.* 5, one of the appendages of the first segment of the abdomen of a male, from the Gulf of Fonseca. 5a, side view of the same.

IV.—On some alleged specimens of Indian Onomatopœia. By J. Hammond Trumbull.

Professor D. Wilson, in "*Prehistoric Man*" (2d ed., p. 63), has remarked, that "primitives originating directly from the observation "of natural sounds are not uncommon among the native root-words "of the New World." In proof of this, or as "specimens of Indian onomatopœia," he has given twenty-six names of animals, which he had "noted down chiefly from the lips of Indians speaking the closely allied Chippewa, Odahwa and Mississaga dialects of the Algonquin tongue."

Such evidence, introduced on so respectable authority, is of sufficient importance to invite scrutiny. Its importance was evidently not underrated by Prof. Wilson himself, for he tells us that, in "the "names of animals clearly traceable to imitation,"—"this nearest ap-"proximation to verbal creation,"—is to be found that which "car-"ries us back to the very foundation of language, and helps to solve "one of the profoundest problems in philology." (*Ib.*, p. 55).

The position that onomatopœic primitives are *not uncommon* in North American languages, will be generally conceded,—even by "those who share Prof. Wilson's conviction that "the onomatopœic "theory will neither account for the origin of language, nor supply a "complete series of roots *for any portion of the vocabulary*." (p. 56). So far, then, as these selected specimens serve to establish *that* position, it matters little whether they are well or ill chosen. But so serviceable a collection is not likely to escape the notice of those who maintain, with more zeal and less discretion than the author of *Prehistoric Man*, the *universality* of the imitative principle in language. Several of Prof. Wilson's examples have already been appropriated by a well-known writer (the Rev. F. W. Farrar, in his *Chapters on Language*, pp. 24, 25,) to sustain the position, that, in the vocabulary of almost every savage nation, "*almost every name for an animal is a striking and obvious onomatopœia*."* To this sweeping generalization, I shall have a word or two to say, presently. First, however, I propose to examine some of Prof. Wilson's specimens, for the pur-

* This assertion is quoted by Mr. Wedgwood in his volume "On the Origin of Language," (p. 29).

pose of estimating the value of the whole collection, as evidence of the predominance of the onomatopœic element in the vocabulary of the North American languages.

These languages, it must be premised, have—even in their principal dialects—been so superficially studied and are so imperfectly known, that it is not always possible to trace derivatives to primitives, even when the fact of derivation is obvious,—or to prove the negative against every assumed onomatopœia, by exhibiting the true etymology. Of some of the names under consideration, I can say no more than that their onomatopœic origin is not, *primâ facie*, apparent, and that they are quite as *likely* to be proved holophrastic or descriptive, as mimetic. Of others, I can more positively affirm that they have not the least claim to inclusion with specimens of onomatopœia.

Take first, the name "*koo-koosh*, the sow." This is specially noticed by Dr. Wilson (p. 62) as "purely onomatopœic." It is, in fact, one of a considerable group of derivatives from a well-defined Algonkin root. When the hog was introduced by European colonists, the Algonkin tribes of the Atlantic coast adopted its English name,—modified by the characteristic affixes of the Indian animate-nouns. In Eliot's translation of the Bible in the language of Massachusetts, 'swine' is rendered by *pigs* for the singular, *pigs-og* for the plural. Roger Williams, in the Narragansett, wrote, sing. *hogs*, and *pigs;* pl. *hógs-uck*, *pígs-uck;* Rasles, for the Abnaki, *píkess*, pl. *píks-ak*. Sometimes, however, the Indians transferred to this (as to other newly introduced species) the name of some animal previously known, which the new-comer was thought most nearly to resemble, or they compounded a new name which denoted such a resemblance. The Narragansetts occasionally called swine by the name of the Woodchuck or Ground Hog, *Ockqutchaun*,—which R. Williams describes as "about the bigness of a pig and *rooting like a pig*." (*Indian Key*, ch. xvii.) This name signifies 'burrower' or 'digger.' Similarly, the Shyennes—an off-shoot of the Algonkin stock—call the pig, the 'sharp-nosed dog' (*e kú si sí o tum*), and the domestic cat 'the short-nosed dog' (*ka e sí o tum*).

Koo-koosh is a Chippewa form of a descriptive name which was perhaps first used by the Delawares or Nanticokes. It is found (as *kws kus*) in the vocabulary of New Sweden compiled by Campanius before 1696. The root, *kô* or *koo*, has its place in nearly all Algonkin languages. It signifies 'sharp-pointed.' Hence, in the Massachusetts as written by Eliot, *kô-us*, 'a thorn, or briar;' *kô-uhquodt*, 'an arrow' [*lit.* 'sharp-tipped,' or 'sharp at the end,'] and *kô wa* (Narr. *có waw;* Del. *cu we*), 'a pine tree,' named, as in other languages, from its pin-like leaves. Hence too, the Algonkin name of the only native animal which has a pin-like or bristly covering,—the *porcupine.* [Abn. *kansis*, 'thorn,' 'spine;' *kansiak*, a porcupine's skin, lit. 'pin skin;' Cree, *kawk'wă*, porcupine; Chippewa, *kaugk;* Blackfoot, *kaí ska.*] In nearly all dialects, the affix *'sh* (strongly aspirated) denotes aversion or depreciation. For example, in the Chippewa, *chimaun* means 'a canoe;' *chimaunish*, 'a *bad* or worthless canoe;' *kaugk*, 'a porcupine,' and *kaugk-ŏsh* [*gag-osh*, Baraga,] 'a bad porcupine.' This name is etymologically identical with '*koo koosh*,' a hog,—and the latter, so far from being a true specimen of onomatopœia, is seen to be built up, from its monosyllabic primitive, to describe "a bad animal with a bristly (or, pin-like) skin."

Only one other name of a quadruped appears in Dr. Wilson's list: "*Pe-zhew* or *Bi-zhew*, the Lynx or Wild Cat." The Indians of Massachusetts called the domestic Cat *poopohs*,* and Dr. Pickering† thought that this name might have been "formed from the English *poor puss.*" But Roger Williams gives *pussóugh* as the Narragansett name of the Wild Cat, and Rasles's Abnaki Dictionary has *pesouis* for 'Chat,'—which, again, Dr. Pickering thought might be a corruption of "the familiar English *puss* or *pussy.*" Without accepting this derivation, it seems plain enough, at least, that the Narr. *pussóugh* and Abnaki *pesouis* are equivalents of the modern Chippewa *pe shoe* or *pe zhew*, 'the Wild Cat,' and of the Menomenee *pay shay ew.* The Chippewa name of the Panther is *mis'si-pe zhew*, 'great *pezhew*' or 'great Cat.' It is not impossible, certainly,—but it is hardly probable, that a name which appears in so many forms and which has been given to the domestic Cat, to the Lynx, and to the Panther, originated by imitation of the cry of one or another of these animals. Those who maintain the universality of onomatopœia, are entitled to the benefit of the doubt.

Of the twenty-six specimens presented, nineteen (or nearly three-fourths) are names of *birds.* Four or five of these are *apparently* mimetic; six or seven are *possibly* so; and nearly all the rest are demonstrably derivative, and independently significant. As might have been anticipated, the names of Owls and of the Crow are among those which are least doubtfully onomatopœic. The Chippewa *ko-ko'-ko-o* (Mass. *kook kook haus;* Narr. *ko ko' ke hom;* Mohawk, *o-ho-ho-wah;* Onondaga, *ke kô a;*) represents very nearly the call of the Cat

* Cotton's Vocabulary, 3 Mass. Hist. Coll., ii. 156.

† In note to Rasles' Abnaki Dictionary, s. v. *Chat.*

Owl (*Stryx Virginiana*). "*Kah kah be' sha*, the Screech Owl" ought not however to be separately counted as an 'onomatopœic primitive,' for it is merely the diminutive of the name which Dr. Wilson writes "*gah kau ban*,* a small owl which repeats the cry *gah kau*,"—perhaps the Long-eared Owl (*S. otus*). So also, "*Oo-oo-me-see*," another 'screech owl,' is a regularly formed diminutive,—'the little *Oo-oo*,'—denoting probably the Gray Screech Owl (*S. nævia*).

"*Aund a gosh' kwan*, the crow" and "*Gah gau ge' shin*, the raven," are both derivatives, in the dialect of the Saginaw Chippewas, from the primitives *ahn daig* and *ka gâ gi*. The former is *perhaps* onomatopœic; the latter, obviously so.

"*Tchin dees*, the blue jay," and "*Dend dai*, the bull-frog," are counted as two specimens. The former (in Chippewa proper, *dain da' see* or *tĭn dē sē*), is a diminutive of the latter; and the jay is the "bull-frog bird." So, of the two names of 'the gull,' one '*gah yaush ko shan*' is a derivative of the other, *gai ashk* (or, as Dr. Wilson writes it, *kuh yaushk*), the more common Chippewa form, which may or may not be onomatopœic.

The first specimen in the list (and the first which is borrowed by Mr. Farrar,) is

"*Shi sheeb*, the duck." In the Massachusetts language, Cotton wrote this name '*se sep*.' It has the same sound in the Cree, '*see' seep*.' In Chippewa, both sibilants are aspirated, '*shee sheeb*' or, as Dr. Wilson has it, '*shi sheeb*.' The root, *seep* or *sheeb* enters into the composition of the names of several species of water-birds or *divers*. In the Labrador dialect one species of duck is called *masheshēp* [i. e. 'great *sheeb*']; Cotton gives *qunussēps* [evidently compounded of *qunni* 'long' and *sēp*], as one name for 'duck:' in the Chippewa, *muk ud a chib* (from *muk ud a*, 'dark' or 'black,' and *sheeb*), is the name of the 'black duck,' and was the title of a famous warrior of that nation, on the Upper Mississippi, some fifty years ago; and in the same language, the cormorant is called *ka-ga-gi-wĕ shēb*, or 'raven-like duck;' &c. *Shee'-sheeb*, or *sē-sēp*, is the frequentative or intensive form; and, in some of the western Algonkin dialects, this receives one or more additional syllables, as in the Shawnee, *see' see' bah*; Saganaw-Chippewa, *shi shee' be an*,—both which forms are unmistakably *verbals*. The root, *sēp*, signifies primarily, to *extend*, to *stretch out*, and secondly, to *dive*. (Eliot wrote '*se sep a' eu*,' 'he stretches himself.') The Massachusetts '*se sep*,' the Cree *see' seep*, the Chippewa

* "Noctua lucifugans *cucubat* in tenebris."—Auct. *Philomelæ*.

shee' sheeb, and the Shawnee *see' see' bah*, are names of a *diving* bird,—literally, a *duck*. Compare, Lat. *mergus* from *mergere;* Dutch *duycker* (a dob-chick) from *duycken* (to bow the head).

The name '*ah áh wa*, a diver, a kind of duck,' is less doubtfully onomatopæic. This bird is the *totem* of one of the principal families of the Chippewa nation, from which have come some of their most renowned sachems.

Dr. Wilson supposes that the "*Pau-pau-say*, the common spotted woodpecker," is so called "from the sound it makes in striking a tree with its bill." Perhaps so; but, to uncultivated ears, the name does not so exactly reproduce the sound as to compel belief in its mimetic origin. He describes the woodpecker as "spotted." Why may not the Indian have fixed upon the same distinguishing mark? *Pau pau say* is the Saganaw name. In the Menomenie, we find *pah pah nch* for the woodpecker, *pah pah nay ew* for the robin, and *pah pe quoh kah* for the *toad*. In the Chippewa, *pah be' ko dain' dai* is the "speckled toad" (*dain-dai* meaning 'toad' or 'frog'). In the Delaware, *pa pa chees* (as Zeisberger wrote it), is 'woodpecker,' and *po po cus*, 'partridge,' or quail. In the Abnaki, the verb *pe pe sagh i gou* signifies 'he is *spotted*' ("il est moucheté," Rasles). The modern Cree, *pa pa tay oo*, has the same meaning. If *pau pau say* is onomatopœic, it is certainly *descriptive*, as well,—and marks a 'spotted' bird.

"*Moosh-kah-oos*, a kind of crane which frequents marshy places, "and makes this sound, with a choking cry, in the evening." *Moosh-kah-oos*, or *mooshkowĕsé*, is the Chippewa name of the bittern (*Ardea lentiginosa*). "Frequenting marshy places," it derives its name from Chip. *mahs koosch*, 'a marsh or bog,' or *moos-keeg*, 'a swamp,'—both words being nearly related to *mush-koo-deh*, a meadow or prairie, and more remotely to Chip. *mush koos iew* or *mĕzh ush*, 'green grass.'

Why "*No-no-no-caus-ee*," as a name for the Humming Bird, is put among specimens of onomatopœia, is not easily guessed. Was it supposed to 'imitate' the little creature's length of bill? No polysyllabic name in any American language is less doubtfully synthetic and independently significant. The root *nok*, or *nonk* (with *on* nasal), is nearly equivalent to the Latin *tener*. It means 'tender,' 'delicate,' 'soft;' hence, 'light of weight' (*levis*), 'slender,' and sometimes, 'young.' Roger Williams translates *nàuk-i*, by 'light.' Cotton's Vocabulary has *nonk-ke*, and (as a prefix or in composition) *nónk-*, for 'light.' Eliot wrote *noohk-i* [it is], tender, or soft; with an animate subject, *noohk-ésu*, [he is] tender, or soft,—applied to the flesh of a young animal, as in Genesis xviii. 7: and in composition, he wrote *nunk-omp* (= light male, or young male) for 'boy,' or stripling. The modern Chippewa has nearly the same form of the animate verb-adjective, *no-kĕ-see*, which, by intensive reduplication, becomes *no-no-kĕ-see*, 'he is *very* tender, or light.' So, in the old Abnaki, we find *nan-nank-es-es-oo* [= *no-nok-ēs ēs-u*], 'il est leger' (Rasles). In a Chippewa Vocabulary published by Schoolcraft (*History, &c. of the Indian Tribes*, v. 599), I find "*no no' kaw sé*, the humming bird." With the double augment, as Dr. Wilson wrote it (*no-no-no-caus-ee*), the name becomes a superlative, and denotes "an *exceedingly* light, or slight, or delicate creature,"—as if we should say, 'the *tiny-tawniest* little creature.'

If we prosecuted our examination through the whole list of names, we should find that not more than one-fourth of them could be fairly set down as onomatopœic. And if this is true of a few carefully selected specimens, gleaned from three dialects, how much less is likely to be the proportion of such names, in the whole vocabulary of any one tribe?

It may be safely affirmed, that by far the greater number of names of animate beings are *not*, in any Algonkin language, onomatopœic primitives, but are descriptive derivatives from predicative roots; that some names of *birds*, *reptiles* and *insects* are *apparently* formed by imitation of natural sounds, but that the species so named are generally those which are more often *heard* than *seen*, and consequently more easily indentified by their cries, or by sound, than by peculiarities of form, color, or habit;* and finally, that it is yet doubtful if any Indian name of a *quadruped* can be shown to be purely onomatopœic.

Of many animal-names, the composition or derivation is sufficiently obvious. Of others, the form of word or observation of changes which it has undergone in passing from dialect to dialect, enables us to say confidently that they are compounds or derivatives, and not primitives formed by imitation.

How utterly unfounded is Mr. Farrar's assertion of the universality of onomatopœia in the vocabularies of savage nations, may be shown by a few examples taken for the most part from eastern Algonkin dialects.

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* Thoreau, in an account of a canoe-voyage up the Penobscot, remarked that his guide (an Abnaki Indian) "sometimes could not tell the name of some small bird which [Thoreau himself] heard and knew, but he said, "I tell all the birds about here,—this country; *can't tell littlum noise, but I see 'em, then I can tell*."—Maine Woods, p. 172.

The Beaver (Mass. *tummunk;* Narrag. *tummóck;* Abn. *tema 'koué;*) is a 'Cutter-off' or 'Feller' [of trees]. Another name (Abn. *ameskou;* Del. *amochk;* Cree *amisk;* Chip. *amik;*) signifies the animal which 'puts his head out of the water,' i. e. the air-breathing water-animal.

The Otter (Narr. *nkéke;* Alg. *nikik;*) is a 'Biter,' or rather, 'He 'who *tears* with his teeth.' The Delaware name (*gunnamochk*, Zeisberger) means 'Long beaver-like animal.'

The Raccoon, was called by the Delawares 'Soft hands' (*wtackelinsche*, Zeisb.), and 'Scratcher' (*nachenum*). The latter name is the equivalent of the Abnaki *aréskané*, and the Virginian *aroughcun* or *arocoun*, corrupted by the English to 'Raccoon.'

The Bear was sometimes called a 'night-walker' (Narr. *paukúnnawáw*); and the same name was given to the constellation Ursa Major, perhaps because it was seen to 'travel by night' about the pole star. Another and the more common name of the Bear, signifies, I think, the 'Hugger' or 'Squeezer' (Cree, *múskwah;* Mass. *mosq;* Chip. *makwá;* Del. *machk*).

The Panther, in some eastern dialects, was 'Long Tail;' in Chippewa and other western languages, he was the 'Great Lynx.'

The Moose (Abn. *moos;* Narr. *móos;*) was a 'Smoother' or 'Trimmer' of trees; so called from his manner of feeding by stripping the young bark and the twigs from the lower branches.

The Oppossum, in Delaware, was 'White Face,' or 'Great White Face.'

The Horse received from the Indians of New England and Delaware a name which might pass, better than some of Dr. Wilson's specimens, for onomatopœic (Narr. *nay-nay-o-úm-e-wot*, R. W.; Mass. *nah-nai-ye-um-oo-adt*, Cotton); but it is in fact a verbal, and signifies "one who carries on his back an animate burden." The Chippewas called him "The animal with undivided hoofs," and sometimes "my "servant" or "my domestic animal," *par excellence* (*n'di*). The Blackfeet named him "elk dog" (*pu no ká mi ta*), and the Sioux, the "marvellous (or supernatural) domestic animal."

The Bald Eagle was 'White Tail' (Del. *woapalanne*, Zeisb.).

The Red-tailed Hawk, *F. borealis*, was 'Red Tail' (Del. *meechgalanne*, Z.; Mass. *mashquanon*). The Swallow-tailed Hawk, *F.* (*Nauclerus*) *furcatus*, was the Delaware 'Fork tail' (*chauwalanne*) probably, which Zeisberger calls "an Eagle with a forked tail."

The Turkey, in eastern dialects was 'Scratcher' (Abn. *ne he me;* Narr. *neyhom*).

The King-bird, *Tyrannus intrepidus*, was called by the Narragansetts and other New England tribes, "the Sachem."

Examples might be multiplied to hundreds, but enough have been given to answer the present purpose.

If time permitted, I would direct attention to some curious features of Indian nomenclature of animals and plants that are not without interest to students of language. Just now, I will mention only one of these, namely, the *generic affix*, or *formative*, by means of which a specific or individual name is referred to a known class, family or group. For example; the names of certain aquatic air-breathing animals, such as the Beaver, the Otter, the Muskrat, &c., receive, in some dialects, a common suffix, derived from a verb which signifies "to put the head out of water" or "to come to the surface," some rodents are characterized by a generic affix as "biters," and others are, in the same way, classed with "scratchers" or "tearers." In the Algonkin, these generics *follow*, in some other languages they are *prefixed to* the specific names. Thus, in Dakota nouns, the prefix *ta–* limits the signification to *ruminating* animals; *wa–*, to animals of 'bear kind;' *ho–*, to 'fish kind.'* Similar affixes are employed for the classification of vegetables and plants. One distinguishes such fruits (melons, cucumbers, squashes, etc.) as may be 'eaten raw' or 'before they are ripe;' another (*min* or *minné*), which may be regarded as an inseparable noun-generic, makes part of the names of edible *ripe* fruit, grain, nuts, &c.,—especially of *berries* and other small fruit; a third refers to one class all plants which produce edible *tubers*, (potatoes, the several species of ground-nuts, &c.); and so on. It is true that the American languages are deficient in general names, but it is likewise true that this deficiency is in great measure compensated by the number of inseparable generics which enter into the composition of specific names. Sometimes this affix is purely grammatical,—the formative of the participial or verbal which is used as a noun,—and has no independent significance. Such is the termination *-gun* or *-jegun*, which characterizes a numerous class of nouns in the Chippewa and other nearly-related languages. This is the formative of a participle of causative verbs, and denotes the *instrument* by which the action of the verb is caused or effected. Mr. Schoolcraft was led into the error of regarding this terminal *-gun* or *-jegun* as a primitive noun, "denoting, in its modified forms, the various senses implied by our words 'instrument,' 'contrivance,' 'machine,' &c.*

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* Riggs, Dakota Grammar, § 62.

† Information respecting the Indian Tribes, &c., vol. ii, p. 390.

Mr. Farrar, in *Chapters on Language*, (p. 34), has fallen into a worse mistake. In illustration of the assumed fact that, "in some cases the "onomatopœic instinct is so strong, that it asserts itself *side by side* "*with the adoption of a name*" from a foreign language,—he tells us that "the North American Indian will speak of a *gun* as an *ut-to-tah*-gun, or a *paush-ske-zi*-gun." *Ut-to-tah*-gun, as Mr. Farrar might have learned by a more careful reading of the page of 'Prehistoric Man' from which the word was borrowed, signifies—*not* 'a gun,' but 'a bell.' Moreover, the final *-gun* which Mr. Farrar mistook for an 'adopted' English name was, as I have pointed out, merely the formative of the instrumentive participial. The Chippewa name for 'gun,'—*paush-kiz'-zi-gun*, literally 'instrument of explosion' or 'exploding instrument,'—is not more indebted to the English for its last syllable than is (in the same language) *op waú gun*, 'a tobacco pipe' [smoking instrument], *ne bau gun*, 'a bed,' *pug gi mau gun*, 'a war club' [striking instrument], or *ni mi ba gun*, 'a water pail.' It would be easy to prove that neither *ut-to-tah-gun* nor *paush-kiz-zi-gun* is directly or purely onomatopœic, but the demonstration is uncalled for. It is plain enough that as illustrations of the exercise of "onomatopœic instinct," Mr. Farrar's examples were not well taken.

V.—On the Molluscan Fauna of the later Tertiary of Peru.* By Edward T. Nelson, Ph.D.

The following pages give the results of an examination of a collection of fossil Mollusca from Zorritos, Peru, presented to the Museum of Yale College, in 1867, by Mr. E. P. Larkin and Prof. F. H. Bradley.

The paper is simply a preliminary one, giving a catalogue of the genera found in the collection, with descriptions of a part of the species. It is to be hoped that other collections may be received from that very interesting region, both in order to complete the fauna and to afford the means for the description of many species, which, in this collection, are too imperfectly preserved for satisfactory description.

GASTEROPODA.

Bulla, sp. ind.

A single specimen was found, resembling *Bulla Adamsii* Mke., but differing in the following points. Shell less convex above and proportionally broader at the extremities. Aperture, below, also appears broader than in any specimen of *B. Adamsii* that I have seen. Further specimens may prove this to be a distinct species. The outer lip is slightly broken, and hence the following measurements are only approximate. Length 24·6 millim.; breadth 16·6 millim.

Callopoma lineatum, sp. nov.

Plate VI, figure 2.

Shell turreted; spire elevated; whorls six (?), convex. Upper whorls slightly depressed in front, marked by a few, strong, subnodulous ridges, alternating with finer revolving lines.

Body whorl very convex, marked above by two strong tuberculose ridges, and laterally and below by a few revolving lines, varying in size, as on the upper whorls. Whole surface marked by very fine and numerous longitudinal lines, rather broader than the spaces between them. Aperture not observed.

Length (4 whorls) 15·8 millim.; breadth 13·8 millim.

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* A graduating thesis presented at the Sheffield Scientific School, July, 1869.

This beautiful species, although quite distinct, closely resembles both *Callopoma saxosum* Wood and *Callopoma fluctuosum* Mawe.

From *C. saxosum* it may be distinguished by having the whorls less flattened above; lacking the row of tubercles at top of the body whorl; and in having much finer and smoother longitudinal lines. From *C. fluctuosum* it may be distinguished by lacking the strong rows of tubercles near the base of the body whorl; by having fewer revolving lines, and stronger and more distinct longitudinal ones.

Callopoma, sp. ind.

I refer to this genus a very large cast found with the preceding species. It gives the following approximate measurements: length 105 millim.; breadth 95 millim.

Calliostoma noduliferum, sp. nov.

Plate VI, figure 1.

Shell conical and elevated; whorls six, moderately convex; sutures very distinct. Surface of spire marked by a few nodulous or beaded lines, six to eight on each whorl, well elevated and about half the width of the spaces between them. Body whorl convex above, keeled below, marked by the beaded lines and intermingled finer nodulous ridges. Aperture subquadrangular; outer lip sharp; columellar lip covered thickly by callus.

Length (4 whorls) 8·8 millim.; breadth 10·9 millim.

The marking of the body whorl is very peculiar and characteristic. The strong elevated lines bear on their summits a row of nodules resembling beads, while alternating with these lines there are finer ridges, also nodulous. This species is less elevated, has more distinct sutures and fewer striæ than *Calliostoma lima* Phil., the nearest related species.

Uvanilla, sp. ind.

I refer very doubtfully to this genus a specimen too poor for identification. It is mostly in the state of a cast and bears resemblance to this genus. External characters mostly wanting.

Breadth 77·2 millim.

Crepidula, sp. ind.

Genus represented by six casts. The generic relation was proven by breaking open one of the casts, when the transverse partition became apparent.

Crucibulum inerme, sp. nov.

Most of the specimens of this genus are also casts, but a fortunate break laid open the interior of one and showed the "cup" of a *Crucibulum.* The shell is oblong-oval, twice as long as high, and smooth externally, thus differing from all known species of the West Coast. The cup is large, semi-lunar, and apparently strongly attached to the shell along the whole of the convex side. On the free margin the cup is *depressed*, with a shallow sinus similar to that in *C. spinosus* Sby.

The following are the approximate measurements: shell, length 24 millim.; height 11·6 millim; cup, length 13·4; height 8 millim.

Vermetus, sp. ind.

I refer to this genus, doubtfully, a mass of irregular tubes which may, perhaps, be those of a species of *Serpula.* In the size of the tubes and manner of growth it resembles somewhat the species now living on the West Coast, but no characters remain for identification. The size of the tubes varies from six to eight millimeters.

Turritella plana, sp. nov.

Shell elongated, turreted, with from 13 to 19 (?) nearly flat whorls, gradually tapering to a point. Whorls flat above, slightly convex below, marked by fine, equal revolving lines, 20 to 25 in the space of 5 millim. Sutures deeply impressed and broad. Two lower whorls much more convex than the upper ones; revolving lines stronger and crossed by distinct lines of growth.

I have not seen a perfect specimen of this very interesting species, and hence measurements and the number of whorls can only be given approximately. A specimen consisting of the 8 lower whorls gives the following measurements: length 117·4 millim.; breadth 34·6 millim.; breadth of upper whorl 13·4 millim. A fragment belonging apparently to the same specimen gives for the length of the upper seven whorls 35 millim.

The species may easily be distinguished from any with which it might otherwise be confounded, by its nearly flat whorls and equal, thickly crowded, revolving lines; its impressed sutures; and the convexity of the two lower whorls.

Turritella suturalis, sp. nov.

Shell turreted, whorls twelve to fifteen; upper ones regularly convex; lower ones most convex about one-fourth from the bottom of the whorls; marked by four to seven strong, sharp revolving lines, which are strongest on the lower whorls. Above and below the point of greatest convexity the strong lines are supplemented by finer and more numerous ones.

Sutures very deeply impressed. No perfect specimens found except young shells. A specimen with six whorls measures: length 76·90 millim.; breadth 25 millim.; breadth of upper whorl 12·6 millim. A young specimen measures: length 30·1 millim.; breadth 10·6 millim.

This species seems almost as variable as abundant. Some of the specimens resemble *T. tigrina* Kien., but may easily be distinguished from that species by the greater convexity of the whorls, and stronger revolving lines. On all mature specimens the finer striation of the lower part of each whorl is very characteristic, but in younger specimens the striations appear nearly uniform from base to apex. Some few specimens show occasional fine lines, intermediate between the larger and stronger ones. The place of greatest convexity of the whorls varies in a few specimens, owing to a flattening of the whorls. Lines of growth very distinct on some specimens.

Turritella bifastigata, sp. nov.

Shell turreted, slender; whorls twelve to sixteen, flat or slightly concave, except the body whorl, which is regularly convex; whorls bordered on each side by a strong obtuse ridge.

Intermediate spaces ornamented by fine raised, nearly equidistant, revolving lines, about ten in the space of five millimeters. Sutures small and narrow, or rendered indistinct by the development of the bordering ridges. Body whorl somewhat convex, except in young shells; strongly wrinkled by the lines of growth, which, on well preserved specimens, are sharp and acute. Base of this whorl marked by from seven to ten lines, nearly as strong as the ridges of the upper whorls. Aperture rounded; outer lip thin and slightly produced below. A specimen consisting of the seven lower whorls gives the following measurements: length 61 millim.; breadth 19·1 millim.; breadth of upper whorl 7 millim. Nine whorls from a younger specimen gives: length 39·05 millim.; breadth 10·6 millim.; breadth of upper whorl 3·2 millim.

This interesting species shows some resemblance both to *T. plana* Nelson and *T. goniostoma* Val. But *T. plana* is a much stronger shell, and lacks the bordering ridges, so characteristic of this species. *T. goniostoma* Val. has only one bordering ridge, viz., on the lower side of each whorl, while a central ridge gives to the whorl a slight convexity, which this species lacks.

Turritella, sp. ind.

Shell elongated, turreted; whorls broad and very concave; sutures indistinct. Surface just above each suture marked by a very strong ridge. Intermediate surface marked by a few distinct concentric lines, five to seven on each whorl. If the characters just given be constant, this species is very distinct from any of those described above, and from any now living on the West Coast. It is perhaps most nearly related to *T. bifastigata* Nelson, but has the whorls more concave and lacks one of the bordering ridges. Only four specimens of this species were found, all so badly worn and covered by Bryozoa and Serpulæ that it is impossible to give a more detailed description.

Eight whorls measure: length 63·4 millim.; breadth 19·4 millim.; breadth (basal, along the ridge) 26·2 millim.; breadth of upper whorls 5·6 millim.

Aphera Peruana, sp. nov.

Plate VI, figure 3.

Comp. *Cancellaria tessellata* Sby., Proc. Zoöl. Soc. Lond., 1832; Kiener, Iconog., p. 32, pl. 9, fig. 4.

Aphera tessellata Adams; Chenu, Manuel Conch. et palé., ii. p. 276.

Shell elongated, sub-fusiform; spire short, pointed, formed by five or six moderately convex whorls. Body whorl large, three-fourths the length of the shell, ventricose. Surface marked by nearly equal longitudinal and transverse ridges, which form strong raised cancellations, and are so arranged as to form blunt, obtuse granulations at the point of contact.

Longitudinal lines finer, and much crowded near the outer lip. Aperture oblong-oval, narrow, half as long as the shell. Lips covered with callus, which is continuous above and below the aperture. Callus of columella lip strongly reflexed over the shell, much broader above than below, almost completely covering the umbilicus. Outer lip thick, and reflexed above, furnished within with a few rather strong teeth. Inner lip with two plaits near the center, the upper one being much the stronger. There is also a plait at top of the lip, small but quite distinct. Canal wanting. Aperture prolonged into a short, open sinus. Length 17·4 millim.; length of spire 4·4 millim.; breadth 10 millim.

This species closely resembles *Aphera tessellata* Adams, but is distinguished from that species by its less slender form, stronger cancellating ridges, by its shorter and more open aperture, and by the third fold at the top of the columellar lip.

Cancellaria triangularis, sp. nov.

Plate VI, figure 10.

Shell ovate, ventricose, spire elevated acuminate, composed of five or six whorls. Three upper, are regularly convex, and marked by prominent ribs and lines; the remaining whorls are very angular, flattened and depressed above. Body whorl large, very triangular, nearly two-thirds the whole length of the shell, strongly depressed. Sutures distinct, but not prominent.

Ribs strong, ten to twelve on each whorl, and well marked on the top of each whorl. Whorls of spire are marked just below the sutures by two or three distinct but fine lines, and much depressed in front of them; and marked laterally by three strong ridges, the upper one nodulous. Body whorl with the ribs strong above, gradually disappearing below, and with nine to eleven transverse, nearly equal lines, which form, with the ribs, quadrilateral cancellations, averaging 4· millim. by 1·8 millim.

Aperture long and narrow; outer lip thin. Columellar lip covered by a thin callus, strongly reflexed over the whorl above, and having within two strong plaits, the upper one much the larger. Umbilicus small, nearly covered by callus, surmounted by a prominent keel. Canal short, nearly straight and open. Length 25·4 millim.; length of spire 7·6 millim.; breadth 17 millim.

Cancellaria spatiosa, sp. nov.

Shell ovate, ventricose; spire short, elevated, acuminate; sutures distinct, especially the one separating the spire from the body whorl. Whorls seven, convex. Body whorls very convex and ventricose, three-fourths the length of the shell, broadest near the center of the shell and rising into more or less of a shoulder above the aperture. Surface of upper whorls not examined. Remaining surface smooth, except the markings of the lines of growth.

When the outer surface is removed there is seen a series of strong transverse lines, about five or six in the space of 10 millim. Aperture semi-oval, nearly as long as the body whorl; outer lip sharp, marked within by rather distant teeth, which extend well into the interior, but gradually thin out. Columellar lip covered by a strong, thick callus, which spreads over the convex surface of the whorl, and over the umbilical region, rising within the aperture into three strong plaits, the upper being much larger than either of the others. Canal short, open, slightly reflexed, and surmounted by a prominent keel. Our largest specimen measures: length 65·4 millim.; length of spire

15 millim.; breadth 48·45 millim. Second specimen measures: length 61·2 millim.; length of spire 12·2 millim.; breadth 42·25 millim.

Cancellaria Bradleyi, sp. nov.

Plate VI, figures 8, 9.

Shell thick, ovate; spire turreted, elevated, and acuminate, composed of six convex whorls, slightly depressed above. Whorls separated by distinct sutures, and marked by from 13 to 15 strong, nearly equal ribs to each whorl, and four or five revolving elevations.

Body whorl somewhat ventricose, convex; ribs more distant and accompanied on some specimens by lines of growth. Aperture oblong-oval, prolonged into a short, open, and slightly reflexed canal. Outer lip thick and smooth. Columellar lip covered by callus, almost covering the umbilical region; furnished within the aperture with two strong folds, the upper much the largest. Umbilical ridge strong and rugose.

Length 27·1 millim.; length of spire 8·4 millim.; breadth 16·75 millim.

Cancellaria Larkinii, sp. nov.

Plate VI, figure 7.

A fifth species of *Cancellaria* has the spire elevated and turreted; whorls slightly depressed above. Sutures deeply impressed. Body whorl ventricose, three-fourths the length of the shell; ribs strong above, but absent over the base of the whorl; transverse ridges strong and distinct. A row of strong, acute tubercles covers the center of each upper whorl, and the point of greatest convexity of the body whorl. Outer lip very thin, and furnished within with a few strong teeth. Columellar lip with two nearly equal plaits, and a third, quite indistinct one, below. Umbilicus small, covered by a deposit of callus. Umbilical keel very strong. Canal short, open, and slightly reflexed. Owing to the bad state of preservation of our specimens it is impossible to give exactly the measurements or number of whorls. Our most perfect specimen gives, for four whorls, these measurements: length 27 millim.; breadth 18 millim. A much larger specimen measures (5 whorls) length 40·1 millim.; breadth 23 millim.

Strombus, sp. ind.

This genus is represented by four specimens in the condition of casts, which bear strong resemblance to the young of *S. Peruvianus* Swain. Outline conical, reflexed below. The largest specimen has the outer lip produced above the top of the shell. These characters, together with the general form, lead me thus to refer the specimens, although specific determination is impossible.

Myurella tuberosa, sp. nov.

Shell turreted, slender and acuminate; whorls eight to ten, depressed or slightly concave, except the body whorl; sutures indistinct. Cincture broad, elevated, with obtuse tubercles, not as wide as the spaces between them. Longitudinal ribs distinct. Whorls marked by from four to six nearly equal transverse ridges, which rise into strong tubercles over the ribs.

Body whorl large, over one-third the length of the shell, depressed above, convex below, rising in the middle into more or less of a shoulder. Shoulder marked by two or three concentric ridges, covered by tubercles much larger than those of the others. Base nearly destitute of tubercles, but with the concentric lines very distinct. Whole surface, on well preserved specimens, marked by fine, minute, longitudinal lines. Aperture elongated-oval; outer lip sharp; columella plicated; canal well reflexed, with the keel only moderately elevated. Only three specimens of this species were found, all having the apex slightly broken. Seven whorls give the following measurements: length 25·2 millim.; breadth at shoulder 8·4 millim.; breadth at upper whorl 1·95 millim.

Myurella, sp. ind., A.

A badly worn and broken specimen apparently represents another species. Whorls convex. Cincture scarcely raised above the level of the whorls, marked by rather small tubercles, and separated by deeply impressed sutures. Longitudinal ribs strong. Body whorl evenly convex and without a shoulder, concentric lining indistinct. Four whorls, giving the following measurements, show this to be a less slender species than *M. tuberosa* Nelson. Length 28·45 millim.; breadth 10·4 millim.; breadth at upper whorl 8·4 millim.

If the characters given above be constant, the specimen is quite distinct from the *M. tuberosa*, but it has not characters sufficient for complete specific determination.

Myurella, sp. ind., B.

A single specimen differs from the species described above in having only slightly convex whorls and indistinct sutures. Cincture elevated above the level of the whorl. Longitudinal ribs strong; transverse ridges broad. Three whorls measure: length 26·2 millim.; breadth 98 millim.; breadth at upper whorl 7·45 millim.

Pleurotoma, sp. ind.

I refer to this genus three specimens too imperfectly preserved for specific determination or measurement. They agree in form and details with this genus, but further specimens will be necessary to settle the question accurately.

Conus, sp. ind., A.

Three species of *Conus* occur in this collection. The first resembles *C. mahogani* Rve., and might at first sight be confounded with that species. But the two may easily be distinguished by the whorls of the spire. In *C. mahogani* the spire is regularly conical, and the whorls have all an equal slope, while in this species the whorls are slightly turreted. The transverse lines of the body whorl are also slightly narrower and extend further up the side of the whorl. This species is a very abundant one, both as casts and well preserved specimens. Length 20 millim.; length of spire 5·05 millim.; breadth 8·95 millim. A larger specimen measures: length 36·2 millim.; breadth 16·2 millim.

Conus, sp. ind., B.

Our second species more closely resembles *Conus purpurascens* Brod., but has the spire more elevated than the average of that species; whorls more depressed above, and the transverse striæ less distinct or wholly wanting. Body whorl not examined. Length 73·4 millim.; breadth 39·2 millim.

Conus, sp. ind., C.

This species, represented by four specimens, is remarkable for the very short spire. The shell is nearly flat above, except the last three or four whorls, which at the summit rise into an acuminate spire. Sutures very distinct. Our largest specimen gives the following measurements: length 75 millim.; length of spire 6 millim.; breadth 47·8 millim.

Solarium sexlineare, sp. nov.

Plate VI, figure 11.

Shell circular, depressed; whorls seven to eight, moderately convex, separated by distinctly marked sutures, ornamented by broad, subequal revolving lines. Body whorl large, two-thirds the heighth of the shell, marked with four revolving lines, of which that next the suture is the broadest, the remaining ones nearly equal in size. The line which forms the edge of the whorl is double the width of the others. Base marked by six revolving lines. First narrow, separated by deeply marked sutures. The next four form a series, narrowing toward the interior, or umbilical region. The last, forming the wall of the umbilicus, is broad and deeply notched Umbilicus widely open. Three specimens, only, of this species have been found, all slightly worn; it is therefore impossible to state the superficial markings of the upper whorls. The species, however, appears to have been notched transversely. Length 13·8 millim.; breadth 25·2 millim. This species resembles *S. granulatum* Lam., but that species has seven lines on the base of the body whorl, instead of six as in our species.

Polinices subangulata, sp. nov.

Plate VI, figures 4, 12, 13.

Shell varies from obliquely oval to sub-globular, moderately heavy and ventricose; spire short and pointed; whorls from six to seven, convex; body whorl large, nearly seven-eighths the length of the shell, convex, slightly produced anteriorly, broadest about one-fourth from top. From this point the whorl slopes, becoming very much flattened and presenting a marked angular appearance. Surface marked by distinct but irregular lines of growth. Sutures quite indistinct, except when the epidermis is slightly worn off. Aperture semi-lunar, half as wide as long, broadest a little below the middle. Outer lip sharp and thin. Columellar lip covered by a very thick callus, which rises into a more or less prominent ridge at the broadest part of the shell. Umbilicus small; in most specimens reduced to a mere chink by the callus, which is prolonged below. Young, medium sized, and full grown specimens give the following measurements:

First,	Length, 12·6 millim.	Breadth, 9·4 millim.
Second,	" 28·2	" 22·2
Third,	" 47·4	" 39·2

This is the most common species in the collection. In manner of growth it resembles *P. uber* Val. sp., and is as variable as that species. Young specimens of the two might easily be confounded. The young are obliquely-oval; by growth the body whorl becomes ventricose, and the flattening of the upper part becomes more distinct and prominent. The umbilicus also varies greatly. In some specimens it is open and almost circular in outline, while in others it is almost completely closed by a thick covering of callus. All full grown specimens, hence, may easily be distinguished from any species with which they might be confounded, by the short spire, the flattening or angularity of the body whorl, and the small umbilicus.

Malea, sp. ind.

I refer, very doubtfully, to this genus three casts, which resemble somewhat the young of *M. ringens* Sby. Further specimens are necessary to settle their relations accurately.

Argobuccinum Zorritense, sp. nov.

Plate VII, figures 1, 2.

Shell slender, ventricose; spire elevated, conical; whorls about seven, moderately convex, and depressed above. Sutures distinct, but not deeply impressed. Surface marked by strong, flattened revolving ribs, varying in width. Spaces between the ribs well marked, as wide or wider than the ribs (except on the body whorl), smooth, or ornamented with fine revolving lines. Upper ribs of each whorl somewhat nodulous, forming a more or less distinct shoulder. Body whorl large, more than half the length of the shell; ribs wider than the spaces between them; upper ribs forming a distinct shoulder, depressed above, and forming a strong angulation with the rest of the shell; lines of growth strong, giving to the whorl somewhat of a cancellate appearance. Aperture oblong, regularly ovate, and broadest just above the center, one-third as long as the shell. Outer lip sharp and having within numerous teeth, extending well into the interior of the shell, nearly equidistant, about one-fourth as wide as the spaces between them, and ten in the space of 5 millim. Columellar lip covered thinly by callus, which is thickened below into a distinct ridge. Umbilicus wanting. Umbilical keel strong and rugose. Canal open, short and reflexed. A large speci_ men measures: length 51·2 millim.; breadth 29 millim. A smaller specimen gives the following measurements: length 35·4 millim.; length of spire 18 millim.; breadth 19·2 millim.

This species, one of the finest of the whole collection, is very abundant, especially in the condition of casts. One cast measures: length 59 millim., by breadth 30 millim. On all mature specimens the nodulous character of the top of each whorl is very characteristic. On the body whorl these nodules rise into obtuse tubercles, about ten or twelve to the whorl. In mature specimens, also, the lower whorl is produced in front, having its greatest width near the central line of the whorl, and causing the aperture, when viewed obliquely, to appear somewhat quadrilateral. Young specimens differ in lacking the teeth of the outer lip, and the tubercles of the body and adjacent whorls.

Mitra, sp. ind.

Three specimens have been found, which I refer to the same species, and to this genus. The spire is very elongated. Sutures distinct, whorls moderately convex. Body whorl slightly depressed and angulated above. Outer lip sharp and thin. Columellar lip covered by callus and furnished with four strong plaits. The two upper are nearly equal in size and much larger than the lower ones. The specimens are so badly worn and broken that it is impossible to give any characters except those mentioned above. Our largest specimen, of five whorls, gives as measurements: length 98·2 millim.; breadth 34·2 millim.

Marginella incrassata, sp. nov.

Plate VI, figures 5, 6.

Shell large, conical, ovate, two-thirds as wide as long, thick. Spire rather short and acuminate. Sutures indistinct. Body whorl regularly conical, very convex, broadest one-fourth from top, forming a well rounded shoulder, and tapering rapidly from this point to end of spire. Aperture linear and narrow. Outer lip with the margin thick and broad. Columellar lip with four nearly equal, well developed plaits; the two upper more widely separated than the lower ones.* Measurements as follows:

Young,	Length, 20·60mm	Length of spire, 2·60mm	Breadth 10·40mm
Medium,	23·05	2·65	14·0
Mature,	27·8	3·01	18·6

This large and fine species may easily be distinguished from any now living on that coast by its proportionate measurements, by its thicker outer lip, great prominence of the top of the body whorl, and the short spire.

Oliva, sp. ind., A.

This genus is represented by a specimen slightly resembling *O. palpaster* Mke., but the body whorl is less regularly convex; proportionally broader near the top of the whorl and hence more conical. Our specimen gives the following measurements: length 37·4 millim.; length of spire 5·3 millim.; breadth 19·1 millim.

Oliva, sp. ind., B.

A badly worn specimen differs from the preceding in having a shorter spire, and the body whorl proportionally broader. No other characters observed. Length 41·2 millim.; length of spire 3·4 millim.; breadth 24 millim.

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* The upper plait is not represented in the figure.

Cuma alternata, sp. nov.

Plate VII, figures 3, 4.

Shell slender, fusiform; spire elevated, turreted and pointed; whorls six or seven, convex, separated by well-marked sutures and ornamented by a series of rather prominent ridges, about eight to each whorl. Ridges rise in the middle of each whorl into obtuse tubercles. The body whorl is large, somewhat ventricose, about two-thirds the length of the shell, very convex, broadest about one-fourth from the top of the whorl or near the middle of the shell. Ridges on this whorl are very distinct, but gradually disappear as they approach the suture, and are entirely wanting over the lower half of the whorl. Surface marked by raised revolving lines, arranged in two series; between every two of the larger ones there are from one to five smaller, nearly equal ones; about six of the larger in the space of 5 millim. Striations much larger on the lower part of body whorl. Aperture oblong-oval, half as long as the shell. Outer lip with a row of small, equidistant teeth, about six in the space of 5 millim., but which do not extend into the interior of the shell. Columellar lip smooth and overspread with callus. Canal wide, open, and reflexed. Umbilicus small, reduced to a mere chink in most specimens, bordered by a large well defined keel. Length 52 millim.; breadth 33·4 millim.

This species, which must have been very beautiful when living, may easily be recognized by the concentric striations, which differ notably from any other species known to me. Three species have been described from the Panamian fauna, all of which have stronger lines than the *C. alternata.*

This species is distinguished from *Cuma tecta* Wood, by its more strongly marked sutures; by its less sharp and angular tubercles; by lacking the tooth of the columellar lip; by finer teeth on the outer lip; and by its more orbicular mouth. From *Cuma kiosquiformis* Duel., it differs in having less pointed tubercles; by lacking the loose laminæ of growth which cover the sutures of that species, and by the longitudinal imbricating lines.

Strombina lanceolata Sby. sp.

Columbella lanceolata Sowerby, Proc. Zoöl. Soc. Lond., p. 116, 1832; Kiener, Iconog., pl. 15, fig. 2.

Strombina lanceolata Carpenter, Rep. British Assoc., 1856; Chenu, Man. de Conch. et palé., 1859.

Shell slender, fusiform, and turreted; spire long and tapering; whorls seven or eight, moderately convex, flattened above. Sutures distinct. Surface of upper whorls, marked by a row of strong tubercles, eight to ten on each whorl. Body whorl large, ventricose, and triangular in shape, half the whole length of the shell; arched in front and quite depressed above; marked by one strong tubercle on the back just below the suture; by a strong transverse oblique ridge on the left of the aperture; by a more or less distinct ridge along the outer lip; and by a low ridge connecting with the large tubercle. Base of the whorl marked by a few concentric lines. Aperture long, narrow, and slightly winding. Columellar lip covered by a thin callus. Outer lip thickened within and marked by a few strong teeth. Canal open and nearly straight. The following are the measurements of this species: length 27 millim.; breadth 11·4 millim.

I have been unable to find any differences between the specimens of *Strombina* in this collection and specimens of *S. lanceolata* in the Museum of Yale College, and I therefore, without hesitation, pronounce them the same. This is a very interesting circumstance, for the majority of the species, though closely allied, are very clearly distinct from the species now living on the west coast.

Clavella solida, sp. nov.

Shell oval, ventricose, and heavy; spire moderately elevated and tapering. Whorls five to seven, more or less depressed above. Sutures distinct. Body whorl large, more than two-thirds the length of the shell, regularly convex, depressed above the shoulder, which is large and strong, and forms a very distinct ridge, extending more than half around the shell.

The upper whorls are marked by a series of longitudinal ridges, eight or ten to a whorl, and crossed by strong, equidistant, revolving lines. The two lower whorls are destitute of the ridges, but ornamented by revolving lines, which become more or less indistinct on the body whorl in mature specimens. The base of the body whorl is marked by much stronger lines. Variable in size. Aperture oblong-oval; outer lip thin. Canal long and slightly reflexed. Umbilical chink bordered by a broad keel. Measurements as follows: length 43·2 millim.; breadth (at shoulder) 30·6 millim.; breadth (below shoulder) 28 millim.

This species bears strong analogy to *C. distorta* Wood, but is a stronger shell, has a shorter spire, and finer and more numerous revolving lines on the upper whorls.

The shoulder is *convex* above in *C. distorta*, but *depressed* in *C. solida.*

LAMELLIBRANCHIATA.

Pholas, sp. ind.

This genus is represented by one very badly broken specimen. Generic characters quite distinct, but not sufficient for specific determination. Length (from umbo to middle of ventral margin) 30·4 millim.; breadth 32 millim.; height 32 millim.

Panopæa, sp. ind.

A broken valve, apparently belonging to this genus, occurs in this collection. No species of this genus has been described from the Panamic fauna, and only one species from the west coast, the *P. generosa* Gould, from Puget Sound. Our specimen, if perfect, would have had a length of perhaps 15 centim. and a breadth of 7·50 centim.

Corbula Bradleyi, sp. nov.

Shell very ventricose; wedge shape, umbos large, convex, incurved over the hinge area. Anterior margin rounded; lunule very deeply impressed; ligament area twice the length of the lunule; strongly angulated with the posterior margin. Hinge tooth large, recurved; fossette triangular and deeply impressed. Surface of shell marked by strong, convex, concentric lines, separated by narrow but well marked spaces, about five of the lines in five millim. Length 18·8 millim.; breadth 20 millim.

The triangular shape is very characteristic, as also the angulation of the posterior margin; beak very prominent.

Corbula, sp. ind.

A single valve of this species was found; it differs from the preceding species in being much less elongated and having much finer concentric striation. Shell oval; beak small. Anterior margin rounded; posterior acuminate and elongate; tooth large, straight; fossette rather small. Length 10 millim.; breadth 14·8 millim.

Solecurtus, sp. ind.

This genus is represented by two broken specimens of a species allied to *S. affinis* C. B. Ad. It differs from that species in having the callosity of the ligament much more evenly extended, and not so acute, and the shell is more evenly elevated behind than *S. affinis*. Our specimens are casts, except the posterior extremities. Length 26 millim.; breadth 66· millim.

Tellina, sp. ind., A.

I refer to this genus a badly broken specimen, having the general form of a *Tellina*, though no characters remain for its determination. If perfect, our specimen would have about the following measurements: length 33 millim.; breadth 55 millim.

Tellina, sp. ind., B.

A specimen, of which it is impossible to see the hinge, I also refer to this genus. It is proportionally broader than the last species. Surface marked by fine, nearly equal, flat striæ. Length 8·8 millim.; breadth 15·40 millim.; height 3·4 millim.

Mactra Zorritensis, sp. nov.

At least two species of *Mactra* are found in this collection. The shell of the first is ventricose. Umbos convex, prominent, incurved. Anterior margin long, sloping; posterior margin strongly angulated with the lateral margin, and depressed. Hinge line nearly straight; fossette impressed and triangular; cardinals divergent, forming a prominent V; laterals very large, well developed. Length 16·1 millim.; breadth 21 millim.; height 11·05 millim.

Mactra, sp. ind.

This species may be told from the preceding, which it very much resembles, in being broader, having less prominent umbos; and being less convex; posterior margin not so angulated. Length 12 millim.; breadth 18·2 millim.; height 7·6 millim.

? Harvella, sp. ind.

I refer to this genus, doubtfully, some large specimens, which are mostly casts. From lack of specific characters it is impossible to settle the relations definitely. Our best specimen shows the umbos convex and impressed; ligament area very deep; surface of shell marked by strong concentric ribs.

Dosinia grandis, sp. nov.

Shell large, solid, sub-equilateral; length and breadth nearly equal; broadest just above the middle line. Beaks elevated, nearly central, curved inward and forward. Lunule heart-shaped, very deeply impressed, two-thirds as wide as long, marked by striations, which become finer as they pass into it. Anterior end short. Anterior and posterior ends nearly equally rounded. Ligament large; scar long, striated longitudinally. Surface covered by a thick epidermis, and marked by broad, flat, concentric ribs, which become larger and smoother over the middle of the shell, but not wholly obsolete. With the epidermis removed the shell still shows the striations, especially about the beaks. Hinge line nearly straight, very broad. The median tooth (cardinal) of the right valve is large and pointed; posterior cardinal deeply bifid. Lateral tooth large, nearly as long as the posterior cardinal, and parallel with it. In the left valve the median cardinal is bifid throughout the upper half of its length. Hinge area forming a very obtuse angle with the ligament area. Muscular scars and palial impression not observed. A young and a full grown specimen give the following measurements:

Young,	Length,	46·05mm	Breadth,	47·1mm	Height,	22·6mm
Mature,	"	95·60	"	95·2	"	47 2

This is the most common bivalve in the collection. The species is peculiar in that the young specimens are proportionally wider than long, while full grown specimens are slightly longer than wide. The species most nearly resembles *D. ponderosa* Gray, but is much thicker and stouter, more elongated, and has the sulcations more distinct. *D. grandis* is much larger, also, than *D. Dunkeri* Phil., and more elongated, and the ribs are coarser and flatter.

Chione variabilis, sp. nov.

A very variable species, somewhat resembling *Chione gnidia* Brod. and Sby., and also allied to *Chione amathusia* Sby. The "concentric frills" are not preserved, but the position of the scars which they have left, and the arrangement of the radiating ribs, show the species closely allied to *Chione gnidia.*

It differs from that species in having the central tooth of the hinge line more strongly furcate; in having the ligament scar less deeply impressed and the lunule broader. The shell is also proportionally longer and the posterior margin shorter. The crenulations of the hinge margin resemble *Chione gnidia*, while the teeth more closely resemble *C. amathusia*; the cardinals are, however, more divergent and apparently more rounded on the summit. Measurements as follows: length 28·42 millim.; breadth 30 millim.; 2d, length 28·85 millim.; height 19·9 millim.

Specimens having a length of 50 to 60 millim. occur, but not perfect enough for measurement.

Chione, sp. ind., A.

With the preceding species there was found a fragment of a right-valve, which differs in having the lunule very elongated and the umbos not reaching to the margin.

Chione, sp. ind., B.

A species closely related to *Chione amathusia* Phil., is represented by three specimens in very poor condition. In form it agrees very closely with the typical forms of *Chione amathusia*, but it appears to have been a thicker shell; the lunule is proportionally broader, the breadth nearly equaling the length. The "concentric frills" are much more numerous, but as the hinge line can not be seen the exact relations of this species can not be made out.

Length 46 millim.; breadth 54·4 millim.; height 34·6 millim.

Crassatella gibbosa Sby.

C. gibbosa Sowerby, Proc. Zoöl. Soc., London., p. 56, 1832.

Plate VII, figure 9.

Shell oval, very gibbous, marked by strong, flat, concentric lines; surface smooth. Umbos depressed, undulate. Anterior margin regularly rounded, short, with the lunule very deeply impressed. Posterior margin longer, distinctly angulate, and strongly ridged; ligament area very long and narrow. Hinge line nearly straight; teeth divergent; cardinals bifid; surface between cardinals coarsely crenulate; remaining surface of hinge area finely nodulose; fossette large and triangular. Young shell depressed and surface undulate. Three specimens give the following measurements:

Length, 10·4 millim.	Breadth, 15·2 millim.	Height, undetermined.
" 20·0 "	" 26·4 "	" "
" 63·1 "	" 76·4 "	" 39·4 millim.

This species is of special interest. I have been unable to find any constant characters of difference between our specimens and those of *C. gibbosa* Sby., in the Museum of Yale College. Differences observed, also, are mostly due to age. The shells are more gibbous; lunule more deeply impressed; and ligament scar straighter and proportionally longer than in any living specimens which I have examined. But as they agree so closely in all other respects, even to the crenulations of the teeth and the nodulous character of the depression of the right-valve, into which the corresponding lateral tooth fits, and the annular markings of the muscular scars, our species can not be regarded as anything more than a *variety* of *C. gibbosa*. Our specimens are larger than the type of Sowerby, or any of the specimens of that species in the Museum of Yale College.

Cardium, sp. ind.

Shell oval, large, very convex; ribs strong and rounded, well elevated, as broad as the spaces between them, about six in the space of

10 millim. Beak, elevated, large; cardinals quite curved and divergent.

Length 45 millim.; breadth 41 millim.

Hemicardia affinis, sp. nov.

Two specimens were found, belonging to this genus, and related to *H. obovalis* Carp., but may easily be distinguished from that species by the following differences. Ribs much finer, more elevated, and the spaces between them broader. The two species differ also in the proportional measurements.

Length 19·1 millim.; breadth 10·4 millim.; height 10 millim.

Arca Larkinii sp. nov.

Plate VII, figures 5, 6, 7.

Shell thick and heavy. Anterior extremity short and rounded; posterior more or less produced. Beaks widely separated, raised and very prominent. Ligament area large, about half as broad as long. Surface marked by from 30 to 33 radiating ribs, which are rounded and broader than the spaces between them. Ribs ornamented by rounded tubercles and crossed by numerous fine lines of growth. Teeth numerous, strong, nearly straight, equidistant, except at the extremities of the hinge line, where they become divergent and much stronger. The margin of the shell is deeply scalloped by the extremities of the exterior ribs and grooves. Just above the marginal teeth the inner surface of the shell is marked by fine radiating lines, from one fourth to one half of an inch in length. Anterior muscular scar almost circular; posterior elongated and narrow.

Length 27·4 millim.; breadth 29·6 millim.; height 25·8 millim; between umbos 5·8 millim.

The specimen, whose measurements are given above, is the largest *perfect* one, and perhaps the most characteristic.

Fragments and single valves of much larger specimens are abundant. A large specimen gives the following approximate measurements: length 35·4 millim.; breadth 37·4 millim.; height 35 millim.; between umbos 8 millim.

This species bears strong analogy both to *Arca grandis* Brod. and Sby., and *Arca tuberculosa* Sby. It agrees with the former in general habit of growth, with the latter in form and tuberculose characters of the ribs. It may, however, be distinguished from *A. grandis* by its more numerous, rounded ribs, less crowded teeth, and more oblong posterior muscular scar. From *Arca tuberculosa* it may be distinguished by its very broad muscular scar.

I take pleasure in dedicating this species to Mr. E. P. Larkin, to whom, and Prof. F. H. Bradley, the collection is due.

Scapharca, sp. ind.

A single specimen I refer to this genus, although its true relationship can not be made out, as it is impossible to see the hinge line. In external characters it resembles *S. nux* Sby., and might at first glance, be confounded with that species. The shell is less elongated; ribs broader and the spaces between the ribs narrower than in *S. nux.*

Length 15·2 millim.; breadth 17·2 millim.; height 11·85 millim.

Leda acuminata, sp. nov.

Plate VII, figure 8.

Shell oblong. Anterior margin slightly produced, but rounded; posterior produced and acuminate. Umbos prominent, very convex above, incurved below. Surface marked by broad, flat ribs, separated by narrow, but well marked spaces. Hinge line slightly curved; teeth numerous and subequal. Shell slightly depressed posteriorly, forming indistinct angulations with the lateral margins. Three specimens measure as follows:

Length, 6·2 millim.	Breadth, 11·6 millim.	Height, --- millim.
" 10·8 "	" 20·0 "	" 8·2 "
" 14·2 "	" 25·1 "	" 11·8 "

This fine species is quite abundant and may be easily recognized by its great convexity, especially in all mature specimens; by its flattened striations, and regular teeth.

Pecten, sp. ind.

Two species are represented by single valves. First valve has 14 broad, flattened ribs, averaging 3 millim. in width at the lower margin, crossed by fine concentric lining.

Second valve is very convex; marked by 20 strong, rather acute ribs; spaces between them narrow. Whole surface marked by strong concentric lines.

First,	Length, 41·4 millim.	Breadth, 44·1 millim.
Second,	" 39·2 "	" 39·6 "

Ostrea, sp. ind., A.

A badly worn valve of this genus is remarkable for its great weight, 5 lbs. 6 oz., and when perfect must have weighed over 6 lbs.

The depression for the animal is long and narrow; muscular scar deeply impressed. The length of this specimen is over 20 centim.; breadth 12·70 centim.; altitude of single valve 8·89 centim.

Ostrea, sp. ind., B.

Two valves were found, representing another species of this genus. Shell is very narrow and long; ligament scar broad and furrowed. Length 144· millim.; breadth 54·2 millim.

Anomia, sp. ind.

Single broken valves of a species of this genus occur in moderate abundance, but without characters for determination.

EXPLANATION OF PLATES.

Plate VI.

Figure 1.—*Calliostoma noduliferum* Nelson.
Figure 2.—*Callopoma lineatum* Nelson.
Figure 3.—*Aphera Peruana* Nelson.
Figure 4.—*Polinices subangulata* Nelson, young.
Figure 5.—*Marginella incrassata* Nelson. The upper fold of the columella is not shown; the edge of the outer lip in perfect specimens is evenly rounded.
Figure 6.—*Marginella incrassata* Nelson, dorsal view.
Figure 7.—*Cancellaria Larkinii* Nelson.
Figure 8.—*Cancellaria Bradleyi* Nelson.
Figure 9.—Dorsal view of the same.
Figure 10.—*Cancellaria triangularis* Nelson.
Figure 11.—*Solarium sexlineare* Nelson.
Figure 12.—*Polinices subangulata* Nelson.
Figure 13.—Ventral view of the same.

Plate VII.

Figure 1.—*Argobuccinum Zorritensis* Nelson.
Figure 2.—Ventral view of the same.
Figure 3.—*Cuma alternata* Nelson.
Figure 4.—Dorsal view of the same.
Figure 5.—*Arca Larkinii* Nelson. The umbos are denuded, showing thin, acute ribs.
Figure 6.—Lateral view of the same, in perfect preservation.
Figure 7.—Interior of the same. The ligament area is denuded, showing radiating striæ.
Figure 8.—*Leda acuminata* Nelson.
Figure 9.—*Crassatella gibbosa* Sowerby.

All the figures are natural size, from photographs made by Mr. Sidney I. Smith.

ERRATA.

Page 1, line 13, for "Flordia." read Florida.
" 11, " 35, " "immargination," read emargination.
" 16, " 26, " "spistome," read epistome.
" 31, " 18, " "*Podopthalmia*," read *Podophthalmia.*
" 35, " 9, " "*Eucrete*," read *Eucrate.*
" " last line but one, for "margin," read margins.
" 106, 4 l. from foot, for *Norton Street*, read *Blake Street.*
" 108, 11 l. from foot, for *twenty rods*, read *twenty-one rods.*
" 138, line 11, for "immargination," read emargination.
" 139, " 11, " "immarginate," read emarginate.
" 153, first line of foot note, for "is marked 3," read is marked 3^e.

TRANSACTIONS

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VI. On the Direction and Force of the Wind, with the Fall of Rain and Snow, at Wallingford, Connecticut, from Observations made by Benjamin F. Harrison, M.D., and reduced by Francis E. Loomis, Ph.D.

Read Jan. 18th, 1871.

The observations described in the following Article were made at Wallingford, Conn., a town situated about twelve miles north of New Haven, in lat. 41° 29′ N., long. 4^h $51\frac{3}{4}^m$ W. of Greenwich. The apparatus employed in the observations was located on or in the immediate vicinity of Dr. Harrison's house, which is situated on a ridge of land extending nearly north and south, with a valley on the west. The elevation of the house above this valley is about 70 feet, and its elevation above the sea is about 130 feet. Both on the east and west sides of the valley is a moderate range of hills extending nearly north and south. In order to indicate to what extent these hills obstruct the horizon of Dr. Harrison's house, the angular elevation of the most prominent points was measured with a small graduated quadrant furnished with a plumb line, and the following is the result:—

Direction.	Distance.	Angular elevation.	Direction.	Distance.	Angular elevation.
North.	7 miles.	2°	S.S.E.	1¼ miles.	2¼°
N.E.	1¼ "	2	S.W.	4 "	2
E. by N.	4 "	1¾	W.N.W.	1¼ "	2½
East.	1¼ "	2			

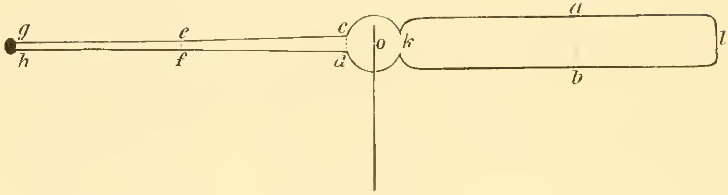
Within about one hundred feet of the house on the south side, is a small church, but the ridge of the roof is less elevated than the vane and anemometer. These facts indicate that the vane employed in the following observations had a pretty fair exposure, and it is inferred that the direction of the wind was not greatly influenced by the neighboring inequalities of the earth's surface.

Direction of the Wind.

The direction of the wind was measured by a self-recording vane having a general resemblance to that employed by Dr. Charles Smallwood,* of Montreal, but with some modifications by Dr. Harrison.

* A description of Dr. Smallwood's meteorological observatory and apparatus is contained in the Smithsonian Report for 1856, p. 311.

The following figure shows the form of the vane,



and its dimensions are as follows:—

Length, g to $l = 10$ ft. 8 in.; o to $l = 5$ ft. 3 in.
Breadth, $ab = 10$ in.; $cd = 3$ in.: $ef = gh = 1\frac{1}{2}$ inch.
Thickness, g to $k = 1\frac{1}{4}$ inch.; k to l tapers to $\frac{1}{4}$ inch.

The vane is of hard wood, and balanced by a leaden ball at gh. It was elevated about 50 feet from the ground, and supported by a mast erected on the back part of the house; while the shaft passed vertically through the roof down to a closet conveniently situated for observation. A vertical cylinder, 3 ft. 8 in. high and $2\frac{3}{4}$ inches in diameter, was firmly attached to the shaft, so as to follow its slightest motion. Near the cylinder was placed a seven-day clock, whose weight (a loaded box descending in a groove) carried a pencil through a vertical height of 42 inches in seven days, being at the rate of one-fourth inch per hour. The pencil was pressed by a spring against a paper pasted upon the the cylinder, and when the cylinder was stationary described a vertical line upon the paper. The vertical motion of the pencil combined with the movement of the cylinder when the wind was irregular, traced a zig-zag line upon the paper. The direction of the meridian was determined by setting up a series of stakes in the range of the pole star. These observations were made with the naked eye, and no care was taken to select the instant when the pole star was on the meridian. The error arising from this latter source might amount to two degrees. The vane having been set in the meridian, the points of the compass were marked upon the cylinder, and thus the directions denoted by the zig-zag line could be readily determined.

The observations on the direction of the wind commenced July 1st, 1857, and were continuous to June 9th, 1862. From July, 1857, to January, 1859, only the eight cardinal points were employed by Dr. Harrison in the copy of his record from which the following reductions were made; but from January, 1859, to June, 1862, sixteen points were employed. To determine the mean direction of the vane for each hour during each month of the year, the number of hours that each direction occurred during the month for the first hour, for the second hour, etc., was counted, and the sum of the corresponding numbers for the five years was taken. These numbers are given in Table I.

[See Table I, pages 212–225.]

In order to deduce from these numbers the mean direction of the wind, the sums of the hours during which each wind prevailed were regarded as distances traveled, and the numbers were resolved into two rectangular components by means of a traverse table, in the same manner as we resolve a traverse in navigation. The sum of all the southerly motions was then subtracted from the sum of all the northerly; also the sum of all the easterly motions from the sum of all the westerly; and the resulting direction was obtained by the principles of trigonometry. A similar computation was made for each of the twenty-four hours for each month. The results are given in Table II.

[See Table II, page 226.]

In order to exhibit the results of this Table palpably to the eye, the numbers are represented by curved lines on Plate VIII. Beginning with January, the wind's direction at 1 A.M. was set off with a protractor, and a line drawn $\frac{1}{6}$ inch in length; from the extremity of this line the wind's direction at 2 A.M. was set off, and another line drawn of the same length as before; and in the same manner were set off the directions for each of the 24 hours. Thus we obtain a broken line which may be regarded as representing the average progress of a particle of air for each hour of the day through the month of January, supposing the wind's velocity to be the same at all hours. In like manner the curves for each of the 12 months were constructed. The points of the compass are indicated upon the margin of the chart.

These curves show a decided diurnal change in the direction of the wind for each month of the year; while for the six warmer months the diurnal change is unexpectedly large. The following comparison with similar observations made at Hudson, Ohio, Philadelphia, Penn., and Toronto, Canada, will show the remarkable character of these results. From a discussion of seven years' observations at Hudson, Ohio,* Prof. E. Loomis obtained for the mean direction of the wind at 9 A. M. and 3 P. M. for each of the twelve months, the results given in the first half of Table III. In the last half of the same Table are given the corresponding results for Wallingford.

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* Am. Jour. Science, vol. xlix, 1845, p. 276.

Table I.—*Direction of the Wind, Wallingford, Conn.*

JANUARY.

	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
North.																								
1858	11½	12	12	12	14	15	14	14	15	15	14	10	11	11½	9	7½	9	11	9	8½	8	9	10	11
1859	7	7	7	7	5	5	6	7½	9	7	6½	5	5	4	4	4	4	4	6	6	5	6	4½	4
1860	5	6	7	7	6	6	6	5	4	4	5	4	4	4	4	3	3	2	3	4	5	4	4	5
1861	10	10	10	11	12	13	10	10	9	7	6	6	6	6	6	7	7	7	6	5	5	6	6	7
1862	5	5	5	6	6	5	5	5	6	6	6	6	6	6	6	7	7	7	8	7	9	7	6	6
Sum	38½	40	41	43	43	44	41	41½	43	39	37½	31	32	31½	29	28½	30	31	32	30½	32	32	30½	33
North-north-west.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	1	1	1	1	4	4	2	3	2	2	2	3	2	2	2	2	3	3	2	1	2	2	4	4
1860	5	4	3	3	4	3	3	3	3	2	2	3	4	4	3	4	1	1	1	2	2	2	3	3½
1861	4	3	3	2	2	2	4	4	4	4	4	3	2	2	2	1	1	2	2	3	3	4	6	7
1862	6	7	7	7	6	6	7	8	8	8	8	7	7	7	7	7	7	6	5	6	3	4	5	4
Sum	16	15	14	13	16	15	16	18	17	16	16	16	15	15	14	14	12	12	10	12	10	12	18	18½
North-west.																								
1858	3	2	2	3	2	2	2	3	2	2	2½	5	5	2½	3½	3	3	4	4	4	4½	5	4	4
1859	1	1	1	0	0	1	1	1	1	1	1	1	1	2	2	2	1	1	0	0	0	0½	1	1
1860	1	1	2	2	2	3	3	4	3	3	3	3	3	3	3	3	4	4	3	2	1	3	3	1
1861	4	4	3	4	4	4	3	3	4	5	5	4	2	2	3	3	3	2	3	3	5	4	3	3
1862	3	3	3	2	3	3	3	3	3	3	3	4	4	4	4	4	4	4	3	3	6	6	6	6
Sum	12	11	11	11	11	13	12	14	13	14	14½	17	15	13½	15½	15	15	15	13	12	16½	18½	17	15
West-north-west.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	4	4	4	5	3	2	3	3	3	2	3	3	3	3	2	2	2	2	2	2½	1	1	1	1
1860	2	2	1	1	2	2	2	0	0	0	2	2	2	2	2	2	2	2	2	1	1	2	3	3
1861	3	3	3	3	3	3	4	4	4	3	3	4	5	6	5	5	4	4	3	3	3	3	3	3
1862	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Sum	11	11	10	11	10	9	11	8	8	6	9	10	11	12	10	10	9	9	8	7½	6	7	8	8
West.																								
1858	5½	6	6	5	3	3	4	2½	1	1	1	3	2	2	1½	1	1	0	0	0	0½	0	2	4
1859	0	0	0	0	0	0	1	0	0	0	0½	1	0½	1½	1	1	1	1	1	1	1	0	0	0
1860	1	2	2	1	0	1	1	1	2	1	1	1	1	1	1	1	0	0	0	1	1	1	0	0
1861	2	2	2	2	2	1	1	1	1	1	0	0	2	2	3	3	4	4	4	4	2	2	2	2
1862	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	8½	10	10	8	5	5	7	4½	4	3	2½	5	5½	6½	6½	6	6	5	5	6	4½	3	4	6
West-south-west.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0	0	0	0	0	0	0	0	0½	1	1	1	2	2	2	2	1½	1	1	1	1	1	1
1860	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1861	0	0	1	1	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
1862	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
Sum	0	0	1	2	3	2	2	3	2	2½	3	3	3	3	3	3	3	2½	2	2	3	2	2	2
South-west.																								
1858	5	6	6	5	5	5	3	4½	6	6	5½	2	4½	4	4	7	7	8	10	10	8	8	7	4
1859	3	3	3	3	3	3	3	3	2	3	3	3	5	3½	4	4	4	2	2	2	3	2½	2½	3
1860	5	4	4	4	5	5	5	5	6	7	6	6	5	5	4	4	4	4	4	4	3	3	3	4
1861	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1
1862	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	14	13	13	12	13	13	11	12½	14	16	15½	12	15½	13½	13	16	16	15	17	17	14	14½	13½	12
South-south-west.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	5	5	4½	4	5	5	5	5	5	4	4	4	4	5	5	5	6	6	5	6	7	7	6½	6
1860	4	5	5	4	4	4	6	6	4	4	4	4	5	5	6	6	7	7	7	6	8	7	6	6
1861	2	2	2	2	2	3	2	2	2	2	2	4	3	3	3	3	3	3	3	3	3	3	3	3
1862	3	3	3	3	3	3	2	2	2	2	2	2	3	3	3	3	2	2	3	3	2	3	3	4
Sum	14	15	14½	13	14	15	15	15	13	12	12	14	15	16	17	17	18	18	18	18	20	20	18½	19

Table I.—*Direction of the Wind, Wallingford, Conn.*

JANUARY (continued).

	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
South.																								
1858	1	1	1½	2	2	3	3	3	3	3	3½	5	2	3	5	4	4	3	2	2	2	2	2	2
1859	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0
1860	4	4	4	5	5	4	4	4	4	4	4	4	4	4	5	5	5	5	5	6	6	5	5	4½
1861	1	2	2	2	0	0	0	0	1	2	2	2	1	1	0	0	0	0	0	0	0	0	0	0
1862	2	1	1	1	1	1	1	1	1	1	1	1	0	2	2	2	2	2	2	2	2	2	2	2
Sum	8	8	8½	10	8	8	8	8	9	10	10½	12	7	10	12	11	11	11	10	11	10	9	9	8½
South-south-east.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	½	1	1	1	1	1	1
1860	1	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1
1861	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1862	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	2	2	1	1	0	0	0	0	0	1	1	0	0	0	0	0	0	½	1	1	1	2	2	2
South-east.																								
1858	1½	1	1	2	2	1	1	½	1	1	1	1	1	3	2	2	2	2	2	2	2	2	1	1½
1859	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0
1860	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1861	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1862	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0
Sum	1½	1	2	3	2	1	1	½	1	1	1	1	1	3	3	3	4	4	4	2	2	2	1	1½
East-south-east.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1860	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	1	0	0
1861	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1862	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	0	0	0	0	1	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	1	0	0
East.																								
1858	1	1	0	1	0	0	0	½	1	1	1	1	2	0	0	1	2	1	1	1½	2	2	1	2
1859	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1860	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1861	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0
1862	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	1	1	0	1	0	1	0	½	2	2	1	1	2	0	0	2	3	2	2	2½	3	3	1	2
East-north-east.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	1	1	1	1	1	1	1	1	1	1	½	0	0	0	0	0	0	0	0	0	0	0	0	0
1860	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	1	0
1861	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0
1862	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	1	1	1	1	1	1	1	1	1	1	½	0	1	1	1	0	0	1	1	1	1	0	1	0
North-east.																								
1858	2½	2	2½	2	3	2	4	2½	2	2	2	4	4	5	6	4½	3	3	3	3	4	3	3	2½
1859	0	0	0	0	0	1	2	1½	1	0½	0	0	1	1	1	1	1	1	1	1	2	2	1	1
1860	1	1	1	2	2	2	1	1	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1861	0	0	0	0	2	1	1	1	2	1	1	2	1	1	0	0	0	0	0	0	0	0	1	0
1862	2	2	2	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1
Sum	5½	5	5½	5	8	7	9	7	8	6½	5	8	8	8	8	6½	5	5	5	6	8	7	7	5½
North-north-east.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	8	8	9	9	9	8	7	6	7	9	9½	10	8½	7	7	7	6	7	7	8	8	8	8½	9
1860	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	3	3	3	2	1	1	1	1
1861	4	5	5	4	2	3	5	5	4	6	6	5	7	6	7	7	7	7	8	8	7	7	6	5
1862	8	8	8	8	8	9	9	9	8	8	8	8	8	8	8	7	7	8	8	8	7	7	7	7
Sum	21	22	23	22	20	21	21	21	20	24	24½	24	24½	22	23	22	23	25	26	26	23	23	22½	22

Table I.—*Direction of the Wind, Wallingford, Conn.*

FEBRUARY.

	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
North.																								
1858	13	13	12½	10½	10	10	10½	11	11	10	9	8	7	9	10	8	8	9	9	10	9½	11½	13	13
1859	4	6	6	6	5	4	4	4	5	7½	7	6	5	3	3	2½	3	3	3	3	3	3	3	3
1860	6	7	3	5	3	4	4	2	2	1	2	2	1	1	2	3	4	5	5	6	7	8	7	7
1861	4	4	3	4	4	3	4	3	2	2	2	1	1	1	1	2	2	1	2	2	3	2	2	3
1862	4	4	5	5	12	13	10	8	7	7	7	7	8	8	4	4	4	4	3	3	3	3	4	4
Sum	31	34	29½	30½	34	34	32½	28	27	27½	27	24	22	22	20	19½	21	22	22	24	25½	27½	29	30
North-north-west.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	1	1	1	1	2	2	2	2	2	0	0	1	0½	2	2	2	2	2	2	1	1	1	0	1
1860	3	1	2	1	5	6	5	5	4	3	2	1	2	2	3	2	2	2	2	1	0	1	1	1½
1861	1	1	1	1	1	2	3	3	4	4	4	3	2	2	2	1	1	1	1	1	2	3	2	1
1862	4	4	3	3	2	2	4	5	6	6	6	5	3	5	5	5	4	4	5	5	5	6	6	5
Sum	9	7	7	6	10	12	14	15	16	13	12	10	7½	11	12	10	9	9	10	8	8	11	9	8½
North-west.																								
1858	5½	5	6½	8	6	6½	5½	4	5	8½	7	7	7½	7	7	9½	11½	11	10	8	8½	7½	6½	7
1859	1	1	1	2	1	2	1½	0	1	1	1	1	1	1	1	2	2	1	2	2	2	2	2	1½
1860	1	1	1	2	1	2	2	2	3	3	4	5	5	5	4	5	4	3	3	4	3	2	2	1
1861	3	3	5	4	3	1	1	1	2	2	2	3	4	4	4	4	5	6	5	5	4	4	5	6
1862	6	6	7	7	6	5	5	5	5	6	8	8	6	4	4	4	7	7	7	7	6	6	6	6
Sum	16½	16	20½	23	17	16½	15	12	16	20½	22	24	23½	21	20	24½	29½	28	27	26	23½	21½	21½	21½
West-north-west.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	1	1	1	1	2	2	2½	3½	2	2	2	3	3	3	5	5	5	4½	2	2	1	1	1	1½
1860	0	1	2	3	3	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
1861	1	1	2	2	2	4	4	3	3	4	4	4	2	2	3	3	3	2	2	2	0	0	0	0
1862	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0
Sum	3	4	6	7	7	6	6½	6½	5	6	6	7	6	6	9	9	10	8½	5	5	2	1	1	1½
West.																								
1858	3½	4	3½	4½	7	8	6	5	4	1½	3	3	4½	4	6	4½	2½	2	2	2	2	1	2½	2
1859	0	0	0	0	0	0	0	0½	0½	0	0	0	0	1	0½	0	0	1	0	1	0	0	0	0
1860	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	1	2
1861	4	5	4	3	3	3	3	4	4	3	4	4	5	5	3	3	4	4	2	2	3	2	2	2
1862	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	2	1	1	1	1	0	0	0	0
Sum	8½	10	7½	7½	10	11	9	9½	8½	5½	7	7	10½	11	11½	9½	7½	8	6	6	5	4	5½	6
West-south-west.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0	0½	1	1	0	0	0	0	0	0	0	2	1	0	0	0	0	1½	1	2	1	1	2
1860	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	1	1	1	2	0	0	0	0
1861	2	2	1	2	2	2	2	2	1	1	0	1	0	0	0	0	0	0	0	0	2	2	2	2
1862	2	2	2	2	2	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	0	1	2
Sum	4	4	4½	6	5	3	3	4	2	2	0	1	2	1	0	0	1	1	2½	4	5	3	4	6
South-west.																								
1858	2	2	2	2	2	2	2	2½	5	3	3½	4	3½	4	2	2	2	2	2	3	3	2	0	0½
1859	0	1	1	0	0	1	1	0½	1½	1	2	3½	2	3	3	2	2	1	1	2	1½	1	1	1
1860	4	3	3	1	1	1	2	3	4	4	4½	6	7	7	7	7	5	6	7	7	9	7	6	4½
1861	1	1	1	1	2	2	2	2	2	3	2	1	1	1	2	2	1	1	1	2	1	2	2	1
1862	1	1	0	0	0	0	0	0	1	1	0	0	1	2	3	3	3	3	3	3	3	1	0	0
Sum	8	8	7	4	5	6	7	8	13½	12	12	14½	14½	17	17	16	13	13	14	17	17½	13	9	7
South-south-west.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	5	4½	3	3	2	2	3	2½	2	2	2	1	1	1	1½	2	2	3	4	4	4½	6	6	5
1860	3	3	2	2	2	2	1	1	1	2	2	1	1	1	1	1	1	2	2	2	2	2	2	3
1861	5	4	4	5	4	4	3	3	3	3	5	7	9	9	9	9	8	7	8	7	7	6	6	6
1862	1	1	1	1	1	1	1	2	1	0	0	0	0	1	1	1	0	0	0	1	1	2	2	3
Sum	14	12½	10	11	9	9	8	8½	7	7	9	9	11	12	12½	13	11	12	14	14	14½	16	16	17

Table I.—*Direction of the Wind, Wallingford, Conn.*

FEBRUARY (continued).

	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
South.																								
1858	1	1	1	1	1	1	1	2½	1	2	2	2	2	1	1	2	2	2	3	3	3	4	4	3½
1859	5	3	2½	2	2	2	2	3	2	2	2½	2	2	1	1	1	1	1½	1½	1	1	1	1	2
1860	1	1	3	2	2	2	3	3	3	2	1½	1	0	1	1	1	1	1	1	1	1	1	2	2
1861	2	2	3	2	2	2	2	2	2	2	1	1	1	1	1	1	1	2	2	2	2	3	3	3
1862	1	1	1	1	1	2	2	0	0	0	0	0	1	1	1	1	1	1	1	0	0	1	1	1
Sum	10	8	10½	8	8	9	10	10½	8	8	7	6	6	5	5	6	6	7½	8½	7	7	10	11	10½
South-south-east.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0½	1	1	1	1	1	1	0	1½	1½	0½	1	1	1	1	1	1	1	1	2	1½	1	0
1860	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0
1861	1	1	1	1	2	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2
1862	2	2	1	1	0	0	0	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0
Sum	3	3½	3	3	3	3	2	3	2	2½	2½	2½	2	2	3	3	3	3	3	2	4	3½	3	2
South-east.																								
1858	1	0	0	0	0	0	1	½	0	0	0	1	1	2	2	2	2	2	1	0	0	0	0	0
1859	0	0	0	0½	1	1	0	0	1	1	0	0	0½	2	1	1	1	1	1	1	1	1	1	0
1860	1	2	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
1861	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0
1862	0	0	0	0	0	1	1	0	0	0	0	0	0	0	2	2	2	2	2	2	2	3	3	3
Sum	2	2	1	1½	2	3	3	½	1	1	0	1	1½	4	5	5	5	5	5	4	4	5	5	4
East-south-east.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1860	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0
1861	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
1862	1	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
Sum	2	2	0	0	0	0	0	1	1	0	1	1	1	1	1	1	1	1	1	0	1	2	1	1
East.																								
1858	1	2	1½	1	0	0	0	0	0	0½	1	0	0	0	0	0	0	0	0	1	1	1	1	1
1859	1	1	2	1½	2	2	1	1	2	1½	1	1	0	0	0	0	0	0	0	0	0	0	0½	1
1860	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0
1861	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
1862	2	1	1	0	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	1
Sum	4	4	4½	2½	3	2	1	1	2	2	2	1	0	0	1	1	1	1	1	3	2	2	2½	4
East-north-east.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0	0	0	0	0	0½	1	2	1½	1	0	1	1	1	1	1	1	1	1	1	1	0	1
1860	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	1
1861	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
1862	0	0	1	0	0	0	0	0	0	0	0	1	2	1	0	0	0	0	0	0	1	0	0	0
Sum	1	1	2	1	1	1	1½	1	2	1½	1	1	3	2	1	2	1	1	1	2	3	1	1	2
North-east.																								
1858	1	1	1	1	2	1½	1	1½	2	2½	2½	3	3	1	0	0	0	0	1	1	1	1	1	1
1859	2	2	0½	0	0	0	1	1	0½	0	0	2	2	0	1	1	1	1½	2	2	2	2	2½	2
1860	4	4	6	6	6	7	7	7	7	7	7	6	6	5	5	4	4	3	3	3	3	3	3	3
1861	1	1	1	1	2	2	1	1	1	1	1	0	0	0	0	0	0	1	1	2	2	2	2	2
1862	1	2	1	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	2	2	0
Sum	9	10	9½	9	10	10½	10	10½	10½	11½	11½	12	12	7	7	6	6	6½	8	9	9	10	10½	8
North-north-east.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	7½	7	8½	9	9	9	8½	8	6½	7	8	7	7	8	7	7½	7	6½	6	6	6	6½	8	7
1860	5	5	5	5	4	3	3	5	5	6	5	5	5	5	4	3	4	3	2	2	2	2	3	3
1861	1	1	1	1	1	1	2	3	3	3	3	3	3	3	3	3	3	3	3	1	0	0	0	0
1862	2	2	4	6	3	3	4	5	5	5	5	5	4	3	2	2	2	2	2	2	2	2	1	2
Sum	15½	15	18½	21	17	16	17½	21	19½	21	21	20	19	19	16	15½	16	14½	13	11	10	10½	12	12

Table I.—*Direction of the Wind, Wallingford, Conn.*

MARCH.

	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
North.																								
1858	6	6	6	6	5	6	5	7	5½	9	10	8	7	7	5½	2½	3	3	4	6	6	6	6	6
1859	6	7½	7½	9	9	7	9	11	11	9	9	8½	4	4	3	3	3	2	2	2	3	4	5	4
1860	6	5	4	5	4	4	4	7	6	4	5	4	5	3	2	1	1	1	1	2	6	7	8	7
1861	7	7	6	7	7	7	7	8	7	7	5	5	2	2	1	1	2	1	4	3	2	2	3	4
1862	8	8	8	9	9	8	8	7	7	8	9	9	9	8	7	7	7	7	6	4	4	4	5	6
Sum	33	33½	31½	36	34	32	33	40	36½	37	38	34½	27	24	18½	14½	16	14	17	17	21	23	27	27
North-north-west.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	4	4	2	1	2	2	1	1	2	3	3	3½	5	5	5	5	5	5	5	5	5	4½	4	4
1860	5	6	7	5	6	7	7	5	4	7	7	6	6	6	5	6	6	6	8	8	5	5	3	3
1861	4	5	5	4	4	4	4	4	6	6	5	5	6	6	6	6	7	7	6	5	5	5	5	4
1862	6	6	6	6	6	6	6	5	5	4	3	3	2	2	3	4	5	5	5	7	8	8	8	8
Sum	19	21	20	16	18	19	18	15	17	20	18	17½	19	19	19	21	23	23	24	25	23	22½	20	19
North-west.																								
1858	10½	9	9½	10½	13½	12	13	11½	12	10½	11	12	15	15	15½	15½	15	13	13	13½	10½	11	10	10
1859	3	2½	4	3	3	4	2	2	2	2	2	1	3	3	3	3	3	3	4	4	5	6	5	6
1860	3	3	2	3	1	3	3	3	5	5	5	6	6	6	7	6	7	6	4	3	2	2	1	2
1861	1	1	1	1	1	1	1	1	2	2	3	3	2	2	2	3	3	2	3	3	3	2	2	2
1862	4	4	5	5	5	5	5	7	7	7	8	9	9	9	8	8	6	6	6	5	5	5	4	3
Sum	21½	19½	21½	22½	23½	25	24	24½	28	26½	29	31	35	35	35½	35½	34	30	30	28½	25½	26	22	23
West-north-west.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	2	2	2	2	2	2	4	4	4	5	5	5	4	3	3	3	2	2	3	3	1	0	0	0
1860	0	0	1	1	1	3	3	4	3	2	2	1	1	1	1	1	1	2	3	3	1	1	1	1
1861	2	2	2	3	4	5	4	3	2	2	2	2	3	3	4	3	2	3	2	1	1	2	2	2
1862	0	1	1	0	0	0	0	1	2	2	2	2	3	3	3	3	3	3	3	3	3	2	2	2
Sum	4	5	6	6	7	10	11	12	11	11	11	10	11	10	11	10	8	10	11	10	6	5	5	5
West.																								
1858	3	4	4	4	4	4	4	4½	5	5½	4	4	3	2½	1½	2	1	3	2½	1½	3	2	3	3
1859	1	1	0	1	1	1	1	1	1	1	0	1	1	2	1	1	2	2	2	1	1	1	1	1
1860	1	1	1	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	3
1861	1	1	1	1	1	1	1	0	0	0	0	0	3	3	1	1	1	1	1	2	1	0	0	0
1862	1	1	1	1	1	1	1	2	2	1	2	2	1	0	0	0	2	2	1	2	2	1	1	1
Sum	7	8	7	9	8	8	8	7½	8	7½	6	7	8	7½	3½	4	6	8	6½	6½	7	5	8	8
West-south-west.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0	1	1	1	1	1	1	0½	0	1	1	0	1	2	2	2	3	2	0	0	0	0	0
1860	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
1861	2	0	0	0	0	0	1	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	2	3
1862	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	1	1	1	0	0	0
Sum	3	1	2	2	2	2	4	4	2½	2	2	2	1	2	5	5	3	4	4	2	3	1	2	3
South-west.																								
1858	1½	1	1½	1	0½	0½	1	1	2	1	2	2	3	3½	4	4	3½	3	1½	2	2	1	1½	2
1859	0	0	0	0½	2	2	2	2	2	2	3	3	4	3	2	2	1	1	1	1	1	2	2½	1
1860	3	4	3	3	4	2	2	2	3	4	5	6	6	7	7	6	4	4	4	3	3	2	3	2½
1861	1	0	0	0	0	1	1	2	1	1	1	2	1	1	1	1	2	2	2	1	2	2	1	0
1862	3	2	2	2	3	3	2	1	0	0	0	0	1	1	1	1	0	0	1	0	0	1	1	1
Sum	8½	7	6½	6½	9½	8½	8	8	8	8	11	13	15	15½	15	14	10½	10	9½	7	8	8	9	6½
South-south-west.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	2	2	2	1	1	1	1	1	0½	0	0	0	1	1	1	1	1	2	2	4	3	1	1	1
1860	7	6	6	5	5	5	4	4	3	2	2	3	3	4	4	4	4	4	5	6	6	7	6	7
1861	4	5	5	6	6	5	5	5	6	6	6	5	5	5	5	5	5	5	2	3	4	3	3	4
1862	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3	3	3	2	3	2	2
Sum	13	13	13	12	12	11	10	10	9½	8	8	8	9	10	10	11	12	14	12	16	15	14	12	14

Table I.—*Direction of the Wind, Wallingford, Conn.*

MARCH (continued).

	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
South.																								
1858	7	8½	8	7½	7	6½	6	4	3	4	2	2	2	2	2½	3	5½	6	7	6	6	6½	6½	7
1859	4	5	4	3½	2	1	1	2	3	4	2	3	3	3	4	4	4	4	3	4	5	5	5	5
1860	1	1	1	1	2	1	1	1	1	0	1	1	2	2	3	4	3	4	2	2	2	2	2	1½
1861	5	4	4	3	3	2	2	2	1	1	2	2	2	2	2	2	3	3	5	5	4	6	5	4
1862	2	2	2	2	1	1	1	2	3	3	3	2	2	2	2	1	1	1	1	1	1	1	2	2
Sum	19	20½	19	17	15	11½	11	11	11	12	10	10	11	11	13½	14	16½	18	18	18	18	20½	20½	19½
South-south-east.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	2	2	2	3	3	3	3	3	4	3	3	2	2	2	2	2	2	2	2	2	2	2	2	3
1860	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	2	1	1	1	1	1	1	0
1861	0	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	2	2
1862	1	1	1	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1
Sum	3	4	4	6	4	4	4	3	5	6	5	3	3	3	3	3	4	3	3	3	3	4	6	6
South-east.																								
1858	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1½	1	1	1	1½	2	1½	1
1859	4	2	2	1	1	0	0	0	0	0	2	2	2	3	4	4	5	4	4	4	4	3½	2½	2
1860	0	0	1	0	1	0	0	1	1	1	1	1½	1	1	1	1	1	0	1	1	1	1	1	1
1861	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1862	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0
Sum	6	5	5	3	2	0	0	1	1	1	3	3½	4	5	6	7	8½	6	7	7	6½	6½	5	4
East-south-east.																								
1858	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	1	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
1860	1	1	1	1	1	2	2	0	0	0	0	0½	0	0	0	0	0	0	0	0	1	1	0	0
1861	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1862	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	1	2	2	1	2	4	4	2	3	1	1	1½	1	1	1	1	1	0	0	0	1	1	0	0
East.																								
1858	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0	0	0	0	1½	2	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
1860	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
1861	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1862	0	0	0	0	0	1	0	0	0	0	0	0	0	2	2	1	1	0	0	0	1	1	1	1
Sum	0	1	1	1	1	3½	4	2	1	2	1	1	0	2	2	1	1	2	0	0	1	1	1	1
East-north-east.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1
1860	1	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	1	0	0	0	0	1	2
1861	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
1862	2	2	2	2	2	2	2	1	1	1	1	1	1	2	2	1	1	1	1	2	2	2	2	2
Sum	3	2	2	3	2	2	2	1	1	1	2	2	2	2	2	1	1	2	2	2	2	4	4	5
North-east.																								
1858	2	1½	1	1	1	1	1	2	2½	1	1	2	0	0	1½	3	2	2	2	1	2	1½	2	2
1859	1	0	0½	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
1860	1	1	1	1	1	0	0	1	0	1	0	0	0	1	1	2	2	1	1	1	1	1	1	1
1861	1	1	0	1	1	1	1	1	0	0	1	1	0	0	0	0	0	0	0	1	1	2	2	2
1862	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Sum	7	5½	4½	6	6	5	4	6	4½	4	4	5	2	3	4½	7	6	5	5	5	6	6½	8	9
North-north-east.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	2	2	3	3	3	4	4	3	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
1860	1	2	2	2	3	2	2	2	4	3	1	1	0	0	0	0	0	0	1	1	1	0	0	0
1861	3	3	4	2	2	2	2	2	2	3	4	4	5	5	6	6	5	6	5	6	7	5	4	4
1862	1	1	1	1	1	1	2	2	2	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0
Sum	7	8	10	8	9	9	10	9	8	8	6	6	6	5	6	6	5	6	6	8	9	6	5	5

Table I.—*Direction of the Wind, Wallingford, Conn.*

APRIL.

	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
North.																								
1858	3	4	6	6	4	4	5½	8½	9½	11	10½	9	8	6½	6	5	2½	3	2½	2	2½	3½	2	3
1859	5	6	8	8	8	8	7	7	7	7	7	7	5	4	1	2	2	2	2	1	1	1	2	5
1860	6	6	7	8	7	7	6	8	7	6	5	3	1	1	1	1	1	0	2	2	3	3	4	5
1861	4	4	3	3	5	4	4	4	5	3	2	2	0	0	0	0	0	0	0	2	2	3	4	4
1862	8	10	12	12	11	10	10	9	10	7	6	4	3	2	2	1	2	1	2	3	3	4	4	4
Sum	26	30	36	37	35	33	32½	36½	38½	34	30½	25	17	13½	10	9	7½	6	8½	10	11½	14½	16	21
North-north-west.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2	3	3	3	2	2	1
1860	3	3	3	2	2	2	2	2	4	5	5	8	8	7	7	7	7	8	9	10	9	7	5	4
1861	1	1	1	2	1	1	1	2	2	2	1	1	3	3	4	4	4	4	4	2	1	2	1	0
1862	3	3	2	2	2	2	2	1	1	1	1	1	1	2	2	3	5	6	5	5	6	5	5	5
Sum	8	8	7	7	6	6	6	6	8	9	8	11	13	13	15	16	19	20	21	20	19	16	13	10
North-west.																								
1858	10	9½	8½	8½	8	8	7	7	7	7	6	6½	6	6	7	7	9	9½	10	12	12	12½	11½	12
1859	6	6	5	5	5	5	6	6	6	6	5	5	5	6	6	6	7	8	8	8	6	6	6	6
1860	1	2	3	0	1	1	1	1	0	0	1	1	1	1	1	1	1	3	1	0	0	0	0	0
1861	0	1	1	1	1	1	1	1	3	3	4	4	4	4	4	4	4	4	6	5	5	3	2	1
1862	1	1	1	1	1	1	1	2	2	3	4	5	4	4	4	4	2	1	2	1	1	1	1	1
Sum	18	19½	18½	15½	16	16	16	17	18	19	20	21½	20	21	22	22	23	25½	27	26	24	22½	20½	20
West-north-west.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	5	4	4	4	4	4	5	5	5	6	7	7	7	6	6	4	3	3	3	3	4	4	4	4
1860	0	0	0	2	0	1	1	1	2	2	3	1	1	1	1	0	0	0	0	0	0	1	0	0
1861	0	0	0	0	0	0	0	1	2	2	1	2	1	1	1	1	1	1	0	0	0	0	0	0
1862	0	1	1	1	1	1	1	1	1	1	1	1	2	2	3	1	1	1	0	0	0	0	0	0
Sum	5	5	5	7	5	6	7	8	10	11	12	11	11	10	11	6	5	5	3	3	4	5	4	4
West.																								
1858	2	3	4	4	5	3½	3	4	5	4	6	6	4½	4	3	5	5	4	3½	2	3	2	3½	2½
1859	1	2	2	2	3	2	2	2	2	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0
1860	0	0	0	1	1	0	1	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0
1861	1	1	1	2	2	2	2	3	3	3	3	2	2	2	1	1	1	1	1	1	0	0	1	1
1862	0	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Sum	4	7	7	9	11	7½	8	10	11	8	10	9	6½	7	5	8	8	7	5½	3	3	2	4½	3½
West-south-west.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1
1860	0	0	0	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
1861	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0
1862	0	0	0	.0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	0	0	0	0	1	3	2	2	2	2	2	2	2	2	1	1	1	1	0	1	2	2	2	1
South-west.																								
1858	2	0	0	0	0½	1	0	0	0	0	0	0½	2½	2½	2½	2	1	2½	3	4	3	3	0½	1
1859	1	1	2	2	1	1	0	0	0	1	0	0	0	2	4	4	3	3	1	1	0	0	0	1
1860	2	3	2	1	3	1	1	2	1	2	2	2	3	4	4	5	7	5	5	4	3	3	4	4
1861	2	2	2	2	2	2	2	1	1	0	0	0	0	0	1	2	2	2	2	1	1	1	1	2
1862	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0
Sum	8	6	6	5	6½	6	4	3	2	3	2	2½	5½	8½	11½	14	14	13½	12	10	7	7	5½	8
South-south-west.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	2	2	0	0	0	0	0	0	0	0	1	1	2	2	4	5	6	5	5	4	3	4	3	2
1860	7	6	6	6	6	6	5	3	3	2	2	2	2	2	3	3	3	4	5	4	5	5	4	4
1861	3	2	3	3	2	2	2	2	1	1	1	2	2	2	2	2	2	2	2	4	5	5	4	3
1862	3	3	3	3	3	3	4	4	4	5	5	5	6	6	5	6	6	6	4	4	3	2	3	3
Sum	15	13	12	12	11	11	11	9	8	8	9	10	12	12	14	16	17	17	16	16	16	16	14	12

TABLE I.—*Direction of the Wind, Wallingford, Conn.*

APRIL (continued).

	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
South.																								
1858	9	9½	7	7	6	6	5½	4	3	3	2	2	3	5	4	6	9	7	5½	5½	5	5	7½	7
1859	2	2	2	1	1	1	1	1	2	1	1	1	0	0	0	0	0	0	1	1	2	2	3	2
1860	3	1	1	1	0	1	2	2	2	2	2	2	3	3	3	2	1	0	0	1	1	3	3	2
1861	4	4	4	3	3	4	4	2	1	1	2	2	3	4	4	4	5	5	4	4	4	3	3	3
1862	6	4	4	4	4	4	2	3	2	1	1	1	4	5	6	6	6	7	9	9	9	9	8	8
Sum	24	20½	18	16	14	16	14½	12	10	8	8	8	13	17	17	18	21	19	19½	20½	21	22	24½	22
South-south-east.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	2	2	2	3	1	1	1	1	0	0	0	0	0	0	0	0	1	2	3	3	4	4	2	2
1860	0	1	0	0	0	0	0	1	1	1	1	1	1	1	1	2	3	3	3	4	4	2	2	1
1861	3	3	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	2	3	3	3	3	4	4
1862	2	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	2	3	3	3	3
Sum	7	7	5	6	4	3	3	4	3	4	4	4	3	3	3	4	6	8	10	12	14	12	11	10
South-east.																								
1858	0	0½	1	1	1	1	1	0½	1	1	2½	3½	4½	3½	4½	2½	2	3	4	3½	2	1	0½	0
1859	2	2	2	1	2	2	2	2	1½	1	1	2	2	1	1	1	0	0	0	0	1	1	2	2
1860	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	1	1	1	1	1	1	1	1
1861	0	0	0	0	0	0	0	0	0	1	3	3	4	4	4	4	4	3	3	2	3	2	1	1
1862	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	1	1	1	1	1	1	1	1	1
Sum	5	3½	4	3	4	5	4	3½	3½	4	8½	10½	12½	10½	11½	10½	8	8	9	7½	8	6	5½	5
East-south-east.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0	0	0	0	0	0	0	0½	1	2	2	1	1	1	2	1	1	1	1	0	0	0	0
1860	0	0	0	0	0	0	0	0	0	0	1	1	1	1	2	0	0	0	0	0	0	0	0	0
1861	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
1862	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0
Sum	0	0	0	0	0	0	0	0	0½	1	4	4	3	3	4	3	2	1	1	1	0	0	1	1
East.																								
1858	2	2	2	2	2	2	3	3½	2	3	2	1½	0½	0	0	0	0	0	0	0	2	2	2	2
1859	0	0	0	0	0	0	0	1	1	1	0	0	1	0	0	0	1	0	1	1	2	1	0	0
1860	0	1	0	0	0	0	2	1	1	1	1	2	2	2	0	0	0	1	0	1	2	2	1	1
1861	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	1	1	1
1862	0	0	0	0	0	0	1	1	1	1	1	2	0	0	0	1	1	2	1	1	0	1	0	0
Sum	2	3	2	2	2	2	6	6½	5	8	5	5½	3½	2	0	1	2	3	2	3	6	7	4	4
East-north-east.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0	0	1	2	1	1	0	0	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0
1860	2	2	2	2	2	2	2	1	0	0	1	0	0	0	2	2	2	1	1	0	0	0	0	1
1861	3	3	2	2	1	1	1	2	2	2	2	2	1	1	1	1	1	1	1	1	0	0	0	0
1862	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	1	1
Sum	5	5	4	5	5	4	4	4	3	4	5	3	3	3	5	5	5	4	3	2	2	2	1	2
North-east.																								
1858	2	2	2	2	4	5	4	2½	2½	1½	1	1	1	2½	2½	2	2	1	1	1	0½	1	2½	2
1859	1	1	1	1	1	2	2	1	2	2	2	2	3	4	4	2	1	1	0	0	0	1	1	1
1860	2	3	3	3	4	3	3	2	4	4	2	3	2	2	0	0	0	0	0	0	1	2	2	4
1861	2	2	4	3	4	2	2	2	2	2	2	2	2	1	1	0	1	1	0	0	0	1	1	2
1862	0	0	0	0	0	1	1	1	1	2	1	0	0	0	0	0	0	0	1	0	0	0	2	2
Sum	7	8	10	9	13	13	12	8½	11½	11½	8	8	8	9½	7½	4	4	3	2	1	1½	5	8½	11
North-north-east.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	2	1	1	1	1	1	1	2	1	1	1	1	1	1	0	0	0	1	1	3	3	3	4	3
1860	2	2	3	4	3	4	4	5	4	4	3	3	4	3	3	3	2	2	3	3	1	1	4	3
1861	7	7	7	7	7	9	9	8	6	6	6	6	7	7	6	6	4	4	4	5	5	5	5	7
1862	5	5	5	5	5	5	5	5	5	5	4	5	5	4	3	3	3	2	2	3	2	2	2	2
Sum	16	15	16	17	16	19	19	20	16	16	14	15	17	15	12	12	9	9	10	14	11	11	15	15

Table I.—*Direction of the Wind, Wallingford, Conn.*

MAY.

	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
North.																								
1858	7	8½	10½	10½	12½	13	12	11½	9	9	8	6½	6½	6	5½	5	2	2	2	2	3½	5	6	5
1859	4	4	5	5	7	7	8	8½	4	4	4	4	4	3½	1	1	1	2	1	1	1	1	1	1
1860	2	2	3	3	5	5	6	5	4	3	2	0	0	0	0	0	0	0	1	1	1	1	1	2
1861	5	5	5	6	5	5	4	4	4	4	3	3	3	3	2	1	1	1	1	1	2	2	4	4
1862	7	9	9	9	8	8	8	9	9	8	6	5	2	2	1	1	1	2	2	2	4	4	5	6
Sum	25	28½	32½	33½	37½	38	38	38	30	28	23	18½	15½	14½	9½	8	5	7	7	7	11½	13	17	18
North-north-west.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	1	2	2	1	1	1	0½	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1860	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1861	3	3	3	3	3	3	4	3	2	2	2	2	2	3	3	3	3	3	3	3	4	4	4	4
1862	3	1	3	3	5	5	5	5	4	1	1	1	2	2	2	2	4	5	5	5	5	4	2	2
Sum	6	5	8	8	9	9	10	8½	7	4	4	3	4	5	5	5	7	8	8	8	9	8	6	6
North-west.																								
1858	5	6	5½	4½	5	5	4½	6½	7	5½	4	3½	3½	4	4	3	5½	5	4	3½	3½	4½	4	5
1859	3	2	3	3	3	3	2	1	3	2	2	3	2	2	1	1	2	1	1	1	1	1	1	1
1860	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
1861	0	0	0	0	1	1	2	3	5	5	5	5	5	6	6	7	6	6	5	5	3	2	1	1
1862	0	0	0	0	0	0	0	0	2	5	5	4	5	5	5	5	4	4	4	4	1	1	1	1
Sum	8	8	8½	7½	9	9	8½	11½	18	18½	17	16½	16½	18	17	17	18½	17	14	13½	8½	8½	7	8
West-north-west.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1
1860	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
1861	1	1	1	1	1	1	1	1	2	2	3	4	3	3	3	2	1	1	1	1	1	1	1	1
1862	0	1	1	0	0	0	1	2	1	3	4	4	3	4	3	2	2	1	1	1	2	2	2	2
Sum	1	3	3	1	1	1	2	3	3	5	7	8	6	7	7	6	5	3	2	2	4	4	4	4
West.																								
1858	2	1	1	1	0	0	0½	1	1	1	1½	1½	2	2	2	2	1	1	2	2½	3	3	1	1
1859	0	0	0	0	0	0	1	1	1	2	2	2	1	1	1	1	1	1	2	2	0	0	0	0
1860	1	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1861	0	0	1	0	0	0	0	1	1	1	1	1	0	0	1	1	0	0	1	1	1	0	0	0
1862	1	1	1	3	2	1	1	0	0	0	1	2	2	1	0	0	1	1	1	1	1	0	0	0
Sum	4	3	4	4	3	2	2½	3	3	4	5½	6½	5	4	4	4	3	3	6	6½	5	3	1	1
West-south-west.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1
1860	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
1861	1	1	1	1	2	2	2	2	2	3	3	2	2	1	0	0	1	1	1	1	1	0	0	0
1862	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Sum	2	2	1	1	2	2	3	2	2	3	3	2	2	1	0	2	1	1	1	2	3	2	2	2
South-west.																								
1858	0	0	0	0	0	0	0	1	0	2	2½	2	1½	1	2½	3	3½	2½	2½	1½	0½	0½	1	1½
1859	1	1	1	1	1	1	1	2	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0
1860	0	0	0	1	1	1	0	0	0	0	1	3	3	3	4	4	4	4	4	4	4	3	3	2
1861	2	1	1	1	1	1	0	0	0	0	0	1	2	2	4	5	5	5	2	2	2	1	1	0
1862	1	1	0	0	1	1	0	0	0	1	0	1	0	1	3	3	3	3	2	1	0	0	0	1
Sum	4	3	2	3	4	4	1	3	0	3	3½	7	7½	8	14½	16	15½	14½	10½	8½	6½	4½	5	4½
South-south-west.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	4	4	3	3	3	3	3	3	5	5	5	5	6	6	6	6	6	6	3	3	3	4	4	4
1860	5	3	2	1	0	0	0	0	1	3	4	4	5	3	5	5	5	7	7	7	6	6	5	5
1861	6	8	8	9	8	9	8	7	6	5	5	5	5	5	4	4	6	6	9	9	7	7	6	6
1862	4	3	4	4	3	5	5	8	8	4	4	4	7	8	8	8	5	5	4	5	6	4	3	3
Sum	19	18	17	17	14	17	16	18	20	17	18	18	23	22	23	23	22	24	23	24	22	21	18	18

Table I.—*Direction of the Wind, Wallingford, Conn.*

MAY (continued).

	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
South.																								
1858	8½	8½	8	5½	5½	6	5½	4½	4	5	6	7	7½	8	9½	10	10	12	13½	14	12½	10½	10	10½
1859	8	8	8	8	8	8	7	5	4	5	5	6	6	6½	8	9	9	8	11	11	10	9	9	9
1860	5	6	6	6	6	6	5	5	4	3	1	1	3	6	5	5	5	4	5	6	6	6	6	6
1861	6	6	5	4	3	2	2	2	2	1	1	1	0	1	1	2	2	2	2	2	5	7	7	7
1862	8	8	5	4	6	6	6	5	5	4	5	5	5	5	5	6	8	7	9	9	9	10	10	10
Sum	35½	36½	32	27½	28½	28	25½	21½	19	18	18	20	21½	26½	28½	32	34	33	40½	42	42½	42½	42	42
South-south-east.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	4	4	4	4	4	4	3	3	4	3	3	3	2	2	4	4	4	5	6	6	6	6	6	6
1860	3	2	2	1	1	1	1	1	1	1	3	3	3	3	4	3	4	4	3	2	2	2	3	3
1861	2	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2
1862	1	1	2	1	1	0	0	0	0	0	0	0	0	0	1	1	2	2	2	1	1	2	3	4
Sum	10	8	8	6	7	6	5	5	6	5	7	7	6	6	10	9	11	12	12	10	10	12	14	15
South-east.																								
1858	4	3½	4	5½	2½	2½	3½	0½	1	1	1	1½	1	2½	2	2	2	2	3	3	4	3½	3	3
1859	0	0	0	0	0	0	0	0	0	0½	1	1	1	2	1	1	2	2	1	1	1	1	1	1
1860	3	2	2	2	2	2	2	2	2	2	3	3	2	3	3	4	5	4	4	4	3	3	2	1
1861	0	0	1	1	1	1	1	0	0	1	1	1	2	2	2	2	1	1	1	1	1	1	1	1
1862	2	0	1	1	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	1	1	2	1	1
Sum	9	5½	8	9½	5½	5½	6½	2½	3	4½	7	7½	7	10½	9	10	10	9	9	10	10	10½	8	7
East-south-east.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0	0	0	0	0	0	0	1	1½	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1860	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1
1861	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	2	0	0	0	0
1862	0	1	0	0	1	1	1	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
Sum	1	1	0	0	1	1	1	0	1	3½	2	1	1	1	1	1	1	0	2	2	1	1	1	1
East.																								
1858	1	0	0	0½	1½	0	0	1	2	0½	1½	4	5½	4½	2½	2½	3	3	1	1	1	1	2	0½
1859	1	0	0	0	0	0	1	2	3	1	1	1	2	1	1	1	1	0	1	0	0	0	0	0
1860	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	0	1	0	0
1861	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	0	0	1	1	0	0	0	0	0
1862	0	0	0	1	1	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Sum	2	0	0	1½	2½	0	1	4	6	2½	2½	5	8½	6½	4½	4½	5	6	4	2	1	2	2	0½
East-north-east.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1
1860	1	2	2	3	2	1	2	1	1	1	1	3	3	3	4	3	3	3	4	3	2	2	1	2
1861	0	0	1	1	1	1	2	2	2	2	2	2	3	1	1	1	2	2	0	1	1	1	0	0
1862	1	2	1	1	1	0	1	0	0	0	1	1	1	0	0	0	0	0	1	1	0	0	1	0
Sum	3	5	5	6	5	3	6	4	4	4	5	7	7	4	5	4	5	5	5	6	4	4	3	3
North-east.																								
1858	3½	3½	2	3½	4	4½	5	5	7	7	6½	5	3½	3	3	3½	4	3½	3	3½	3	3	4	4½
1859	1	2	1	1	0	0	0	2	2	2	2	2	2	3	3	1	1	1	1	1	1	2	2	2
1860	1	2	2	2	2	3	4	6	7	8	7	6	6	7	4	3	3	3	2	2	4	4	4	3
1861	2	2	2	2	2	2	2	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	3	3
1862	1	1	2	1	0	0	0	0	1	3	2	2	2	2	1	0	0	0	0	0	1	1	0	0
Sum	8½	10½	9	9½	8	9½	11	13	17	20	17½	15	13½	15	11	7½	8	7½	7	7½	10	12	13	12½
North-north-east.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	3	3	3	3	3	3	3	2	2	3	3	3	4	3	3	3	3	4	4	4	5	4	4	4
1860	9	10	10	12	11	11	10	10	10	8	8	7	5	2	1	1	0	0	0	0	1	1	4	5
1861	3	3	2	2	2	2	2	3	4	4	4	3	2	2	2	2	1	1	0	0	1	1	1	1
1862	2	2	2	2	3	4	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	2
Sum	17	18	17	19	19	20	18	17	16	15	15	13	11	7	6	6	4	5	4	4	7	7	12	12

Table I.—*Direction of the Wind, Wallingford, Conn.*

JUNE.

	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
North.																								
1858	7	7	7	6½	9	10	11½	12	11	10	8	7	5½	6	4	4½	3½	2	3½	4	4	5½	6	7
1859	1	1	1	1	1	1	1	1	4	4	2½	1	1	1	0	0	0	1	1	1	3½	2	2	3
1860	3	6	6	8	7	7	8	7	7	3	3	3	2	2	2	2	1	1	1	1	1	3	3	3
1861	5	4	4	4	4	3	3	2	3	3	2	3	3	3	2	2	2	3	2	2	2	3	3	3
1862	1	1	1	2	2	2	2	2	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1
Sum	17	19	19	21½	23	23	25½	24	26	21	16½	14	11½	12	8	8½	6½	7	8½	9	11½	14½	15	17
North-north-west.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	6	6	5	5	5	6	6	7	3	2	2	2	2	2	1	1	2	2	3	3	3	4	4	4
1860	2	2	2	2	2	2	1	2	3	4	4	4	4	5	5	5	5	4	5	4	4	4	4	4
1861	2	2	2	2	2	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	3	3	4	4
1862	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	11	11	10	9	9	11	10	12	8	8	8	8	8	9	8	8	9	8	10	9	10	11	12	12
North-west.																								
1858	2½	3	4½	6	4	4	3½	4½	3	2½	2½	2	5	6	6	6½	5	4½	3	2	2	1	1	1
1859	4	4	5	7	7	7	6	5	6	7	6	5	4	4	5	5	5	7	6	5	5	4	6½	6
1860	1	1	2	1	1	0	0	1	1	2	3	3	3	3	3	3	3	3	2	2	1	1	1	1
1861	1	1	1	1	2	2	2	2	4	5	5	3	3	3	3	3	3	3	3	3	3	2	1	1
1862	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	8½	9	12½	15	14	13	11½	13½	15	16½	16½	13	15	16	17	17½	16	17½	14	12	11	8	9½	9
West-north-west.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0	0	1	1	0	0	0	0	1	1	1	2	1	2	2	2	0	0	0	0	0	0	0
1860	2	2	2	2	2	2	2	1	1	0	0	0	0	0	0	0	0	0	1	2	2	1	1	2
1861	0	0	0	0	0	0	0	0	0	0	1	2	4	4	3	2	2	2	1	1	0	1	1	1
1862	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Sum	2	2	2	3	3	2	2	1	1	1	2	3	6	5	5	4	5	2	2	3	2	2	2	3
West.																								
1858	0½	0½	0½	1½	0	0½	0	0	0½	1½	4	5½	3	2½	3	2½	3	4	3	1½	1	0	0	0
1859	0	0	0	0	0	0	1	1	0	0	0½	1½	1	1	0	0	0	0	0	0	0	1	0	0
1860	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	3	2	1	0	0	0	0	0
1861	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0
1862	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	0½	0½	0½	2½	0	0½	1	1	0½	1½	5½	8	4	4½	4	4½	6	6	5	2½	1	1	0	0
West-south-west.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1860	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1861	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1862	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
South-west.																								
1858	0	0½	1	1	1½	0½	0	1	1	1	1	2½	2½	0	1	1	2	0	0	0	1	0	0	0
1859	2	1	1	1	1	1	0	0	1	1	1	1½	1½	1	1	1	1	1	1	1	1	1	1	1
1860	1	0	0	0	0	0	1	1	0	0	1	1	1	1	1	0	0	1	1	1	0	0	0	0
1861	0	0	0	1	1	1	1	1	2	2	1	1	1	1	2	1	1	1	0	0	0	0	0	0
1862	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Sum	3	1½	2	3	3½	2½	2	3	5	4	5	7	6	3	5	3	4	3	2	2	2	1	1	1
South-south-west.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	3	3	3	2	2	2	2	2	4	5	7	6½	8	9	10	10	10	9	9	9	5	5	5	5
1860	10	8	7	5	5	7	6	7	8	9	8	7	7	6	7	8	9	9	7	7	11	10	10	10
1861	7	7	7	7	7	7	7	7	7	6	6	6	7	7	8	9	9	9	10	10	9	8	8	7
1862	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	2	1	1	2	1	1	1
Sum	21	19	18	14	14	16	15	16	19	20	21	19½	23	23	26	28	29	29	27	27	27	24	24	23

TABLE I.—*Direction of the Wind, Wallingford, Conn.*

JUNE (continued).

	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
South.																								
1858	13	10½	9½	9	10½	12	9½	10	11	12	10½	9½	9½	12½	12½	11½	13½	15	16	17½	18½	16½	15½	15
1859	9	10	10	8	8	9	10	10	8	7	5½	6	6½	7	7	7	6	6	6	6	9	8	7½	7
1860	2	2	2	2	1	1	1	0	1	1	1	2	2	3	4	3	2	2	5	6	4	3	3	3
1861	7	7	7	5	5	5	5	5	4	4	4	5	5	5	5	6	6	6	6	7	8	8	8	8
1862	1	1	1	0	1	1	1	1	1	2	2	2	3	2	2	2	2	2	1	1	1	2	2	2
Sum	32	30½	29½	24	25½	28	26½	26	25	26	23	24½	26	29½	30½	29½	29½	31	34	37½	40½	37½	36	35
South-south-east.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	2	2	1½	1	1	2	1	1	2	2	2½	1½	0	0	1	1	2	2	2	3	2½	2	2	2
1860	2	1	1	3	2	2	2	1	1	1	0	0	1	1	1	1	1	1	1	1	1	2	2	2
1861	2	2	1	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1
1862	1	1	1	1	1	1	1	0	0	0	0	0	0	1	2	1	1	1	2	2	0	0	0	0
Sum	7	6	4½	6	5	5	4	2	3	4	3½	1½	1	2	4	3	4	4	5	6	3½	4	4	5
South-east.																								
1858	7	8½	6½	4	3½	2	4½	2	1	0½	2½	1	2	2	2	2	2½	2	3	5	3½	5	5½	5
1859	1	1	1	1	1	1	2	2	1	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0
1860	1	2	1	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	0
1861	1	1	0	0	0	1	0	0	1	0	0	2	1	1	1	1	1	1	1	1	1	1	1	1
1862	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1
Sum	10	12½	8½	6	5½	5	7½	5	4	1½	3½	4	4	4	4	4	3½	3	4	6	6½	9	8½	7
East-south-east.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
1860	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1861	1	1	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1862	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Sum	1	1	0	0	1	1	1	1	2	2	2	3	0	1	0	0	0	0	0	0	0	0	0	0
East.																								
1858	0	0	0½	0½	1	0	0	0	1	0½	0½	0½	0	0	0½	1½	0	0½	0	0	0½	1	1	1
1859	0	0	0½	1	1	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
1860	1	1	1	1	3	2	2	1	0	0	0	0	0	1	0	0	1	1	1	1	0	0	1	1
1861	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1862	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	1	1	3	4½	5	3	2	1	1	0½	0½	1½	1	1	0½	1½	1	1½	1	1	0½	1	2	2
East-north-east.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	1	1	1	2	2	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	2	1	1
1860	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1861	0	0	0	1	1	1	1	2	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0
1862	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	1	1	1	3	3	2	1	2	1	1	3	1	1	1	1	1	1	1	1	1	1	2	1	1
North-east.																								
1858	0	0	0½	0½	0½	1	1	0½	1½	2	2	2	2	1	1	0½	0½	2	1½	0	0	1	1	1
1859	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
1860	2	3	2	2	2	2	2	2	0	0	0	0	1	1	0	1	1	2	3	3	3	3	2	2
1861	1	1	1	0	0	0	1	1	0	0	0	0	1	1	1	1	2	2	3	2	2	2	3	3
1862	0	0	0	0	0	0	0	1	1	2	1	1	1	1	0	0	1	1	1	1	1	1	1	1
Sum	3	4	3½	2½	2½	3	5	5½	3½	5	4	4	6	4	2	2½	4½	7	8½	6	6	7	7	7
North-north-east.																								
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	1	1
1860	2	2	4	4	5	5	5	6	6	8	8	8	8	6	6	5	4	4	2	2	2	2	2	2
1861	3	4	6	6	6	6	6	6	5	5	4	4	3	3	3	3	2	1	1	1	2	2	1	1
1862	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2
Sum	8	9	13	12	14	14	14	15	14	16	15	16	15	13	13	12	9	8	6	6	6	6	6	6

Table I.—*Direction of the Wind, Wallingford, Conn.*

JULY.

	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
North.																								
1857	2	4	5	6	7	7	6	6½	6½	4	4	4	4	4	2	2½	2	3	3	3	3	3	3	3
1858	6	7	7	9	9	9	9	8½	10	10	9½	8½	8	6	4	4	5	3	4½	4	3½	6	5½	5
1859	2	2	3	3	3	3	6	7	10	9	8	6	5	4	4	4	3	3	3	2	2	2	3	3
1860	4	4	5	5	6	6	6	6	6	6	6	4	3	2	2	2	3	2	2	1	1	1	1	2
1861	3	4	4	5	5	5	6	6	6	6	3	3	2	1	1	1	1	1	1	1	1	2	2	5
Sum	17	21	24	28	30	30	33	34	38½	35	30½	25½	22	17	13	13½	14	12	13½	11	10½	14	14½	17
North-north-west.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	3	3	3	3	3	3	3	2	1	1	1	1	0	0	0	0	0	1	1	2	1	1	1	1
1860	1	1	2	2	3	3	3	3	2	2	1	1	2	3	3	1	1	2	2	2	2	2	2	2
1861	0	1	1	1	1	2	3	3	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	4	5	6	6	7	8	9	8	5	4	3	2	2	3	3	1	1	3	3	4	3	3	3	3
North-west.																								
1857	3	3	3	2	1	1	4	3½	2½	4	4	3	2½	2	3	2	2	1	1	1	1	2	3	3
1858	4½	4	3	4½	6	6½	7	7	8	7½	5½	5½	4½	5	6	6	6	7½	6	5	4½	2	1½	3½
1859	3	3	3	3	3	3	1	5	4	4½	3	3	6	6	7	7	6	3½	3	3	3	3	3	3
1860	2	2	2	2	1	1	2	2	2	3	3	3	3	3	3	4	1	1	1	2	2	2	3	2
1861	1	1	1	2	3	2	1	2	4	4	4	5	4	4	3	1	2	2	2	2	2	1	1	1
Sum	13½	13	12	13½	14	13½	18	19½	20½	23	19½	19½	20	20	22	20	17	15	13	13	12½	10	11½	12½
West-north-west.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	1	1	2	2	4	4	2	3	1	1	1	1	1	1	1	0	0	1½	2	2	1	1	1	1
1860	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	2	2	3	3	3	2	2	2	2
1861	1	1	1	0	0	0	0	0	0	0	1	1	1	2	2	3	1	1	1	1	0	0	0	0
Sum	2	2	3	2	4	4	2	3	2	2	3	3	3	4	4	5	3	5½	6	6	3	3	3	3
West.																								
1857	1	1	1	1	1	1½	1	1	1½	1	1	1	0	0	0	0	0	0	1	1	1½	2	1	1
1858	0	1	1	1	1½	0	0	0	0	0½	0	0	0½	1	2	2	2	2	2	2	2½	0	0	0
1859	0	0	0	0	0	0	1	1	2	2½	3	3	1	1	1	1	2	1½	1	1	1	0	0	0
1860	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	1	1	1
1861	0	1	1	0	0	0	0	0	0	1	1	1	3	3	3	4	4	3	3	2	2	1	0	0
Sum	2	4	3	2	2½	1½	2	2	3½	5	6	6	5½	6	7	8	9	7½	8	6	7	4	2	2
West-south-west.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	1	1	1	1	1	1	1	1	2	1	0	1	0	0	0	0	0	0	0	0	1	1	1	1
1860	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0
1861	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
Sum	1	1	2	2	1	1	2	2	2	1	0	1	0	0	0	0	1	1	1	0	1	2	2	1
South-west.																								
1857	0	0	0	2	1	1½	1	1	1	3	1½	2	2½	3	3	3	4	3½	2	2	3	2	1	0
1858	0	0	2	1½	1½	1	1	1	2	2	3	3½	4	3½	3	4	2½	0	0	1	1	1½	1½	1
1859	3	4	3	3	2	3	3	2	2	2	2	1	1	1	1	1	2	3½	3	3	3	3	3	3
1860	2	2	2	1	2	2	2	2	2	2	3	4	5	5	5	5	6	4	5	5	4	3	2	2
1861	2	1	0	0	0	0	0	0	0	0	1	1	1	1	2	2	2	3	3	3	2	2	2	3
Sum	7	7	7	7½	6½	7½	7	6	7	9	10½	11½	13½	13½	14	15	16½	14	13	14	13	11½	9½	9
South-south-west.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	5	5	5	5	6	5	5	6	5	5	7	7	8	9	10	10	10	9	8	7	7	7	6	6
1860	6	6	5	5	4	4	2	2	3	4	3	3	3	4	4	4	3	5	5	5	5	4	6	6
1861	6	6	6	6	6	6	7	7	6	9	8	9	10	10	10	10	11	11	9	8	7	7	8	8
Sum	17	17	16	16	16	15	14	15	14	18	18	19	21	23	24	24	24	25	22	20	19	18	20	20

Table I.—*Direction of the Wind, Wallingford, Conn.*

JULY (continued).

	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
South.																								
1857	15½	16	16	13	14	13	12	13	12	10	12½	13	14½	16	16	18	18	17½	18	17	13½	13	14	15
1858	15	14	13½	12	10	9½	10	10½	11	11	12	12	12½	12½	13	12	12½	15	16½	16	15	17	17½	16
1859	6	5	4	4	3	3	2	1	1	1	1	1	1	1	1	2	3	3	6	6	6	6	6	6
1860	6	5	5	5	4	4	5	4	5	3	4	5	6	5	5	5	8	9	9	10	10	10	8	8
1861	13	12	12	10	8	9	7	7	7	6	7	6	5	5	7	8	8	8	9	11	13	13	13	11
Sum	55½	52	50½	44	39	38½	36	35½	36	31	36½	37	39	39½	42	45	49½	52½	58½	60	57½	59	58½	56
South-south-east.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	3	3	3	3	2	2	2	2	2	2	2½	2	1	1	1	1	1	1	2	3	3	3	3	3
1860	2	2	2	2	2	2	2	2	1	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1
1861	1	1	1	2	2	1	1	1	1	1	0	0	0	0	0	0	1	1	2	2	3	2	2	1
Sum	6	6	6	7	6	5	5	5	4	4	2½	2	1	1	1	2	3	3	5	6	7	6	6	5
South-east.																								
1857	3½	2	2	1½	1	1	1	0	0	0½	0½	1	1	0	1	0½	0	1	1	2	4	4	4	4
1858	4	4	4	2½	2	3½	3	3	0	0	0	0½	0	0	1	1½	1	1	1	1	4	4	3	4
1859	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	1	0	0
1860	0	1	1	1	1	1	1	1	1	0	0	1	0	0	0	0	1	1	0	0	1	1	0	0
1861	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Sum	7½	7	7	5	4	5½	5	4	1	0½	0½	2½	2	1	3	3	3	4	2	3	9	10	7	9
East-south-east.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
1860	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0
1861	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	1	1	1	1	1	1
East.																								
1857	0	1	0	1½	2	1	0	1	3½	3½	2	1	2	2	2	2	2	2	1½	1	1	1	1	0
1858	1½	1	0½	0	1	1½	1	0½	0	0	0	0	0½	1	1	0	1	2½	1	1	0½	0	0½	1½
1859	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	2	0	0	0	0	0	0	1	0
1860	0	0	0	1	1	1	0	0	0	1	2	1	2	2	2	2	0	0	0	0	1	1	0	0
1861	0	0	0	0	0	0	0	0	0	0	1	1	2	2	0	0	0	0	0	0	0	1	1	1
Sum	1½	2	0½	2½	4	3½	1	1½	3½	4½	5	3	7½	9	7	6	3	4½	2½	2	2½	3	3½	2½
East-north-east.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
1860	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2
1861	1	1	1	1	0	1	1	1	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0
Sum	3	3	2	2	1	2	1	1	0	0	1	1	0	0	0	1	1	1	1	1	1	2	3	3
North-east.																								
1857	3	1	1	1	1	2	3	2	1½	2	2½	3	1½	1	1	0	0	0	0½	1	1	1	1	2
1858	0	0	0	0½	0	0	0	0	0	0	1	1	1	2	1	1	1	0	0	1	0	0½	1½	0
1859	1	2	2	1½	1	1	0	0	0	0	0½	1	1	1	0	0	0	0	0	0	0	0	0	1
1860	1	1	1	2	2	2	2	2	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1
1861	1	0	0	1	2	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	6	4	4	6	6	6	6	5	3½	3	5	6	4½	5	2	1	1	0	0½	3	2	2½	3½	4
North-north-east.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	1	1	2	2½	3	3	2	1	1	2	2	4	4	3	2	2	2	2	0	0	1	1	1	1
1860	5	5	5	4	4	4	5	6	7	7	5	5	3	3	4	4	3	1	1	1	1	1	2	2
1861	2	2	2	2	4	4	4	3	4	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1
Sum	8	8	9	8½	11	11	11	10	12	12	10	12	10	9	9	7	6	4	2	2	3	3	4	4

Table I.—*Direction of the Wind, Wallingford, Conn.*

AUGUST.

	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
North.																								
1857	4	4	4	5½	5½	7	7	7	7	7	7½	6	4	5	5½	4½	3	3	5	4½	4	5	5	5
1858	11	10	11	10	12	11½	11½	11	11	11	9½	10½	6½	4½	4	2	1½	2	2	2	2	4	7½	8½
1859	9½	10	9	11	13	13	13	14	12	11	8	6	4	4	3	3	2	2	2	2	2	4	4	5
1860	3	3	5	5	5	5	6	7	8	9	7	6	6	6	6	5	5	4	3	3	3	4	4	4
1861	5	5	7	9	9	9	9	11	11	9	9	8	4	3	3	3	2	2	2	3	4	4	5	5
Sum	32½	32	36	40½	44½	45½	46½	50	49	47	41	36½	24½	22½	21½	17½	13½	13	14	14½	15	21	25½	27½
North-north-west.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	1	2	3	2	2	2	1	1	1	1	2	1	1	1	1	1	0	0	0	0	0	0	0	0
1860	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	1
1861	1	1	1	1	1	1	1	2	1	1	0	0	1	1	1	0	0	1	1	1	2	2	2	2
Sum	3	4	4	3	3	3	2	3	2	2	2	2	2	2	2	1	0	2	2	1	2	2	2	3
North-west.																								
1857	4½	5	5	5	5½	7	7	6	6	5	4	7	6	5	4½	3½	5	3	2	2½	3	3	3	3
1858	3½	3½	3½	7	6½	5½	5	6	7	8½	9	8	8	6½	6	7	6	5½	5	5	5	5½	4½	5
1859	1½	0	0	0	0	0	0	0	1	2	3	4	3	2	2	2	5	4	3	2	2	2	2	2½
1860	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	2	3	1
1861	0	0	0	2	1	2	2	0	2	3	2	2	3	4	3	3	3	2	2	1	1	1	1	1
Sum	10½	9½	10½	16	15	16½	16	14	18	20½	20	23	22	19½	17½	17½	21	16½	14	13½	14	13½	13½	12½
West-north-west.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0½	1	0	0	0	0	0	0	1	1	2	3	2	2	0	0	0	1	1	1	0	0	0
1860	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	1	1	0	0
1861	0	0	1	1	1	1	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
Sum	0	0½	2	1	1	1	1	1	0	1	1	2	3	3	4	1	1	1	1	1	2	1	0	0
West.																								
1857	1½	1	1	1	2	3	2	1	1	1	1½	2	2	3	3	2½	3½	5	5	3½	2	2½	3	1½
1858	0	1½	1	0	0	0	0	0	1	1½	0½	1	1	3	2½	1	1	1½	0½	0	0	0	1	0
1859	0½	1	1	1	1	2	1½	0	1	0	0	0	1	1	2	1	1	0	0	1	2	1	3	3
1860	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1861	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	2	1	1	0	0	0	0
Sum	2	3½	3	2	4	5	3½	1	4	2½	2	3	4	7	8½	5½	7½	8½	6½	5½	4	3½	7	4½
West-south-west.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0	0	1	1	0	0	0	0	0	0	0	1	2	2	2	1	2	1	1	0	0	0	0
1860	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	1	0	0	1
1861	0	0	0	0	1	1	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	1	2	0	1	2	1	2	2	1	1	0	0	1	2	2	2	1	2	3	2	1	0	0	1
South-west.																								
1857	7	6	5½	4	4	2½	3	4	3	6	4½	4	5	6	5½	5½	3½	4½	4	7	7	4	4	5½
1858	1	1	1	1	1	1	2	1	3½	4	4	3	3	3	3	3½	1½	2	2½	2	1	1	1	1
1859	2	1	1	1	1	1	1	2	2	2	2	2	2	1	1	4	3	3	3	3	2	2	1	2
1860	7	6	5	5	5	6	7	7	6	6	8	9	9	8	9	9	8	8	7	8	7	9	8	7
1861	1	2	1	0	0	1	1	2	2	2	2	1	1	1	0	0	0	0	0	0	0	0	0	0
Sum	18	16	13½	11	11	11½	14	16	16½	20	20½	19	20	19	18½	22	16	17½	16½	20	17	16	14	15½
South-south-west.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	4	4	4	3	3	3	4	4	4	4	4	4	3	3	4	4	5	5	5	5	5	5	5	3½
1860	5	4	5	4	3	2	2	2	2	4	4	5	6	6	6	8	8	8	7	6	5	4	4	4
1861	10	12	12	10	9	7	6	5	5	5	6	6	7	7	7	9	9	9	11	11	10	10	9	10
Sum	19	20	21	17	15	12	12	11	11	13	14	15	16	16	17	21	22	22	23	22	20	19	18	17½

Table I.—*Direction of the Wind, Wallingford, Conn.*

AUGUST (continued.)

	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
South.																								
1857	6	6	8½	8	6	4½	3	5	5	4½	6	6	6½	6	6	8½	8½	8½	8	7	7	9	10	9
1858	8	7½	6	6	6	6	6	7	3½	2	3	4½	6	5	5½	5½	8	7	9	11	11	11½	11	9½
1859	6½	5½	4	4	4	4	3	1	0	1	3	3	4	5	6	6	6	7	8	8	9	8	7	8
1860	4	4	3	4	4	3	3	3	3	1	0	0	1	1	2	1	1	1	2	3	5	4	5	4
1861	3	2	2	2	1	1	1	1	1	1	3	4	3	3	2	3	4	5	5	4	4	4	4	3
Sum	27½	25	23½	24	21	18½	16	17	12½	9½	15	17½	20½	20	21½	24	27½	28½	32	33	36	36½	37	33½
South-south-east.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	2	2	1	1	1	1
1860	0	1	2	3	3	2	1	1	1	1	1	1	2	2	2	2	3	3	3	3	2	1	1	1
1861	3	1	1	0	1	1	1	0	0	0	0	0	1	2	3	2	3	2	2	3	4	4	4	4
Sum	4	3	3	4	5	4	3	2	2	2	2	2	3	5	6	5	7	6	7	8	7	6	6	6
South-east.																								
1857	4	4	2	3	3	4	3	3	3	2	2	3½	3	3	4	4	4½	3	3	3	4	4	3½	3
1858	3	2½	4½	4	3½	4	3½	3	2	1	1½	1	1½	2	3	3	5½	6½	7	7	8	5	4	4
1859	3½	2	2	1	1	1	1	1	3	2	2	2	2	3	2	2	2	2	2	2	3	4	3	3
1860	1	0	1	1	1	1	1	1	0	0	1	1	1	0	1	1	1	0	0	0	0	0	0	0
1861	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	2	3	2	2	1	1
Sum	12½	9½	9½	9	8½	10	8½	8	8	5	6½	7½	7½	8	11	11	14	13½	14	15	17	15	11½	11
East-south-east.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
1860	0	1	0	0	0	1	1	1	1	1	2	3	1	1	0	0	0	1	1	1	0	0	0	0
1861	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	0	1	0	0	0	1	1	1	1	1	2	3	1	2	0	0	0	1	1	1	0	0	0	0
East.																								
1857	2	2	2	2	3	2	4	2	2	1½	1	0	0	0	0	0	0	0	2	2	2	1	2	2
1858	2½	3	2	1	1	1½	2	2	2	2	1	1	1	2	1½	1	2	2½	1½	0	1	2½	2	2½
1859	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0½	0
1860	2	2	1	0	0	0	0	0	0	1	1	0	1	1	1	1	0	0	0	0	1	2	2	2
1861	2	2	1	1	1	1	1	1	0	0	0	0	1	1	0	0	1	2	1	0	0	0	1	1
Sum	8½	9	6	4	5	4½	7	5	4	4½	3	1	4	5	3½	3	4	4½	4½	2	4	5½	7½	7½
East-north-east.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0½	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	2	2	1	1	0½	1
1860	2	2	1	2	2	2	2	1	2	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
1861	1	1	0	0	0	0	0	0	2	2	2	3	2	1	2	2	0	0	0	0	0	0	0	0
Sum	3½	4	2	2	2	2	2	1	4	3	2	4	2	1	3	3	1	1	2	2	1	1	0½	1
North-east.																								
1857	3	3	3	2½	2	1	2	3	4	4½	4½	2	4	3	3	3½	3	3	2	2	2	2½	1	1
1858	2	2	2	2	1	1½	1	1	1	1	2½	2	4	5	5	7	5½	4	3½	4	3	1½	0	0½
1859	0	1	1	1	1	1	2	2	1	1	1	2	3	1	1	1	1	3	1	1	1	1	2	1
1860	1	0	1	1	1	3	2	2	2	2	2	1	1	1	0	1	1	1	1	1	1	2	2	2
1861	0	0	0	0	1	1	1	1	1	1	2	1	1	2	2	2	1	2	2	2	1	1	2	2
Sum	6	6	7	6½	6	7½	8	9	9	9½	12	8	13	12	11	14½	11½	13	9½	10	8	8	7	6½
North-north-east.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	2	2	4	5	3	3	3½	5	5	5	4	4	3	3	2	2	2	1	1	1	2	2	2	2
1860	3	4	5	4	4	4	4	4	3	3	3	2	1	1	1	1	1	1	2	2	2	2	2	3
1861	4	4	5	5	5	5	5	5	5	6	5	6	7	6	5	4	5	3	2	2	3	3	2	2
Sum	9	10	14	14	12	12	12½	14	13	14	12	12	11	10	8	7	8	5	5	5	7	7	6	7

Table I.—*Direction of the Wind, Wallingford, Conn.*

SEPTEMBER.

	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
North.																								
1857	4	7	7	7	8	9	11	10	9½	7	6	4½	3	5	5	5	5	4	4	4	3	3	3	2½
1858	5	5½	6	7	8	8	8	8	8	9	7½	6	6	6	7	5	4	3½	2½	2	2½	3	4	3½
1859	9	9	10	10	10	11	11	12	12	11	9	6	5	5	5	4	3	3	2	3	5	5	5	6
1860	3	3	3	5	10	11	11	12	11	11	8	4	4	1	1	1	1	1	2	2	1	2	2	3
1861	5	5	5	7	7	7	8	8	10	8	7	7	5	4	3	3	2	3	3	2	2	3	4	5
Sum	26	29½	31	36	43	46	49	50	50½	46	37½	27½	23	21	21	18	15	14½	13½	13	13½	16	18	20
North-north-west.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	4	3	1	0	1	1	1	1	2	2	3	3	3	3	3	3	3	3	2	3	3	3	3	3½
1860	3	3	2	2	1	1	1	1	2	2	2	1	1	2	1	1	1	1	1	1	1	2	2	2
1861	3	3	2	2	2	4	4	4	2	2	2	2	2	2	2	2	3	3	3	3	5	4	3	2
Sum	10	9	5	4	4	6	6	6	6	6	7	6	6	7	6	6	7	7	6	7	9	9	8	7½
North-west.																								
1857	4½	4	4	4	3	3	2	3½	5	7	8	9	7½	6½	4	4	4	5	4	4	4	3	3	5
1858	6	6	6	6	6	6	8	7½	7	7	7	6	6½	7	6	6	6	4	3	5	6	5	4½	6½
1859	1	1	1	1	2	3	3	3	2	2	1	2	4	3	5	3	3	5	7	6	4	4	4	1
1860	2	1	0	2	2	1	0	0	1	2	3	7	8	8	7	6	5	5	4	4	4	2	2	2
1861	2	2	3	4	3	2	2	1	2	3	3	3	3	4	4	4	3	3	3	3	1	1	1	1
Sum	15½	14	14	17	16	15	15	15	17	21	22	27	29	28½	26	23	21	22	21	22	19	15	14½	15½
West-north-west.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0	1	0	1	0	0	0	0	0	0	1	2	4	4	4	4	3	2	2	1	0	0	0
1860	2	2	1	0	0	0	0	0	1	1	1	1	1	1	3	2	3	3	2	2	2	1	1	1
1861	0	0	0	0	0	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Sum	2	2	2	0	1	0	1	1	1	2	2	3	4	6	8	7	8	7	5	5	4	2	2	2
West.																								
1857	3½	3	2	2	3½	4	3	2½	1½	1½	3	2½	3	2½	2	3½	3½	3	4	4	4	4½	4½	5
1858	2	1½	3	3	2	2	2	1½	1	1	2	3	2½	1	3	3	2½	4	6	1	0	1	1½	2
1859	2	2	3	3	1	0	0	0	0	3	4	3	1	1	0	0	1	1	1	1	1	1	1	3
1860	2	3	3	2	1	1	2	1	1	0	0	0	0	0	1	1	1	1	1	1	0	0	0	1
1861	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0
Sum	9½	9½	11	10	7½	8	7	5	3½	5½	9	8½	6½	4½	7	8½	9	10	13	8	5	6½	7	11
West-south-west.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	1	1	1	2	2	2	1	1	2	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0
1860	1	1	2	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	2	2	2	2
1861	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	2	2	3	3	2	2	1	1	2	1	2	0	0	0	0	0	0	0	1	1	2	2	3	2
South-west.																								
1857	1½	2	3	3	1½	1	2	2	2	1½	0	0½	2	1½	4½	3½	3	3	2½	1	1½	2	2	2½
1858	1	2	0	0	1	2	1	0½	1	1	3	2½	3½	3	2	1	2	2	0	1½	1	2	1½	1½
1859	1	1	0	0	1	0	0	0	0	0	1	1	1	2	3	4	2	2	2	2	2	2	2	2
1860	1	1	1	1	1	1	1	2	1	2	2	2	2	2	2	2	2	3	2	2	2	3	2	2
1861	1	1	1	1	3	3	3	3	2	1	0	0	0	1	1	1	1	1	1	1	1	1	1	2
Sum	5½	7	5	5	7½	7	7	7½	6	5½	6	6	8½	9½	12½	11½	10	11	7½	7½	7½	10	8½	10
South-south-west.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	5	5	5	5	5	6	6	6	6	5	5	7	7	6	5	7	7	6	6	6	5	5	3	3
1860	7	7	8	7	7	7	7	7	7	8	7	9	9	10	10	12	12	11	12	11	9	9	9	7
1861	8	8	8	7	7	7	7	8	8	9	10	9	10	10	10	10	10	9	8	7	7	7	7	7
Sum	20	20	21	19	19	20	20	21	21	22	22	25	26	26	25	29	29	26	26	24	21	21	19	17

Table I.—*Direction of the Wind, Wallingford, Conn.*

SEPTEMBER (continued).

	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
South.																								
1857	9	7	6	6	6	6	5	4	4	4½	4	5	6	6½	7	7	7½	8	8½	10	9½	9	8½	8
1858	13	12	12	12	12	11	10	10½	11	10	8	8	9	10	9	10	10½	11	12	13	12	11	11	12
1859	3	4	4	4	3	3	4	4	2	2	1	1	3	2	2	2	3	2	3	3	5	6	6	5½
1860	2	2	2	3	1	1	1	1	1	0	0	0	0	0	0	0	1	2	2	2	3	3	3	3
1861	5	5	5	4	3	1	0	0	1	1	2	3	3	3	3	3	4	4	5	6	6	6	6	5
Sum	32	30	29	29	25	22	20	19½	19	17½	15	17	21	21½	21	22	26	27	30½	34	35½	35	34½	33½
South-south-east.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	2	2	2	2	1	1	1
1860	2	1	1	1	3	3	2	2	2	2	3	3	2	2	2	2	1	1	1	1	1	1	1	2
1861	0	0	0	0	0	0	0	0	0	0	0	0	2	2	1	1	2	3	3	3	3	3	3	3
Sum	2	1	1	1	3	3	2	2	2	2	3	4	4	4	3	3	4	6	6	6	6	5	5	6
South-east.																								
1857	2½	3	4	3	2	2	1	1	2	2½	2	1	2	2	1	1	1	2	2	2½	4	4	3	2
1858	1	1	1	0	0	0	0	0	1	1	1	2	0½	0	1	2	2	2½	3	2½	4½	4	4	2
1859	2	2	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
1860	0	0	0	0	0	0	0	1	2	1	0	0	0	0	0	0	0	0	0	0	1	1	1	0
1861	0	0	0	0	0	0	1	1	1	1	1	1	1	0	1	1	1	1	1	0	0	0	0	0
Sum	5½	6	6	4	2	2	2	3	6	5½	4	4	3½	2	4	5	5	6½	7	6	10½	10	9	5
East-south-east.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
1860	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1861	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
Sum	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	2
East.																								
1857	1	0	0	1	2	1	1	1	1	1	2	2	1	1	1	1	1	1	2	1½	1	1	1	1
1858	0	0	0	0	0	0½	1	1	0	0	0	2	2	2	2	1	1½	1	0½	3	3	2	1	0
1859	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
1860	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
1861	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	2	1	2	2	2	1½	2	2	1	1	3	4	3	4	3	2	2½	2	2½	4½	4	3	3	2
East-north-east.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0	0	2	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
1860	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1	1	1	0	0	0	0	0	0	0
1861	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	0	0	0	2	1	1	1	1	1	1	1	1	2	3	2	2	1	0	0	0	0	0	0	0
North-east.																								
1857	4	4	4	4	4	4	5	6	5	5	5	5½	5	5	5½	5	5	4½	3	3	3	3½	5	4
1858	2	2	2	2	1	0½	0	1	1	1	1½	0½	0	0	0	2	1½	2	3	2	1	2	2½	2½
1859	0	0	0	0	1	1	1	1	1	1	1	3	2	1	0	0	1	1	1	0	0	1	1	1
1860	2	3	4	3	3	3	2	1	0	0	1	1	1	1	1	1	1	1	2	3	3	3	3	3
1861	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0
Sum	8	9	10	9	9	8½	8	9	7	7	8½	10	9	8	7½	9	8½	8½	9	8	7	9½	11½	10½
North-north-east.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	1	1	1	1	2	2	2	1	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	2
1860	2	2	2	2	1	1	3	2	1	1	2	2	1	1	1	1	1	1	0	0	1	1	1	1
1861	6	6	6	5	5	5	4	4	4	4	4	4	2	2	2	2	2	1	1	2	3	3	3	3
Sum	9	9	9	8	8	8	9	7	7	7	8	7	4	4	4	4	4	3	2	3	5	5	5	6

Table I.—*Direction of the Wind, Wallingford, Conn.*

OCTOBER.

	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
North.																								
1857	9	9½	12	13	13	12	12½	12	11	15	14	12½	12½	11½	11	10	9	8½	6	6	10	8½	9	9
1858	13	13	12½	12	12	12	12½	11	12	10	7	7	7	8	8	9	7½	7	8	9	10	13	13	13
1859	4	4	3	4	5	5	5½	7	5	6	7	7	5	4	3	3	2	2	3	2	2	2	3	4
1860	8	10	12	13	14	13	12	10	8	6	5	4	2	1	1	1	2	2	1	2	3	5	5	6
1861	14	14	14	13	13	14	14	14	13	12	12	9	9	7	6	4	3	3	3	3	6	6	7	7
Sum	48	50½	53½	55	57	56	56½	54	49	49	45	39½	35½	31½	29	27	23½	22½	21	22	31	34½	37	39
North-north-west.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	2½	2	3	3	3	4	4	4	5	6	5	4	4	5	3	2	5	5	4	4	3	2	3	3
1860	4	3	4	4	4	4	3	4	5	4	4	3	2	2	2	2	2	3	6	6	6	6	6	4
1861	1	1	1	3	3	3	2	2	3	3	2	2	1	2	1	1	1	1	1	1	1	1	1	1
Sum	7½	6	8	10	10	11	9	10	13	13	11	9	7	9	6	5	8	9	11	11	10	9	10	8
North-west.																								
1857	7	7	7	6½	8	8	8	7	7	6½	8	8	6	7	6	6	6	6	5½	5	5	6½	7	7
1858	3½	4½	6½	7	6½	7	6½	7	7	8	8	7½	6	6	6	6	5	5	4½	3	3	2½	3	3½
1859	4	3½	3	4	4	5	4	3	3	3	4	6	9	9	11	11	9	8	7	7	8	7	7	5
1860	1	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	3	3	2	2	0	0	0	0
1861	0	0	1	0	0	0	1	1	2	1	2	1	3	3	4	3	3	3	3	3	0	0	1	1
Sum	15½	16	18½	18½	19½	21	21½	20	21	20½	24	25½	27	28	30	29	26	25	22	20	16	16	18	16½
West-north-west.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	2	2	1	1	1	1	1	2	2	4	4	4	2	2	2	2	3	4	4	3	1	1	0	1
1860	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	2	1	0	0
1861	1	1	1	1	2	2	2	3	3	3	3	5	3	3	3	3	3	2	3	2	2	1	0	0
Sum	3	3	2	2	3	3	3	5	5	7	8	10	6	6	6	6	7	7	8	6	5	3	0	1
West.																								
1857	1½	1	1	1½	2	2	2	2	2	2	2½	2	2	1	1	1	1	1	2	2	1	1	1	1
1858	1½	0½	0	0	1	1	1	1	1½	2½	5	5	5	5	5	4	5	4	3½	4	2	1½	2	3½
1859	0	0	1	2	0	0	0	0	1	1½	1	1	2	2	2	3	0	0	0	1	2	2	1	1
1860	0	0	0	0	0	0	0	2	1	1	1	1	1	2	3	2	2	1	0	0	0	1	1	0
1861	0	0	0	0	0	0	0	0	0	0	0	1	3	2	2	2	2	3	2	2	2	3	2	1
Sum	3	1½	2	3½	3	3	3	5	5½	7	9½	10	13	12	13	12	10	9	7½	9	7	8½	7	6½
West-south-west.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	3	3	2	3	3	2	2	1	1	1	1	1	1	2	2	1	1	1	1	1	3	3	3	3
1860	1	2	2	0	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1
1861	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	1	1	1	2	3	2
Sum	4	5	4	3	4	3	3	2	3	2	2	3	2	2	2	1	2	1	2	2	4	5	7	6
South-west.																								
1857	3½	4	4	1	1	1	2	1	2	1	1	2½	3	3	1	3½	2	2	2	2	3	2	2	2½
1858	1	1	1	1	1	1	2	2	3½	2	1	2	1	1	1	1	0	1	1½	0	1½	2½	2	1
1859	5	5	6	5	4	5	5	6	6	3	3	3	2	2	2	3	5	5	4	3	1	2	3	3
1860	3	2	1	2	2	1	1	1	2	3	3	4	4	3	2	2	2	1	1	1	1	3	3	4
1861	3	2	3	3	2	1	1	0	0	0	0	0	0	1	1	1	0	1	0	0	1	1	1	2
Sum	15½	14	15	12	10	9	11	10	13½	9	8	11½	10	10	7	10½	9	10	8½	6	7½	10½	11	12½
South-south-west.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	7	7	7	5	5	4	4½	4	5	5½	6	5	6	5	6	6	5	5	6	6	6	6	7	8
1860	2	3	3	2	2	2	2	2	3	3	3	4	4	5	5	5	3	4	3	2	3	1	1	1
1861	5	5	5	5	5	5	5	4	3	5	5	3	5	5	5	6	6	8	8	10	9	8	8	8
Sum	14	15	15	12	12	11	11½	10	11	13½	14	12	15	15	16	17	14	17	17	18	18	15	16	17

Table I.—*Direction of the Wind, Wallingford, Conn.*

OCTOBER (continued.)

	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
South.																								
1857	3	3	2	3	3	3	2	4	3½	3½	1½	1	2	2½	5	3½	6	6	6	5½	5	5	4	3½
1858	8	7	7	7	9	8½	8	8	6	5	7	6	8	8	8	8	9	9	8½	10	9½	8½	8	7
1859	1	1	1	1	3	3	3	2	0	0	0	0	0	0	0	0	0	0	0	1	2	2	2	2
1860	2	1	2	3	2	4	4	3	2	1	0	0	0	0	0	1	2	2	2	3	2	1	1	3
1861	4	4	2	2	2	2	2	2	2	2	2	4	2	2	3	4	4	2	2	2	2	1	1	1
Sum	18	16	14	16	19	20½	19	19	13½	11½	10½	11	12	12½	16	16½	21	19	18½	21½	20½	17½	16	16½
South-south-east.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1860	1	1	1	0	0	0	0	0	0	1	1	1	3	4	4	4	4	4	4	3	3	3	2	1
1861	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	0	0	1	1	2
Sum	2	3	3	2	2	1	1	1	1	2	2	2	4	6	5	5	5	5	5	3	3	4	3	3
South-east.																								
1857	2	2	2	2½	0	0	0	0	0	0	0	0	0	0½	1	1	1	1	1	1½	1	2	2	2
1858	2	2½	2	2½	0½	0½	0	0	0	0½	0	1	1	1	1	1	1	1	1	2	2	1	2	2
1859	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1860	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	1
1861	1	1	1	0	0	0	0	0	0	0	1	0	0	0	1	2	2	2	2	2	2	1	1	1
Sum	5	5½	5	6	1½	1½	1	1	1	1½	2	2	2	2½	4	5	5	5	6	7½	7	6	7	6
East-south-east.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1860	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0
1861	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0
Sum	0	0	0	0	0	0	0	0	0	0	1	2	2	2	2	2	2	2	2	2	2	1	0	0
East.																								
1857	0	0	0	0½	1	1	1	2	1½	1	2	2	1½	2½	3	3	2½	3	3½	4½	4	3	3	1
1858	0	1½	1	0½	0	0	0	0	0	0	1	0½	0	0	0	1	2½	3	2	1	1	1	1	1
1859	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1860	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0
1861	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
Sum	1	3½	2	2	2	2	1	2	1½	1	4	2½	1½	2½	3	4	5	7	6½	5½	5	5	5	2
East-north-east.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
1860	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1861	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0
North-east.																								
1857	5	4½	2	3	3	4	3½	3	4	2	2	3	4	3	3	3	3½	3½	5	4½	2	3	3	5
1858	2	1	1	1	1	1	1	2	1	3	2	2	3	2	2	1	1	1	2	2	2	1	0	0
1859	2½	3½	3	2	2	2	2	2	3	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1
1860	0	0	0	0	0	0	0	0	1	2	1	1	1	1	2	2	2	2	2	3	3	2	3	3
1861	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	1	1	2	2	3	3	2
Sum	9½	9	6	6	6	7	7½	8	10	9	5	6	9	7	8	7	7½	7½	10	11½	9	10	10	11
North-north-east.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	3	3	2	0	0
1860	8	7	5	5	5	5	5	6	5	6	6	6	7	7	6	6	6	5	5	5	5	5	6	6
1861	1	1	1	2	2	1	1	1	1	2	2	3	2	2	2	2	3	3	3	2	2	2	1	3
Sum	9	8	6	7	7	6	6	7	6	8	8	9	9	9	8	8	10	9	10	10	10	9	7	9

Table I.—*Direction of the Wind, Wallingford, Conn.*

NOVEMBER.

	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
North.																								
1857	6½	7	7	7	8½	8	9	8½	8	8	8	6	5	5	3	3	3	3	3	3	2	2	2½	3
1858	11	11½	13	9½	11	11	10½	11	11	11	10	9	8	7	7½	7	5	6	7	7	9	10½	8	8
1859	3	4	5	5	6	7	8	9	11	10	8	8	5	2	1½	0	0	0	1	2	2	3	3	3
1860	7	8	8	8	7	7	7	7	8	8	7	5	4	3	2	2	2	2	2	2	4	5	6	6
1861	9	10	9	9	9	8	9	9	8	7	7	5	3	3	2	2	2	2	2	3	3	6	7	9
Sum	36½	40½	42	38½	41½	41	43½	44½	46	44	40	33	25	20	16	14	12	13	15	17	20	26½	26½	29
North-north-west.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	6	5	4	4	4	4	4	4	4	4	4	3	3	3	4	4	4	6	6	5	4	3	3	4½
1860	5	5	5	5	6	6	6	6	5	6	7	6	5	5	5	6	7	7	7	7	5	6	5	5
1861	3	3	4	4	5	5	5	4	5	5	6	6	5	4	3	3	3	3	3	3	5	4	3	3
Sum	14	13	13	13	15	15	15	14	14	15	17	15	13	12	12	13	14	16	16	15	14	13	11	12½
North-west.																								
1857	6	6	7	7	6	6	7	7½	7	6	5	9	7½	5½	6	6	7	6	6	6½	7	9½	7	6
1858	10	9½	8½	9	8	6½	5½	5	5	5	6	8½	9½	10	10	10	12	12	10½	10½	11	10	12	11
1859	1½	2	2	2	3	2	2	3	3	5	6	6	6	6	3	4	5	3	2	2	3	2	3	2½
1860	3	1	1	1	1	2	3	4	4	2	2	2	4	4	4	3	3	4	4	4	4	2	2	2
1861	5	5	5	5	4	5	5	6	6	6	4	4	5	7	8	8	8	7	6	6	4	3	4	4
Sum	25½	23½	23½	24	22	21½	22½	25½	25	24	23	29½	32	32½	31	31	35	32	28½	29	29	26½	28	25½
West-north-west.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	2½	2	1	1	1	1	3	1	1	1	0	1	2	3	4	3	2	2	2	2	2	2	2	2
1860	3	2	2	2	2	2	1	1	1	1	1	2	2	2	2	2	1	0	0	0	0	0	1	1
1861	2	2	2	1	1	1	1	1	0	0	1	1	2	1	1	1	1	3	4	4	3	2	2	2
Sum	7½	6	5	4	4	4	5	3	2	2	2	4	6	6	7	6	4	5	6	6	5	4	5	5
West.																								
1857	4½	5½	4	6½	7½	5½	5½	5	4	5	6	4½	6	8½	8	6	4½	6	5	6	5½	6½	7	8½
1858	1	1	1½	1	1	2½	3½	4	4½	7½	6½	5	6	6	6	6	4	5	5	4	4	2½	1	1
1859	2	2	3	3	3	3	1	1	1	2	3	2	4	3	1	0	0	0	0	0	0	1	1	2
1860	2	2	2	1	1	1	1	1	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3
1861	0	1	1	1	1	1	1	1	2	3	2	2	2	2	1	1	1	1	1	1	2	2	1	1
Sum	9½	11½	11½	12½	13½	13	12	13	13½	19½	19½	15½	21	22½	19	16	12½	15	14	14	14½	15	13	15½
West-south-west.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1	1	0	1	0	0	0
1860	1	1	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0
1861	1	2	2	2	2	2	2	2	2	2	2	2	1	1	1	2	2	1	1	1	1	1	1	0
Sum	2	3	2	2	2	2	2	2	3	3	3	4	1	1	2	3	3	2	2	1	2	2	1	0
South-west.																								
1857	7½	5½	6	3½	3	4½	6	6½	6½	6	5½	5	3½	3	2	4	4½	4½	6	5½	5	3	6	5½
1858	4	4	4	3½	3	3	5	5	5½	2½	3½	2½	2½	1½	1½	1½	3	2	2½	3	1½	2	3	4
1859	2	2	2	1	1	1	1	1	3	2	1	1	2	2	2½	3	3	3	4	4	4	4	3	2
1860	0	0	1	3	3	2	2	1	1	1	1	1	1	2	2	2	3	3	3	3	3	2	3	2
1861	1	1	1	1	1	1	0	0	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
Sum	14½	12½	14	12	11	11½	14	13½	17	11½	11	9½	9	8½	8	10½	14½	13½	16½	16½	14½	12	16	14½
South-south-west.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	2½	2	2	4	4	4	4	5	3	3	3	2	4	5	6	7	6	6	6	6	5	5	6	5
1860	2	3	3	3	2	3	3	3	2	3	3	5	5	4	5	5	4	3	2	2	2	2	2	3
1861	2	1	1	1	1	1	2	2	1	2	3	3	3	3	4	4	4	4	4	4	3	2	2	1
Sum	6½	6	6	8	7	8	9	10	6	8	9	10	12	12	15	16	14	13	12	12	10	9	10	9

Table I.—*Direction of the Wind, Wallingford, Conn.*

NOVEMBER (continued).

	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
South.																								
1857	3½	4	4	4	3	4	1½	1	2	1	1½	3½	5	5	7	8	9	8½	8	7	7	5½	3	3
1858	0	0	0	2	2½	2	1	1	2	2	2	1	0	1	1	0½	0	1	1	0½	0	0	0	0
1859	4	4	4	4	2	2½	3	2	4	3	3	4	2	4	4	4	5	4	3	3	4	4	3	3
1860	3	3	3	3	5	3	3	3	2	1	1	1	0	0	0	0	0	1	1	1	1	1	1	1
1861	0	0	0	1	1	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
Sum	10½	11	11	14	13½	11½	8½	8	11	8	8½	10½	8	11	13	13½	14	14½	13	11½	12	10½	7	7
South-south-east.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	2½	3	4	3	2	0	0	0	0	0	0	0	1	1	1	1	1	2	3	4	2	2	2	2
1860	1	2	2	1	0	0	0	0	0	1	1	1	2	2	2	2	2	2	3	2	3	3	2	2
1861	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	1	2	2	2	2
Sum	3½	5	6	4	2	0	0	1	1	1	1	1	3	3	3	3	3	4	7	7	7	7	6	6
South-east.																								
1857	1	0½	1	1	1½	1	1	1	1	2	2	1	2½	3	3	2½	2	2	2	1½	1½	1½	1	1
1858	0	0	0	0	0½	0½	0	0	0	0	0	0	0	0½	0½	0	1	0	0	0½	1	0	0	0
1859	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	2	2	2
1860	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1	2	2	2	1
1861	1	1	1	1	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Sum	3	2½	3	3	4	5½	4	3	2	3	3	1	2½	3½	3½	3½	5	4	4	4	5½	6½	5	4
East-south-east.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0
1860	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1861	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Sum	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	2	2	1	1	1	1
East.																								
1857	1	1½	0	0	0½	1	0	0½	1½	2	2	1	0½	0	1	1	0	0	0	0½	1	1	1½	1
1858	0	0	0	0	0	0½	1	1	0	0	0	1	1	1	1	1	1	1	0½	0	0	0	0	0
1859	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0
1860	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	4	4	3	3	1	1	1	1
1861	0	0	0	0	0	0	0	0	0	1	1	2	2	2	3	2	2	2	1	1	1	0	1	0
Sum	3	3½	2	2	2½	3½	3	4½	4½	6	6	7	6½	6	8	7	7	7	4½	4½	4	3	4½	2
East-north-east.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0	1	1	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1860	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	0	0	0	0	0
1861	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	1	0	0	0	0	0	1	1	0
Sum	0	0	1	1	1	0	0	1	1	0	1	1	1	1	2	2	0	0	1	0	0	1	1	0
North-east.																								
1857	0	0½	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1½	2
1858	4	4	3	5	4	4	3½	3	2	2	2	2	3	3	3	4	4	3	3½	5	4	4	6	6
1859	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1	1
1860	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	2	2	3
1861	1	1	1	1	1	1	1	0	0	1	1	0	1	1	1	1	1	1	0	0	0	0	1	2
Sum	6	6½	5	7	5	5	4½	3	2	3	3	2	4	4	5	6	5	4	3½	7	7	8	11½	14
North-north-east.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	2	2	1	1	2	4	3	2	0	0	1	1	0	0	0	0	1	1	0	0	0	0	0	0
1860	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1	1	0	0	0	0	1	0	0	0
1861	5	3	3	3	3	3	3	2	2	2	2	4	5	5	4	4	5	5	5	4	4	4	3	4
Sum	8	6	5	5	6	8	7	5	2	2	3	5	5	6	5	5	6	6	5	4	5	4	3	4

Table I.—*Direction of the Wind, Wallingford, Conn.*

DECEMBER.

	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
North.																								
1857	11	11½	9	10½	11	11	12½	12½	13	11	9½	7½	8½	8	5½	5	5	6	10	10	10½	10	10½	11
1858	12½	15	14½	13½	12	13	13	11	10	9	9	9	10	9	8½	9	9	9	9	10	9	10½	12½	14
1859	9	9	9	9	9	9	11	11	11	10	12	13	12	11	10	10	9	9	9	8	8	9	9	10
1860	10	11	11	11	13	14	14	13	14	14	12	10	8	8	8	8	7	6	8	8	8	9	9	10
1861	7	7	8	8	10	10	9	7	7	6	5	4	3	3	3	3	4	4	4	4	5	5	5	5
Sum	49½	53½	51	52	55	57	59½	54½	55	50	47½	43½	41½	39	35	35	34	34	40	40	40½	43½	46	50
North-north-west.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	6	6	6	6	6	5	4	4	3	4	2	2	3	2	3	4	3	4	4	4	4	4	4	5
1860	3	4	4	4	3	3	3	4	4	5	6	4	5	5	5	5	7	7	6	6	6	5	5	4
1861	6	6	5	5	4	4	4	5	5	7	8	9	9	9	9	8	7	7	7	7	6	5	6	6
Sum	15	16	15	15	13	12	11	13	12	16	16	15	17	16	17	17	17	18	17	17	16	14	15	15
North-west.																								
1857	4	4	5	7	7	6	5	5	6	6	8	12	9	7	10	10	9½	9½	6½	6½	6½	5½	4	4
1858	6	4	4½	5	6	6	5	4	5	6	6	6	5	6	7	7	7	7	7	7	6	4	4	4
1859	0	0	0	0	0	1	1	1	1	4	4	5	4	6	5	4	4	2½	2	2	3	2	3	1
1860	5	5	5	4	3	3	4	5	5	5	6	9	9	8	7	7	6	5	5	4	4	4	5	5
1861	3	3	3	3	2	2	3	3	2	2	2	2	2	2	2	3	3	4	4	6	6	6	4	4
Sum	18	16	17½	19	18	18	18	18	19	23	26	34	29	29	31	31	29½	28	24½	25½	25½	21½	20	18
West-north-west.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0	0	0	0	1	3	3	4	3	3	4	3	2	2	2	3	2½	2	3	1	2	0	0
1860	2	1	1	1	2	2	1	0	0	0	1	1	1	1	1	1	1	1	1	2	2	2	3	2
1861	1	1	1	1	0	0	0	0	0	0	1	1	1	2	2	2	3	3	3	2	1	1	1	1
Sum	3	2	2	2	2	3	4	3	4	3	5	6	5	5	5	5	7	6½	6	7	4	5	4	3
West.																								
1857	4	3½	3	3	3	3	3	3	2	3½	4	1½	2½	3½	5	7	5	5	4½	4½	4	4½	5	5
1858	3	4	4	4	3½	3	3	2	1½	0	1½	2	5	5	3	3	4	4	3	3	1½	2	2	3
1859	1	1	1	2	3	2	1	1	1	1	3	1	2	2	2	2	1	1	2	2	3	3	4	3½
1860	1	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
1861	3	3	2	2	2	2	1	2	2	2	0	0	0	0	0	0	0	0	0	0	0	1	1	1
Sum	12	13½	12	13	12½	11	9	9	7½	7½	9½	5½	10½	11½	11	13	11	11	10½	9½	8½	10½	12	12½
West-south-west.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	3	4	4	2	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
1860	2	1	2	1	2	2	3	2	2	2	1	1	1	1	2	2	2	2	2	3	3	3	3	3
1861	0	0	0	0	0	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	1
Sum	5	5	6	3	3	4	5	4	4	3	2	1	2	1	2	2	2	2	2	4	3	3	3	4
South-west.																								
1857	3	3	3	2	2	2	3½	3	3	3½	3½	3	6½	6½	4½	4	5½	6½	6	5	4	3	4	3½
1858	1	1	1	1	1½	2	3	3	3	3	2	3	2	2	3	3	2	2	2	2	2	1½	2	1
1859	2	1	2	2	2	2	3	2	3	3	2	2	2	2	2	2	3	2	2	3	3	3	3	4½
1860	1	1	0	1	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1	1
1861	2	1	1	1	1	1	0	0	0	1	1	2	1	1	1	1	1	1	1	0	3	3	4	3
Sum	9	7	7	7	7½	8	9½	8	9	10½	8½	10	12½	12½	10½	10	11½	11½	11	10	12	11½	14	13
South-south-west.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	4	4	6	7	7	7	5	6	6	5	4	4	3	3	3	3	3	4	4	3	2	1	1	1
1860	1	2	2	1	1	1	1	1	1	0	0	0	1	2	2	2	2	2	3	3	3	2	0	0
1861	6	6	7	7	6	6	7	7	8	6	6	7	8	8	8	9	9	9	9	9	6	5	5	5
Sum	11	12	15	15	14	14	13	14	15	11	10	11	12	13	13	14	14	15	16	14	11	8	6	6

Table I.—*Direction of the Wind, Wallingford, Conn.*

DECEMBER (continued).

	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
South.																								
1857	3½	4	4	4	4	4	2½	3	3	2½	2	4	1½	1	2	1½	2	1	1	2	3	2½	2	2½
1858	5½	5	5	4	3	3½	4	5	5	6½	7	6	5	5	5	6	6	6	6½	6	6½	7	5½	5
1859	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1	1	1
1860	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1861	1	1	1	1	2	1	1	1	1	1	2	2	3	3	3	3	2	2	2	3	3	4	4	3
Sum	12	12	10	10	10	9½	8½	10	10	11	12	13	9½	9	10	10½	10	9	9½	12	14½	14½	12½	11½
South-south-east.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	1	1	0	0	0	0	0	0	0	0½	1	0	0	0	0	0	0	0	0	0	1	2	2	2
1860	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
1861	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	2	2	1	1	1	1	2	1	0	0½	1	0	0	0	0	0	0	0	0	0	1	2	3	3
South-east.																								
1857	2½	1½	2	2½	3	3	3	3	2	2	1	0	0	0	0	0½	1	1	1	1	1	2½	3	3
1858	0	0	0	0½	1	0	0	2	1½	1	0½	0	0	0	0	0	0	0	0½	0½	1	0	0	0
1859	0	0	0	0	0	0	0	0	0	0½	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1860	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0
1861	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2
Sum	2½	1½	2	4	4	3	3	5	3½	3½	1½	1	1	1	1	1½	2	2	1½	1½	3	3½	4	5
East-south-east.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1860	2	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
1861	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Sum	3	1	1	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	2
East.																								
1857	3	2½	3	0	0	0	0	0½	1	0½	0	0½	1	1½	1	1	1	1	2	2	2	2	2	2
1858	0	0	0	0	1	0½	0	0	0	0½	0½	1	0	0	1	1	1	1	0	0	1	1	1	1
1859	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1860	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1861	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	3	2½	3	0	1	0½	0	1½	1	1	0½	1½	1	1½	2	2	2	2	2	2	3	3	3	3
East-north-east.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	2	2	1	1	1	1	0½	0	0	0	0	0	1	1	1	1	1	1	2	2	2	2	2	2
1860	0	1	1	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1861	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	2	4	3	3	2	2	0½	0	0	0	0	0	1	1	1	1	1	1	2	2	2	2	2	2
North-east.																								
1857	0	1	2	2	1	2	1½	1	1	2	3	2½	2	3½	3	2	2	1	0	0	0	1	0½	0
1858	3	2	2	3	3	3	3	4	5	5	4½	4	4	4	3½	2	2	2	3	2½	4	5	4	3
1859	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	2	2	2	1	1	1	1
1860	0	0	0	0	0	0	1	2	2	1	1	1	1	1	2	2	1	1	1	1	2	2	0	0
1861	0	0	0	2	0	0	0	1	1	1	1	2	1	1	0	0	0	0	0	0	0	0	0	0
Sum	4	4	5	8	4	5	5½	8	9	9	9½	9½	8	10½	9½	7	6	6	6	5½	7	9	5½	4
North-north-east.																								
1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	0	0	1	1	2	2	1½	1	0	0	0	0	1	1	2	2	3	3	2	1	1	1	1	0
1860	3	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	5	4	4	3	3	3	3
1861	1	2	2	1	4	4	4	4	4	4	3	2	2	2	2	2	2	1	1	0	0	0	0	0
Sum	4	3	4	3	7	7	6½	6	5	6	5	4	5	5	6	6	8	9	7	5	4	4	4	3

TABLE II, Part 1.—*Hourly Means.—Direction of the Wind, Wallingford, Conn.*

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept	Oct.	Nov.	Dec.	Av.
	°	°	°	°	°	°	°	°	°	°	°	°	°
1h	31·4	27·1	41·4	36·4	195·2	166·2	170·7	173·1	90·8	36·0	39·6	34·5	57
2	30·5	24·7	39·4	25·1	235·5	173·3	162·7	156·2	81·5	27·4	38·3	32·1	55
3	27·0	24·0	39·6	17·4	349·8	136·3	155·9	48·5	81·7	35·1	40·1	33·4	52
4	27·6	25·4	37·8	17·3	334·5	49·8	149·0	24·2	61·1	27·7	41·9	31·8	39
5	25·4	23·4	34·0	16·1	350·2	15·4	110·5	22·6	46·5	29·1	37·9	30·0	31
6	24·4	23·5	36·3	14·5	359·1	40·2	106·0	13·2	39·8	26·7	35·8	30·0	32
7	26·1	22·5	36·3	9·3	350·5	14·4	67·5	10·0	31·6	28·8	37·5	30·7	25
8	26·2	23·8	35·4	13·5	1·6	23·9	67·9	8·5	30·3	27·4	35·0	28·4	27
9	23·1	23·7	38·1	14·8	355·6	53·5	58·6	10·9	30·8	29·0	43·3	29·4	29
10	23·3	21·1	35·8	10·4	0·4	62·5	67·8	18·3	37·1	29·6	42·0	29·5	31
11	27·2	22·4	38·0	15·5	8·8	83·8	99·3	22·2	43·4	35·3	42·7	31·9	39
Noon	30·4	28.5	40·4	17·7	33·2	99·9	111·2	40·0	59·2	42·9	46·0	34·1	49
13	30·0	34·4	50·6	28·8	146·1	103·2	129·0	74·4	82·6	45·3	52·0	38·5	68
14	35·3	41·5	53·1	45·3	155·6	114·1	134·6	98·3	64·6	49·6	58·5	38·0	56
15	37·0	47·6	56·9	64·7	157·6	130·6	138·2	118·9	91·2	54·3	64·4	38·7	83
16	41·3	48·5	58·9	85·5	156·5	130·2	142·3	144·9	105·3	63·3	69·0	42·8	91
17	41·1	42·4	58·4	95·0	162·1	133·5	146·5	154·0	116·1	61·2	71·7	43·0	94
18	35·7	44·4	64·0	93·0	164·2	138·7	150·6	157·3	119·9	64·0	70·3	42·0	95
19	34·8	46·5	58·7	87·6	169·1	147·7	152·5	163·9	128·1	56·8	74·3	39·6	97
20	35·2	47·9	56·0	83·1	166·2	159·1	154·5	164·7	134·1	55·2	68·5	41·9	97
21	32·3	48·6	51·0	91·6	169·9	160·8	163·2	168·6	145·4	49·6	62·9	39·0	99
22	33·3	38·0	47·3	77·0	181·4	170·7	168·4	171·2	146·8	43·2	51·8	34·6	67
23	32·8	32·7	48·5	59·4	191·3	167·5	169·1	164·1	145·4	42·8	48·3	35·9	65
24	33·2	34·3	45·8	28·4	187·0	162·8	168·8	162·9	123·9	45·3	43·0	34·3	59
Mean	30·5	32·4	45·2	33·7	163·0	132·3	145·8	107·1	85·8	39·4	49·2	35·2	61
Fluct.	18	28	30	86	364	159	112	165	117	37	42	15	

These angles are measured from the North point, round the circle by the West and South.

TABLE II, Part 2.—*Ratio of the Wind's progressive motion in its mean direction, to the total distance traveled. Wallingford, Conn.*, 1857–1862.

	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1h	0·410	0·305	0·295	0·134	0·088	0·195	0·293	0·090	0·152	0·265	0·425	0·386
2	·423	·331	·289	·211	·020	·129	·252	·055	·154	·281	·412	·413
3	·363	·368	·302	·279	·056	·059	·219	·055	·141	·303	·403	·409
4	·412	·424	·329	·298	·109	·078	·139	·108	·150	·335	·380	·425
5	·435	·426	·370	·306	·142	·068	·084	·142	·191	·369	·412	·416
6	·444	·415	·402	·292	·144	059	·069	·187	·222	·379	·419	·448
7	·456	·423	·408	·311	·189	·075	·116	204	·257	·385	·458	·458
8	·459	·398	·449	·383	·222	·127	·135	·232	·241	·393	·451	·418
9	·442	·384	·445	·424	·210	·101	·162	·269	·238	·404	·448	·425
10	·411	·431	·450	·399	·194	·107	·183	·289	·260	·433	·465	·455
11	·412	·440	·454	·328	·125	·126	·162	·214	·258	·419	·447	·489
Noon	·402	·419	·450	·299	·052	·142	·167	·173	·213	·412	·448	·489
13	·408	·382	·459	·228	·032	·170	·199	·119	·217	·353	·423	·489
14	·381	·370	·419	·187	·093	·176	·234	·119	·220	·327	·395	·472
15	·354	·353	·379	·173	·223	·258	·308	·144	·253	·291	334	·462
16	·341	·351	·369	·184	·294	·245	·364	·182	·251	·256	·322	·467
17	·317	·394	·335	·204	·309	·288	·425	·224	·268	·221	·324	·459
18	·321	·366	·347	·216	·294	·265	·453	·254	·279	·201	·335	·457
19	·302	·322	·365	·194	·343	·254	·478	·299	·288	·182	·324	·443
20	·308	·324	·341	·162	·324	·305	·473	·327	·255	·158	·319	·443
21	·312	·273	·302	·132	·281	·290	·481	·298	·226	·165	·318	·389
22	·326	·250	·264	·110	·260	·223	·451	·237	·217	·195	·315	·383
23	·378	·265	·264	·101	·207	·193	·412	·198	·177	·210	·325	·389
24	·384	·280	·269	·122	·198	·164	·378	·161	·182	·223	·365	·385

If we combine the northings and southings, eastings and westings, for the several months, so as to obtain the latitude and departure for the entire year, and hence compute the mean direction for the year, we shall obtain for a result N. 51°·7 W. If we take the arithmetical mean of the twelve monthly directions, we shall obtain N. 74° W. The large difference arises from the greater uniformity in the wind's direction during the colder months, when the direction is most northerly.

The numbers in Table II, part 2, were obtained as follows: After computing the mean direction of the wind for each hour, as described on page 211, the absolute length of the line indicating its direction was computed, and this number was divided by the number of the observations for that hour without regard to direction. These resulting numbers, therefore, represent the ratio of the wind's progress, in the mean direction to its entire motion; and a comparison of these numbers shows at what hour the direction of the wind was most uniform, and at what hour it was most variable.

TABLE III.

Mean Direction of the Wind.

	Hudson, Ohio.			Wallingford, Conn.		
Months.	9 A. M. Course.	3 P. M. Course.	Diff.	9 A. M. Course.	3 P. M. Course.	Diff.
March,	N. 75 ·3 W.	N. 68 ·5 W.	6 ·8	N. 38 ·1 W.	N. 56 ·9 W.	18 ·8
April,	78·2	59·8	18·4	14·8	64·7	49·9
May,	85·3	61·7	23·6	N. 4·4 E.	S. 22·4 W.	162·0
June,	S. 81·9 W	77·1	21·0	N. 53·5 W.	49·4	77·1
July,	N. 84·8 W.	61·7	23·1	58·6	41·8	79·6
August,	81·7	48·4	33·3	10·9	61·1	108·0
September.	S. 69·5 W.	75·2	35·3	30·8	88·8	60·4
October.	73·3	89·5	17·2	29·0	N. 54·3 W.	25·3
November,	70·2	S. 82·9 W.	12·7	43·3	64·4	21·1
December,	82·3	N. 87·2 W.	10·5	29·4	38·7	9·3
January,	71·5	S. 82·6 W.	11·1	23·1	37·0	13·9
February,	79·7	86·3	6·6	23·7	47·6	23·9

For the entire year, the average change in the direction of the wind from 9 A. M. to 3 P. M., is at Hudson 18°·3; while at Wallingford it is 54°·1, or *three times* as great as at Hudson. Moreover, at Hudson the direction at 3 P. M. is always more *northerly* than at 9 A. M., while at Wallingford it is always more *southerly*. These facts seem to indicate that the cause of the diurnal change at Wallingford, must be quite different from what it is at Hudson.

The Philadelphia observations employed for comparison were those made at the Girard College Observatory* in 1842. The results are shown in the first part of Table IV, while in the second part of the

* Magnetic and Meteorological Observations, Girard College, Philadelphia, 1840–45.

Table are given the corresponding numbers for Toronto, Canada.*

TABLE IV, Part 1.—*Hourly Means.—Direction of the Wind, Philadelphia, Pa.*, 1842.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1h	38°	59°	19°	26°	28°	9°	356°	312°	28°	12°	42°	42°	21°
2	49	76	26	20	12	351	348	304	26	23	44	43	20
3	39	74	14	21	10	356	4	313	38	25	43	49	22
4	48	68	16	25	18	1	342	312	40	29	33	47	22
5	62	63	18	11	15	1	356	306	28	20	31	50	20
6	58	67	16	25	18	357	359	327	41	18	34	52	24
7	58	79	17	22	22	347	34	310	35	16	37	37	25
8	53	90	11	11	20	339	35	317	19	19	33	46	23
9	52	64	21	10	32	353	55	308	31	1	31	46	24
10	62	61	20	15	45	359	46	311	75	22	21	48	29
11	63	56	25	13	49	347	46	330	49	48	31	36	31
Noon	64	75	29	27	52	17	30	350	34	59	11	29	35
13	74	61	42	23	62	35	51	19	41	45	32	26	43
14	71	75	61	28	60	40	56	8	49	44	29	39	47
15	68	79	75	26	62	4	50	14	47	54	45	42	46
16	74	82	73	25	71	23	58	357	49	42	45	44	49
17	46	63	77	28	68	15	69	328	54	47	45	46	44
18	54	55	76	28	70	12	48	323	56	42	53	49	41
19	57	53	45	27	67	12	47	323	49	33	57	51	38
20	59	68	30	18	50	356	10	309	31	38	59	50	30
21	38	64	28	16	25	2	357	325	46	17	59	49	26
22	59	36	7	37	15	26	354	307	34	5	58	40	21
23	51	54	29	42	44	33	11	303	31	2	58	34	28
24	45	64	22	27	31	16	13	304	10	5	46	39	22
Fluct.	36	54	70	32	69	61	87	76	46	58	48	18	

General Average. N. 30° W.

TABLE IV, Part 2.—*Hourly Means.—Direction of the Wind, Toronto, Canada*, 1854–1859.

	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1	71°	55°	54°	2°	354°	17°	14°	22°	20°	51°	81°	62°	40°
2	70	56	54	3	358	16	11	26	20	52	80	57	40
3	74	59	53	2	350	21	9	25	17	43	79	54	39
4	70	61	50	2	345	18	11	20	15	43	83	56	39
5	73	62	53	2	345	24	15	18	14	39	84	56	38
6	73	64	53	1	344	29	15	30	21	39	86	62	40
7	71	66	52	10	333	42	14	38	36	45	82	56	42
8	68	65	53	9	331	67	19	55	49	50	83	59	48
9	69	68	62	12	324	126	140	74	78	58	87	59	63
10	75	72	72	40	299	145	171	112	121	66	88	62	80
11	82	76	78	89	276	157	173	138	145	79	92	67	96
Noon	84	83	83	111	253	158	180	142	146	86	91	73	103
13	86	82	84	110	252	164	175	139	142	87	90	79	103
14	87	81	83	97	280	168	175	123	135	84	90	81	101
15	82	79	80	75	311	154	176	105	120	77	88	82	90
16	79	72	76	51	341	118	153	79	92	70	83	82	77
17	82	70	74	45	0	87	94	56	78	70	84	80	70
18	82	64	72	47	3	52	55	49	61	66	83	80	64
19	76	62	66	34	1	39	52	41	55	60	83	81	59
20	79	61	68	25	354	24	36	38	44	59	78	81	56
21	81	56	64	20	0	16	32	32	35	51	77	76	51
22	76	58	61	13	359	16	29	30	30	52	80	70	48
23	73	62	58	9	357	18	28	29	21	51	79	68	46
24	72	58	56	2	354	18	18	24	22	44	79	66	43
Mean	77	67	70	23	340	73	66	58	61	62	85	70	62
Fluct.	17	28	34	110	111	152	171	124	132	48	15	28	

* Abstracts of meteorological observations made at the Magnetical Observatory. Toronto. during the years 1854 to 1859. inclusive. Toronto. 1864.

The numbers in both tables represent degrees counted from the north point around the circle by the west and south.

The diurnal fluctuation at Philadelphia during the cold months is greater than at Wallingford, but during the warm months it is decidedly less. The fluctuations at Philadelphia appear greater in consequence of the shortness of the period of comparison (one year). In order to discover what would be the effect of extending the period of comparison, that month was selected, (May), which at Wallingford, showed the most remarkable diurnal fluctuations. Table V shows the results of the Philadelphia observations for the month of May, for a period of four years.

TABLE V.—*Hourly Means. Direction of the Wind for May at Philadelphia.*

	1842	1843	1844	1845	Mean		1842	1843	1844	1845	Mean
1h	28°	38°	78°	72°	54°	13h	62°	351°	56°	56°	41°
2	12	24	103	69	52	14	60	346	38	68	38
3	10	357	88	69	41	15	62	19	63	59	51
4	18	357	74	62	38	16	71	33	85	58	59
5	15	357	65	65	36	17	68	34	71	68	60
6	18	1	62	64	36	18	70	21	70	65	57
7	22	2	63	61	37	19	67	30	69	54	55
8	20	356	61	52	32	20	50	30	59	72	53
9	32	354	43	59	32	21	25	28	49	71	43
10	45	354	42	66	37	22	15	0	59	80	39
11	49	5	60	66	45	23	44	346	45	82	39
Noon	52	7	64	63	47	24	31	6	52	75	41

The mean diurnal fluctuation is here reduced to 28 degrees, while at Wallingford, for the same month, it amounts to 364 degrees. The cause of this great fluctuation at Wallingford, must be very different from that which operates at Philadelphia; or if the cause be the same, it must operate with far greater intensity.

The results of the observations at Toronto, exhibit a strong resemblance to those at Wallingford. For the six colder months the mean diurnal change is nearly the same, and the curves representing the change of direction are similar, although the corresponding changes are not simultaneous. At Toronto the wind is most southerly about an hour after noon, while at Wallingford the wind is generally most southerly about 5 P. M. During the six warmer months, the diurnal change of direction at Toronto is nearly as great as at Wallingford; and if we omit the month of May, it is greater than at Wallingford. Moreover, the curves representing the changes of direction at the two places, bear some resemblance to each other; although the change of wind from north to south generally occurs four hours earlier at Toronto than at Wallingford.

A comparison of these facts naturally suggests the idea, that the diurnal change in the direction of the wind is mainly due to inequality of temperature over neighboring portions of the earth's surface; and that at Wallingford, as well as at Toronto, the great changes in the warmer months are due to the proximity of a large surface of water. The diurnal change at Wallingford cannot be ascribed simply to the inequalities of the earth's surface. This cause might affect the mean direction of the wind, but could not produce a change in the wind's direction from hour to hour. Moreover, the facts stated on page 209, show that the horizon at Wallingford is but little obstructed by hills; while the great regularity in the changes shown by the curves on Plate VIII, indicates that the inequalities of the earth's surface do not here greatly affect the wind's direction.

We propose, then, to inquire whether the diurnal changes in the direction of the wind at Wallingford, can be explained by the influence of the difference of temperature of the land and the neighboring water. For this comparison we will take the temperature of New Haven as the standard for the temperature of the land at different periods of the day and year, and for the water we will take the numbers derived from Maury's thermometrical charts of the Atlantic.*

In Table VI, column second shows the mean temperature of the different months at New Haven; column third shows the mean temperature of the warmest hour of each month; and column fourth shows the mean temperature of the coldest hour of each month.

TABLE VI.—*Temperature of New Haven and Ocean compared.*

	New Haven.			Ocean.	G. Str.		New Haven.			Ocean.	G. Str.
Months.	Mean	Max'm	Min'm	Mean	Mean	Months.	Mean	Max'm	Min'm	Mean	Mean
Jan.	26°·5	32°·9	22°·1	42°·5	59°·4	July	71°·7	79°·5	64°·0	64°·0	71°·8
Feb.	28·1	35·1	22·8	39·7	61·9	Aug.	70·3	78·0	63·2	69·0	75·0
March	36·1	43·6	29·9	40·5	57·9	Sept.	62·5	70·5	55·1	63.2	74·1
April	46·8	55·2	39·3	42·4	61·3	Oct.	51·1	59·2	44·3	59·2	71·7
May	57·3	65·8	48·8	48·2	63·7	Nov.	40·3	46·9	35·5	52·8	66·5
June	67.0	75·3	58·1	60·4	67·9	Dec.	30·4	36·5	26·4	46·5	62·2
						Year	49·0	56·5	42·6	52·4	66·1

Column fifth shows the mean temperature of the Atlantic Ocean for a zone extending a little over a degree on each side of the parallel of New Haven, and reaching eastward to longitude 69°; while column sixth shows the mean temperature of that portion of the Gulf Stream, which is comprehended within the limits of the same zone. The diurnal change of temperature of the water is not accurately known, but is presumed to be less that half what it is at New Haven. The distance from Wallingford to the nearest point of the Gulf stream is about 300 statute miles; its distance from the nearest point of the Atlantic Ocean is about 50 miles; but Long Island Sound, which is

* Maury's wind and current charts, Thermal sheets, Series D.

here 20 miles in breadth, is distant only ten miles. It is presumed that the temperature here given for the Atlantic Ocean would not differ greatly from the temperature of Long Island Sound for the corresponding months.

Near the parallel of 40° N. lat. the average wind is from a point a little South of West. We will call this the normal wind, and inquire whether the temperatures shown in Table VI. will enable us to explain the departures from this normal direction shown in the observations at Wallingford. Beginning with the month of January, we find the temperature of the land, even at its maximum, to be many degrees lower than the neighboring water. This cause should then produce a deflection of the normal wind in the direction from the land toward the water; and this should continue throughout the 24 hours, but should be most decided during the colder half of the day, which conclusion corresponds very closely with the observed facts. The same remark is applicable to the month of February, except that during the warmest part of the day, the temperature of the land differs from that of the ocean less than in January, and the deflecting force should be less; which conclusion also corresponds very well with the observed facts. The phenomena for January and February are therefore very well explained by the unequal temperature of the land and the *neighboring* water, without ascribing any influence to the more distant and warmer water of the Gulf Stream.

For the month of March, the same remark is applicable during the colder half of the day; but about the hour of maximum heat the temperature of the land and that of the neighboring water is about the same, while observation shows the wind still tending from the northwest. This would seem to indicate that the heat of the Gulf Stream was the principal deflecting force; but perhaps the facts may be explained from the inertia of the air set in motion from the northward, because the neighboring water is warmer than the land during nearly the entire day, and the slightly higher temperature of the land continuing but for an hour or two, is insufficient to arrest this steady current from the north. The phenomena for March are easily explained by reference to the higher temperature of the Gulf Stream; and may, perhaps, be explained without ascribing any very important influence to this more remote body of water.

During the month of April, the mean temperature of the land is higher than that of the neighboring water; and even at the coldest hour of the day, the land cannot be much colder than the water. Nevertheless, observations show a strong deflecting force from the

North prevailing more than half the day. It does not appear how this fact can be explained, except by ascribing it to the influence of the warmer water of the Gulf Stream.

The northerly wind, which prevails during a considerable portion of the day in the month of May, cannot be ascribed to the influence of the neighboring water, but is easily explained by the higher temperature of the Gulf Stream; while during the principal part of the day, the temperature of the land rises so much above that of the neighboring water, that a breeze springs up from the colder water toward the land.

The northerly wind which prevails during a portion of the day in the month of June, seems also to indicate the influence of the Gulf Stream, while the southerly wind, which prevails during more than half the day, is explained as in the month of May.

In July the northerly wind almost entirely disappears, for now the land is not only warmer than the neighboring ocean, but during a considerable part of the day is warmer even than the Gulf Stream. The strong southerly wind which generally prevails, is a current flowing from the cooler water toward the land.

In the months of August and September the land is warmer than the neighboring water during about half of the day, and colder during the other half; and we find accordingly that the northerly current prevails for about half of the day, and the southerly for the other half.

In the month of October the circumstances are nearly the same as in March, while in November and December they are nearly the same as in January and February.

We find, then, that most of the observed facts can be accounted for from the unequal temperature of the land and the neighboring water; but some of the facts, especially those in April, May and June, seem to indicate a decided influence of the Gulf Stream; and if the influence of the Gulf Stream is appreciable during certain months of the year, its influence must be exerted during the remaining months of the year, although partly masked by being blended with other causes.

If the causes which we have here assigned for the changes in the wind's direction at Wallingford are correct, they ought to produce similar effects at other stations similarly situated; that is, at places all along the Atlantic coast of the United States within the belt of prevalent westerly winds. Observations at such places may then afford a test of the accuracy of the explanation here given.

From a series of hourly observations of the wind, we may infer the best method of deducing the wind's mean direction from observations made at a limited number of hours. For nine months of the year at Wallingford, the direction of the wind at 1 P. M. corresponds very closely with the mean of the 24 hours, while for the other three months (May, June and July) this direction is not attained until 5 P. M. The other hour of the day when the wind's direction corresponds most nearly with the mean of the 24 hours, is about an hour after midnight. At Toronto, the two hours when the wind's direction corresponds most nearly with the mean of the 24 hours, are 9 A. M. and 6 P. M. At Philadelphia they are 10 A. M. and 8 P. M. These critical hours appear, therefore, to vary considerably with the locality.

The hours most generally selected for observations of temperature are 7 A. M., 2 and 9 P. M., and the best result which can be deduced from these observations is obtained by adding twice the 9 o'clock observation to the sum of the other two observations, and dividing the result by four. The same rule gives the true mean direction of the wind at Toronto within less than one degree, although the mean diurnal range amounts to 65 degrees. At Philadelphia also the rule gives an equally accurate result.

At Wallingford this rule is considerably in error, owing to the fact that the critical hours occur much later than at Toronto; but during the six colder months, the mean of the 7 A. M. and 2 P. M. observations corresponds very well with the mean of the 24 hours, while during the other six months, the 2 P. M. observation does not differ greatly from the mean of the 24 hours.

At most observatories where hourly observations of the wind are made, the observations are not reduced with sufficient accuracy to enable us to test the preceding method of deducing the mean direction from a limited number of observations; but at Oxford, England, the rule above given for Toronto furnishes a very accurate result.

The record at Wallingford shows several cases in which the vane indicated the same direction uninterruptedly for two days or more. The following examples are selected from the first two years of the observations; because during this period the force of the wind was recorded, and we are able to distinguish between the period during which the wind blew with considerable force, and that during which the air was nearly or quite calm. Until January, 1859, the records employed only the eight cardinal points; but subsequently sixteen points were employed.

The following Table shows first, the direction indicated by the vane; second, the date at which this direction began to be recorded; third, the period during which the record indicated identically the same direction of the wind; and lastly, the number of hours during this interval when the pressure apparatus showed the wind to blow with a force of at least eight ounces on a plate ten inches square.

TABLE VII.—*Instances of remarkably steady Winds.*

Direction of Wind.	Commencement of Wind.	Duration.	Force of Wind at least 8 oz.
North	1857, Oct. 27d, 1h	2d 17h	35 hours.
North	1857, Dec. 24, 19	2 12	28 "
S.W.	1858, Feb. 16, 16	2 6	54 "
South	1858, July 7, 18	4 0	29 "
South	1858, Sept. 8, 15	2 22	22 "
North	1858, Oct. 23, 22	4 7	46 "
N.W.	1858, Nov. 24, 12	3 11	77 "
N.W.	1859, April 18, 18	2 8	35 "
S.S.W.	1859, May 4, 9	2 9	19 "
S.S.E.	1859, May 16, 15	2 9	9 "
South	1859, May 25, 15	2 3	17 "

Force of the Wind.

The force of the wind was recorded by an anemometer constructed upon the principle of Osler's anemometer, from directions furnished by Dr. Smallwood of Montreal.* The pressure plate was ten inches square, and the spring was a straight steel rod, 2 ft. 7 in. long, and one-fourth inch in diameter. The weight of the clock (the same as employed for recording the direction of the vane) turned a horizontal cylinder nine inches long, and three and three-quarter inches in diameter, with a uniform and known velocity. A long roll of paper, eight inches broad, wound upon a roller, passed over the cylinder, and was wound up on another roller. The ends of the cylinder were armed upon its circumference with sharp points, which caught the paper and carried it forward with the same velocity as that with which the cylinder turned. The motions of the pressure plate were communicated by means of wheel work to a pencil, which was pressed by a spring against the paper. When the pressure plate was stationary, the pencil described a straight line upon the paper; but when the plate was in motion, the pencil traced a zig-zag line.

Before the commencement of the observations, experiments were made to determine the amount of pressure on the plate corresponding to given positions of the spring; and hence the distance of the different points of the zig-zag line from the line of no pressure, could be converted into ounces of pressure on a surface ten inches square. Unfortunately these experiments were not repeated at the close of the observations. In the course of the two years during which the spring

* See page 209 and note.

was employed, the record showed a permanent change, indicating either a change in the elasticity of the spring, or a change in the apparatus by which the motion of the pressure plate was transmitted to the recording pencil.

The observations on the force of the wind commenced 1857, Sept. 7d, 7h, and continued to 1859, July 11th. Until the month of April, 1858, pressures less than ten ounces seem to have been recorded with as great fidelity as the higher pressures. After April 5th, 1858, no pressures were recorded less than ten ounces on a plate ten inches square. About this time, either the spring or the recording apparatus must have sustained some injury. It is impossible now to determine why the apparatus subsequently failed to record the smaller pressures: nor can we determine whether the higher pressures recorded before April, 1858, are comparable with those subsequently recorded. This failure of the anemometer to record the low pressures impairs somewhat the value of the observations; nevertheless, the results are so consistent with each other, and with similar observations made elsewhere (as we shall see hereafter), that the observations are considered worthy of preservation.

Other observers have experienced similar difficulties with the pressure apparatus of Osler's anemometer. At the Observatory of Toronto, Canada, during the years 1840, '41 and '42, in pressures of less than one pound, the pressure plate of the anemometer either did not move at all, or the record of its motion was very uncertain. In higher winds the instrument worked well, but the spring was insufficient to bring the pencil back again to the zero, so that until corrected by hand, the pencil might continue to mark high pressures after the wind had lulled. A similar imperfection was found in the Osler's anemometer employed at the Girard College Observatory in 1840–45.

Table VIII exhibits in detail the entire series of observations at Wallingford, and shows the recorded force of the wind estimated in ounces upon a surface of 100 square inches, for each hour of the day during two years. The average force of the wind is thence obtained for each hour of each month.

Table VIII.—*Force of the Wind, Wallingford, Conn.*

JANUARY, 1858.

Days	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
1	18	10	9	9	6	6	6	6	6	7	9	11	11	11	11	10	10	9	8	9	14	13	14	11
2	--	--	--	--	--	--	--	--	--	--	--	--	4	5	2	--	--	--	--	--	--	--	--	10
3	--	--	--	--	3	3	3	3	--	--	11	11	11	11	11	11	11	13	13	12	11	10	9	10
4	10	11	8	7	6	7	8	8	9	11	11	11	11	11	10	9	9	8	8	8	7	6	5	5
5	5	5	3	--	--	--	--	--	--	--	--	--	3	3	2	--	--	--	--	--	--	2	10	12
6	10	11	11	8	10	10	10	10	13	13	11	11	11	13	13	11	8	7	6	6	6	4	--	--
7	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	11	14	14	14	17	19	11	11	11
8	11	11	9	7	6	7	9	11	14	14	11	11	11	10	9	10	6	--	--	--	--	--	--	--
9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7	8	8	8	8	8	9	11
10	--	--	--	--	--	--	--	--	--	11	11	6	5	3	--	--	--	--	--	--	--	--	--	--
11	--	--	--	--	--	--	--	11	15	18	18	19	18	24	24	18	16	15	11	9	7	7	6	5
12	--	--	11	11	10	7	6	6	8	10	11	14	20	22	22	19	18	14	11	11	3	--	--	--
13	--	--	--	--	--	--	--	--	--	--	4	4	--	3	5	5	3	--	--	--	--	--	--	--
14	--	--	--	--	--	--	--	--	--	--	--	4	5	6	6	5	3	--	--	--	--	--	--	--
15	--	--	--	--	--	--	--	--	--	--	--	9	11	11	11	11	11	11	11	11	11	11	11	11
16	11	11	11	9	8	6	7	7	7	5	--	--	--	--	--	4	5	4	3	--	--	--	--	--
17	7	8	10	8	8	8	8	10	11	9	10	12	12	11	11	11	10	8	7	6	6	6	6	6
18	5	5	6	6	5	5	6	7	9	11	15	16	11	11	11	11	11	5	--	--	--	--	--	--
19	--	--	--	--	--	5	5	--	--	--	--	--	--	--	--	3	4	--	--	--	--	--	--	--
20	--	--	--	--	--	--	--	--	--	--	--	--	--	9	10	9	8	4	--	--	--	--	--	--
21	--	--	--	--	--	--	--	--	--	--	10	12	11	9	8	11	11	8	7	6	4	--	--	--
22	--	--	--	--	--	11	11	11	11	11	13	14	14	14	14	12	11	11	11	8	6	5	5	4
23	3	3	--	--	--	--	--	--	--	4	8	6	--	--	--	--	--	--	--	--	--	--	--	--
24	--	--	--	--	--	--	--	--	--	--	3	11	11	8	8	8	8	8	--	--	--	--	--	--
25	--	--	--	--	--	--	--	--	--	4	6	7	7	7	7	8	6	4	--	--	--	--	--	--
26	--	--	--	--	--	--	--	--	--	--	11	11	9	9	10	11	10	5	--	--	--	--	--	--
27	--	--	--	--	--	--	--	--	--	--	--	5	11	11	8	6	6	6	4	--	--	--	--	--
28	--	--	--	3	--	--	--	--	--	--	3	6	6	6	6	5	6	7	9	11	11	10	6	5
29	4	4	4	3	4	6	8	11	11	11	11	10	11	11	11	8	7	7	13	15	14	14	14	11
30	11	11	11	11	15	15	14	14	14	14	14	14	14	14	14	15	14	14	14	14	12	12	12	11
31	11	13	13	13	14	15	14	14	14	14	14	14	14	14	11	11	11	4	--	--	--	--	--	--
Av.	3·4	3·3	3·4	3·1	3·1	3·6	3·7	4·2	4·6	5·4	7·3	8·4	8·5	9·0	8·6	8·2	8·2	6·3	5·1	4·9	4·5	3·8	3·8	4·0

JANUARY, 1859.

Days	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
1	--	--	--	--	--	--	--	--	--	--	--	--	--	11	18	18	18	--	--	14	--	--	--	--
2	--	--	--	--	--	--	--	--	--	--	11	--	--	--	--	--	--	--	--	--	--	--	--	--
3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11
4	14	11	11	11	14	18	18	18	18	18	18	22	22	22	22	11	14	18	18	18	18	18	18	16
5	--	--	--	--	--	--	--	--	--	14	14	--	--	--	11	11	11	11	11	--	--	--	--	--
6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	26
8	20	18	22	14	14	18	18	--	--	11	22	26	26	30	28	20	14	12	--	--	--	--	--	--
9	--	--	--	--	--	--	--	11	11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
10	--	--	10	11	11	14	14	14	14	14	14	14	14	14	14	14	11	11	11	--	--	--	--	--
11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
12	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
13	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
14	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
15	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
16	--	14	18	14	14	--	--	--	16	18	18	18	18	18	18	14	--	--	--	--	--	--	--	--
17	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	18
18	22	22	22	22	22	18	11	11	11	11	11	11	11	11	--	--	--	--	--	--	--	--	--	--
19	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
20	--	--	--	--	--	--	--	--	--	--	--	10	11	11	11	11	--	--	--	--	--	--	--	--
21	11	11	11	11	11	14	14	22	22	22	13	13	13	22	--	--	--	--	--	--	--	--	--	--
22	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	14	26	26	26	26	26	26	27
23	30	30	26	22	22	14	14	11	11	11	11	11	14	14	14	14	14	--	--	--	--	--	--	--
24	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
25	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
26	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
27	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
28	11	11	11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
29	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
30	--	--	--	--	--	--	--	--	--	--	14	14	26	26	26	18	18	--	--	--	--	--	--	--
31	11	11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11
Av.	3·8	4·1	4·2	3·4	3·5	3·1	2·9	2·8	3·3	3·8	4·7	4·5	5·0	5·8	5·2	4·2	3·7	2·5	2·1	1·9	1·8	1·8	1·8	3·5
2y.	3·6	3·7	3·8	3·2	3·3	3·3	3·3	3·5	4·0	4·6	6·0	6·4	6·7	7·4	6·9	6·2	6·0	4·4	3·6	3·4	3·1	2·8	2·8	3·7

Table VIII.—*Force of the Wind, Wallingford, Conn.*

February, 1858.

Days	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
1	--	--	--	--	--	--	--	--	--	3	4	5	6	8	9	9	11	11	13	13	12	11	11	11
2	11	11	11	11	11	11	11	11	11	9	6	5	4	--	--	3	5	5	6	7	8	9	11	11
3	11	11	11	12	11	11	11	11	11	11	14	18	18	18	17	14	13	11	6	5	5	5	3	--
4	--	--	--	--	--	--	--	--	--	--	--	--	3	4	4	4	4	5	6	7	8	10	11	10
5	7	7	7	7	6	5	5	6	8	11	10	10	10	10	11	11	11	11	11	14	14	14	14	14
6	12	11	13	11	13	14	14	15	14	14	19	13	14	14	11	11	10	5	--	--	--	--	--	--
7	--	--	--	--	--	--	--	--	--	4	6	7	7	7	8	3	--	--	--	10	11	10	8	7
8	--	--	3	3	3	3	3	5	4	11	11	11	11	13	14	14	13	11	11	7	--	--	--	--
9	--	--	--	--	--	--	--	--	--	--	11	8	9	12	14	12	11	11	11	11	11	11	11	11
10	10	8	8	6	4	5	7	11	11	11	13	18	22	26	28	27	21	15	14	14	18	18	16	11
11	11	11	12	12	14	18	18	17	15	13	15	17	14	11	13	12	11	11	5	--	--	--	--	--
12	--	--	--	--	--	--	--	--	--	--	--	4	7	8	11	11	11	5	--	--	--	--	--	--
13	5	6	6	5	5	6	6	8	8	10	11	11	11	11	11	11	11	11	8	6	10	11	11	12
14	13	11	11	11	11	11	11	11	11	12	11	11	11	11	9	7	7	5	--	--	--	--	--	--
15	--	--	--	--	--	--	11	11	12	14	22	27	26	26	28	18	14	14	14	13	11	9	11	6
16	3	5	8	11	8	7	7	7	7	7	7	9	12	15	15	17	17	16	18	20	22	22	22	22
17	19	16	25	21	21	13	11	11	21	20	21	24	30	26	26	23	17	13	15	21	21	14	15	11
18	13	15	11	11	11	9	8	9	9	11	11	11	12	11	13	13	13	15	15	15	11	11	9	9
19	11	8	4	--	--	--	--	5	11	11	11	9	10	8	7	7	6	5	5	5	6	6	8	11
20	11	10	10	11	11	11	11	11	11	14	14	14	16	16	17	22	26	27	22	11	14	12	9	7
21	4	4	2	--	--	--	--	--	--	--	2	3	4	5	5	6	6	6	5	5	5	5	5	5
22	5	4	5	11	12	11	10	11	11	13	17	17	12	11	11	11	9	9	9	4	--	--	--	--
23	3	5	6	6	5	--	--	--	--	--	11	11	11	13	14	11	11	5	--	--	--	--	--	--
24	--	--	--	--	--	--	--	--	--	--	--	--	6	8	8	7	7	7	4	--	--	--	--	--
25	--	--	--	--	--	--	--	--	--	--	4	6	7	10	11	11	8	5	3	2	--	--	--	--
26	--	--	--	--	--	--	--	--	--	--	10	11	10	8	6	4	3	3	3	2	--	--	--	--
27	--	--	--	--	--	--	--	--	--	--	10	11	11	11	14	14	11	12	11	10	9	8	7	6
28	6	5	3	--	--	--	--	--	--	--	3	10	11	11	11	11	10	10	6	6	5	5	5	5
Av.	5·5	5·3	5·6	5·3	5·2	4·8	5·1	5·7	6·2	7·1	9·8	10·7	11·6	11·9	12·4	11·6	10·6	9·4	7·9	7·4	7·2	6·8	6·7	6·0

February, 1859.

Days	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	11
3	14	14	14	14	14	14	18	18	18	18	18	18	18	18	18	18	18	18	18	18	14	14	14	14
4	--	--	--	--	--	--	--	--	--	--	--	11	11	--	--	--	--	--	--	--	--	--	--	--
5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
7	--	--	--	--	--	--	--	--	--	--	--	11	11	11	--	--	--	--	--	--	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	--	--	--	--	--	--	--
9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	--
10	14	14	22	22	22	22	22	22	22	26	26	26	26	26	26	26	26	26	26	18	18	14	14	14
11	14	11	11	11	--	--	--	11	12	14	18	14	14	--	--	--	--	--	--	--	--	--	--	--
12	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
13	--	--	--	--	--	--	--	--	--	11	11	--	--	--	--	--	--	--	--	--	--	--	--	--
14	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	--	--	--	--	--	--	--	--	--
15	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	--	--	--	--	--	--	--	--	--
16	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	--	--
17	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
18	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
19	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
20	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	19	19	22	22	30	30
21	26	26	26	26	26	22	22	26	26	26	26	30	30	30	34	34	34	40	44	36	22	22	22	22
22	26	26	26	26	18	11	11	11	11	14	14	11	11	11	--	--	--	--	--	--	--	--	--	--
23	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
24	--	--	--	--	--	--	--	--	--	22	--	--	--	22	26	30	26	26	22	18	18	14	--	--
25	--	14	14	14	14	14	14	14	11	11	11	11	11	11	11	11	11	11	11	11	11	11	--	--
26	--	--	--	--	--	--	14	14	11	11	11	11	11	11	11	11	11	14	14	11	11	--	--	--
27	--	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	--	--	--	--	--	11	11	--
28	--	--	--	--	--	--	--	18	14	14	22	22	22	22	22	22	22	18	14	14	14	14	14	14
Av.	3·4	3·7	4·0	4·0	3·4	3·0	3·6	4·8	4·5	6·0	5·6	6·3	6·7	7·0	7·0	6·2	5·7	5·5	6·4	5·6	5·4	5·5	4·5	3·8
2y.	4·4	4·5	4·8	4·6	4·3	3·9	4·3	5·2	5·3	6·5	7·7	8·5	9·1	9·4	9·2	8·9	8·1	7·4	7·1	6·5	6·3	6·1	5·6	4·9

Table VIII.—*Force of the Wind, Wallingford, Conn.*

	Days	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
MARCH, 1858.	1	--	--	--	--	--	--	--	--	3	10	12	12	9	6	6	6	4	--	--	--	--	--	4	6
	2	6	7	8	9	11	11	11	12	12	15	16	11	16	17	16	11	11	11	11	11	11	11	11	10
	3	10	10	4	--	--	--	--	--	--	11	11	11	11	11	11	11	11	9	--	--	--	--	--	--
	4	--	--	--	--	--	--	--	--	--	4	5	6	6	6	7	7	11	8	7	5	4	5	5	5
	5	5	5	7	9	11	11	11	11	14	21	21	19	19	22	22	22	22	22	21	16	17	24	16	18
	6	19	17	16	13	12	11	11	17	15	11	14	17	13	12	14	14	11	6	--	--	--	11	14	11
	7	10	10	11	13	14	11	11	17	29	28	26	26	23	19	21	17	19	14	--	--	--	--	--	--
	8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3	5	7	9	11	11	11	11	11	12
	9	11	11	11	11	11	11	11	12	14	14	15	20	22	21	18	16	13	11	7	6	5	5	5	5
	10	5	3	--	--	--	--	--	--	--	10	11	11	15	15	16	15	14	12	5	--	--	--	--	--
	11	--	--	--	--	--	--	--	--	--	4	6	7	7	7	7	6	7	8	11	11	15	11	13	20
	12	15	24	26	26	22	18	18	22	26	25	22	19	17	13	9	7	7	7	7	7	7	7	7	7
	13	6	5	5	5	8	10	11	11	14	13	13	13	11	10	7	10	4	--	--	--	--	--	--	--
	14	--	--	--	--	--	--	--	--	4	10	11	11	11	7	7	8	7	7	8	8	4	--	--	--
	15	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	16	--	--	--	--	--	--	--	--	--	--	--	--	4	6	7	7	7	6	4	--	--	--	--	--
	17	--	--	--	--	--	--	--	--	--	--	4	5	7	8	9	8	7	8	5	--	--	--	--	--
	18	4	5	7	9	9	9	9	13	15	26	22	22	22	22	22	18	20	18	13	11	9	9	10	8
	19	7	8	11	11	11	12	15	15	17	19	13	19	12	11	10	7	5	5	--	--	--	--	--	--
	20	--	--	--	--	--	--	--	--	--	--	--	5	6	6	11	12	10	6	6	5	6	6	6	6
	21	5	5	5	5	6	5	5	7	11	11	11	11	11	11	11	7	5	7	19	8	8	9	11	11
	22	11	11	12	12	13	15	13	12	17	23	25	25	23	16	22	21	18	18	12	9	9	14	14	11
	23	8	8	9	9	9	9	9	8	9	10	6	6	7	9	11	11	11	9	3	--	--	--	--	--
	24	--	--	--	--	--	--	--	--	--	--	--	11	11	13	14	16	17	15	12	10	11	11	10	8
	25	--	--	--	--	--	--	--	--	--	4	7	11	11	11	11	11	10	8	8	9	21	8	--	--
	26	--	--	--	--	5	13	11	14	11	22	29	25	25	25	25	25	25	25	21	16	14	21	21	11
	27	12	11	11	11	20	24	11	11	11	12	13	16	17	13	14	14	14	11	4	--	--	--	--	--
	28	--	--	--	--	--	--	--	--	--	4	5	5	4	4	5	5	5	5	3	--	--	--	--	--
	29	--	--	--	--	--	--	--	--	--	3	5	8	11	11	11	13	15	14	2	--	--	--	--	--
	30	--	--	--	--	--	--	--	--	3	4	5	4	4	4	4	4	5	5	5	4	--	--	--	--
	31	--	--	--	--	--	--	--	6	9	9	7	6	7	7	6	6	6	6	4	--	--	--	--	--
	Av.	4·3	4·5	4·6	4·6	5·2	5·5	5.1	6·1	7·5	10·4	10·8	11·7	11·4	11·1	11.5	11·0	10·6	9·4	6·7	4·7	4·9	5·4	5·1	4·8
MARCH, 1859.	1	--	--	--	18	15	11	--	--	14	18	22	30	44	26	22	22	22	22	22	18	18	18	18	11
	2	--	11	11	--	--	--	--	--	14	14	14	14	14	14	11	11	11	--	--	--	--	--	--	--
	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	11	18
	4	23	26	23	14	11	11	11	15	15	14	11	11	--	--	--	--	--	--	--	--	--	--	--	--
	5	--	--	--	--	--	--	--	--	--	14	14	14	16	18	18	18	18	18	18	--	--	14	14	--
	6	--	--	--	--	--	--	--	--	--	--	--	11	11	11	14	11	11	--	--	--	--	--	--	--
	7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	8	--	--	--	--	--	11	11	11	11	11	11	11	14	14	14	14	14	14	22	22	22	22	18	18
	9	18	18	11	11	--	11	11	11	18	16	14	18	18	22	22	14	14	--	--	--	--	--	--	--
	10	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	--	--	--	--	--	--	--	--	--
	11	--	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	11	11	--	--	--	--
	12	--	--	--	--	11	14	17	11	17	26	26	14	14	14	14	--	--	--	--	--	--	--	--	--
	13	--	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	--	--	--	--	--	--
	14	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	11	11	11	11	11	11	11	11	11
	15	23	26	26	36	44	30	22	26	26	26	18	34	14	22	14	26	22	22	11	14	--	22	11	11
	16	--	--	--	21	21	21	21	21	21	21	26	30	30	30	30	26	26	18	18	--	--	--	--	--
	17	--	--	--	--	--	--	--	--	--	--	11	11	11	13	11	11	11	11	--	--	--	--	--	--
	18	--	--	--	--	11	--	--	--	--	14	26	30	36	40	44	30	26	26	26	26	26	26	26	26
	19	26	26	14	20	26	26	26	26	30	34	34	31	34	34	34	34	34	34	26	26	26	26	26	26
	20	26	26	26	26	18	18	18	18	18	18	25	25	34	34	34	34	34	34	22	26	14	--	14	14
	21	30	34	26	14	11	11	11	11	11	11	11	11	14	14	11	--	--	--	--	--	--	--	--	--
	22	--	--	--	--	--	--	--	--	--	--	11	14	14	14	14	14	11	--	--	--	--	--	--	--
	23	11	11	11	11	11	11	11	11	11	18	14	22	22	18	18	18	18	11	--	--	--	--	--	--
	24	--	--	--	--	--	--	--	--	--	14	14	14	14	14	--	14	14	14	14	14	--	14	14	--
	25	--	--	--	--	--	--	--	--	--	11	11	14	11	--	--	--	--	--	--	--	--	--	--	--
	26	--	--	--	--	--	--	--	--	11	11	18	22	26	30	26	26	22	22	22	22	22	11	11	--
	27	14	11	--	--	--	--	--	--	--	--	--	--	--	--	14	--	--	--	--	--	--	--	--	--
	28	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	11	11	--	--	--	--	--	--	--
	29	--	--	--	--	--	--	--	--	--	--	--	--	18	18	18	18	--	--	--	--	--	11	11	14
	30	--	--	--	--	--	--	--	--	--	--	--	14	14	14	14	14	14	11	--	--	--	--	--	--
	31	--	--	--	14	14	14	18	22	26	22	22	22	26	26	26	30	30	48	31	22	18	18	--	--
	Av.	5.5	6·1	4·8	6·0	6·2	6·1	5·7	5·9	7·8	10·1	12·1	14·3	15·2	15·6	15 5	13·8	12·8	10·9	8·2	6·8	5·1	6·6	6·0	4·8
	2y.	4·9	5·3	4·7	5·3	5·7	5·8	5·4	6·0	7·6	10·2	11·4	13·0	13·3	13·3	13·5	12·4	11·7	10·1	7·4	5·7	5·0	6·0	5·5	4·8

Table VIII.—*Force of the Wind, Wallingford, Conn.*

Month	Days	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
April, 1858.	1	--	--	--	--	--	--	--	--	--	3	5	6	7	7	8	9	11	11	4	--	--	--	--	--
	2	--	--	--	--	--	--	--	2	5	5	6	7	7	8	10	11	3	--	--	--	--	--	--	--
	3	--	--	--	--	--	--	--	--	--	3	5	7	9	11	9	11	11	1	--	--	--	--	--	--
	4	2	4	5	6	6	7	7	7	7	7	6	5	5	5	5	6	3	--	--	--	--	--	--	--
	5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	6	--	--	--	--	--	--	--	--	--	--	11	11	14	19	20	18	18	18	18	18	18	18	18	18
	7	15	18	21	16	14	14	14	14	14	14	14	14	14	14	14	14	14	14	--	--	--	--	--	--
	8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	--	--	--	--	--
	9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	10	--	--	--	--	--	--	--	--	--	11	11	11	11	12	13	13	13	13	13	11	11	11	11	--
	11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	--	--	--	--	--	--
	12	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	13–20	From 13th to 21st pressure not recorded.																							
	21	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	24	17	16	15	8	--	--	--
	22	--	--	--	--	--	--	--	--	--	--	--	--	-	11	14	18	24	20	11	13	14	12	--	--
	23	--	--	--	11	--	--	--	--	11	11	11	--	11	--	--	--	--	22	26	22	22	22	22	22
	24	20	12	--	--	--	--	--	-	12	17	19	22	25	26	26	26	22	19	19	16	12	11	--	--
	25	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	26	--	--	--	--	--	--	--	11	11	11	12	13	18	18	18	18	18	17	12	--	--	--	--	--
	27	--	--	--	--	11	11	11	11	14	15	18	26	21	13	13	13	12	11	11	--	--	--	--	--
	28	11	15	14	12	20	26	27	26	26	26	34	34	32	30	26	22	18	16	12	--	--	--	--	--
	29	--	--	--	--	--	--	--	11	12	12	13	14	14	14	11	11	11	11	11	--	11	11	--	--
	30	--	--	--	--	--	--	--	11	11	--	--	--	11	11	11	11	11	11	11	--	--	--	--	--
	Av.	2·2	2·2	1·8	2·0	2·3	2·6	2·7	4·2	5·6	6·1	7·5	7·7	9·0	9·0	9·5	9·6	10·2	10·3	8·0	4·3	4·4	3·9	2·3	1·8
April, 1859.	1	18	18	26	34	48	48	26	26	30	34	40	50	50	50	50	44	50	40	22	14	--	14	14	--
	2	--	--	--	--	--	--	--	--	--	--	14	14	14	14	--	--	--	--	--	--	--	--	--	--
	3	--	--	--	--	--	--	--	--	11	11	11	11	--	--	--	--	--	--	--	--	--	--	--	--
	4	--	--	--	--	--	--	--	14	26	26	30	34	40	44	48	48	36	30	34	26	30	22	22	22
	5	18	18	14	14	14	14	14	14	14	14	18	22	26	34	34	34	30	30	18	14	14	18	18	18
	6	14	14	18	18	14	14	14	14	18	29	29	30	30	30	30	30	30	26	22	18	14	14	--	--
	7	--	--	--	--	--	--	--	14	14	14	14	14	14	14	14	14	14	14	14	--	--	--	--	--
	8	--	--	--	--	--	--	--	--	14	14	14	14	14	14	14	14	14	14	14	11	11	11	11	11
	9	--	--	14	--	--	--	18	22	30	30	30	30	30	30	22	22	22	18	18	--	--	--	--	--
	10	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	11	--	--	--	--	--	--	14	14	14	18	18	18	18	18	18	18	18	18	18	14	14	14	14	--
	12	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	13	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	14	--	-	--	--	--	--	11	11	11	11	11	14	14	14	14	14	14	14	14	--	--	--	--	--
	15	11	11	11	11	11	--	--	--	--	--	--	--	--	--	13	13	13	13	13	11	--	--	--	--
	16	--	--	14	14	--	--	--	--	--	--	--	18	18	18	22	22	22	22	14	11	--	--	--	--
	17	--	--	--	--	--	--	--	--	--	14	14	14	14	14	14	14	14	--	--	--	--	--	--	--
	18	--	--	--	--	--	--	--	14	14	14	14	14	14	14	14	14	14	14	--	--	--	--	--	--
	19	--	--	--	--	--	--	--	--	14	14	14	14	14	14	14	14	14	14	11	11	11	14	14	14
	20	14	14	14	14	14	14	14	14	22	22	22	22	22	22	22	22	22	22	--	--	--	--	--	--
	21	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	11	11	11	--	--	--	--	--	--
	22	--	--	--	--	--	--	--	--	--	--	--	--	--	13	13	13	13	13	13	13	13	13	14	14
	23	14	14	14	14	14	14	14	14	14	14	14	14	26	26	26	22	22	22	17	17	--	--	--	--
	24	15	15	15	15	15	15	18	18	22	22	30	34	34	26	26	26	26	26	18	18	--	--	--	--
	25	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	--	--	--	--	--	--	--	--
	26	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	27	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	14	14	14	14	--	--
	28	--	--	--	--	11	11	11	11	14	14	14	14	14	14	14	--	--	--	--	--	--	--	--	--
	29	--	--	--	--	--	--	--	14	14	14	14	14	14	14	14	14	--	--	--	--	--	--	--	--
	30	--	--	--	--	--	--	--	--	--	14	14	14	14	--	--	18	18	18	--	--	--	--	--	--
	Av.	3·4	3·5	4·7	4.5	4·7	4.3	5·1	7·1	9·9	11·4	13·0	14·8	15·2	15·3	15·3	15·0	13·9	12·6	9·1	6·4	4·0	4·5	3·6	2·6
	2y.	2·8	2·8	3.2	3·2	3·5	3·4	3·9	5·6	7·7	8·7	10·2	11·2	12·1	12·1	12·4	12·3	12·0	11·4	8·5	5·3	4·2	4·2	2·9	2·2

TABLE VIII.—*Force of the Wind, Wallingford, Conn.*

	Days	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
MAY, 1858.	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	2	--	--	--	--	--	8	11	11	11	11	11	11	11	11	11	11	11	11	11	--	--	--	--	--
	3	--	--	--	--	--	--	--	11	11	11	11	11	11	11	11	11	11	11	11	11	--	--	--	--
	4	--	--	--	--	--	--	--	11	11	11	11	11	11	11	11	11	11	--	--	--	--	--	--	--
	5	--	--	--	--	--	--	--	--	--	--	--	--	8	11	11	--	--	--	--	--	--	11	14	14
	6	13	13	14	14	14	13	13	13	13	11	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	7	--	--	--	--	--	11	--	8	11	11	11	11	8	--	--	--	--	--	--	--	--	--	--	--
	8	--	--	--	--	--	--	11	11	11	11	11	11	--	--	--	--	--	--	--	--	--	--	--	--
	9	--	--	--	--	--	--	--	--	--	--	--	--	8	11	11	11	11	11	7	--	--	--	--	--
	10	--	--	--	--	--	--	--	--	--	11	11	--	--	7	8	--	--	--	--	--	--	--	--	--
	11	--	--	--	6	11	11	13	14	14	13	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	12	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	13	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	14	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	15	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	16	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	17	--	--	--	--	--	--	--	--	--	8	11	11	11	11	11	11	11	11	11	11	11	11	20	--
	18	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	19	--	--	--	--	--	--	--	--	--	--	8	--	--	--	--	--	--	--	--	--	--	--	--	--
	20	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	11	--	--	--	--	--
	21	--	18	--	--	--	8	16	22	25	36	36	36	36	34	29	28	28	28	28	28	20	14	11	--
	22	--	8	11	--	--	--	--	--	13	11	--	11	17	17	14	11	19	12	--	11	--	--	--	--
	23	--	--	--	--	--	--	--	--	--	10	11	16	14	9	16	21	18	14	11	11	17	13	11	21
	24	25	22	18	14	11	12	14	11	11	14	18	22	26	30	33	31	23	21	32	26	16	11	--	--
	25	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	21	23	14	11	--	--	--	--
	26	--	--	--	--	--	--	--	--	--	--	--	20	30	30	17	17	17	20	20	13	11	11	11	11
	27	--	--	--	--	11	14	18	21	23	25	25	22	19	18	17	15	14	13	11	11	11	11	11	11
	28	--	--	--	11	--	--	11	13	15	17	18	18	18	18	18	18	16	10	--	--	--	--	--	--
	29	--	--	--	--	--	--	--	11	11	13	14	14	12	11	11	11	11	11	--	--	--	--	--	--
	30	--	--	--	--	--	--	--	11	--	--	--	--	--	10	11	11	11	10	--	--	--	--	--	--
	31	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	13	13	11	10	--	10	10	--	--
	Av.	1·2	2·0	1·4	1·5	1·5	2·5	3·5	5·4	5·8	7·2	6·7	7·6	8·1	8·4	8·1	7·5	7·9	7·4	5·7	4·3	3·1	3·0	2·5	1·8
MAY, 1859.	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	2	--	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	--	--	--	--	--	--
	3	--	--	--	--	--	--	--	--	--	11	11	11	11	11	11	11	11	--	--	--	--	--	--	--
	4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	--	--	--	--	--
	5	--	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	11	--	--	--	--	
	6	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	11	11	11	--	--	--	--	--	--
	7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	-
	8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	--	--	--	--	--
	9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	23	14	14	14	14	--	--	--	--
	10	--	--	--	--	--	--	--	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
	11	14	14	14	14	14	14	14	14	14	14	18	18	18	14	14	14	14	14	14	14	14	14	14	14
	12	14	14	14	14	14	14	22	22	22	22	22	22	22	18	18	18	14	14	14	14	14	14	14	14
	13	11	11	11	11	11	11	11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	14	--	--	--	--	--	--	--	--	--	11	11	11	11	11	--	-	--	--	--	--	--	--	-	--
	15	--	--	--	--	--	--	11	11	11	11	11	11	--	--	--	--	--	--	--	--	--	--	--	--
	16	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	11	11	--	--	--	--	--	--
	17	--	-	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	11	--	--	--	--	--	--
	18	--	--	--	--	--	--	--	--	14	14	11	--	--	--	--	--	--	--	--	--	--	--	--	--
	19	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	11	--	--	--	-	--	--	--	--
	20	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	21	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	22	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	15	15	--	--	--	--	--	--	--
	23	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	24	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	25	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	11	11	11	--	--	--	--	--	--
	26	--	--	--	--	--	--	--	--	--	--	--	11	11	14	14	14	--	--	--	--	--	--	--	--
	27	--	--	--	--	--	--	--	--	--	--	11	11	11	14	14	14	14	14	11	--	--	--	--	--
	28	--	--	--	--	--	--	--	--	--	--	--	14	14	14	14	14	14	14	14	--	--	--	--	--
	29	--	--	--	--	--	--	--	--	--	--	11	14	14	18	18	18	18	14	11	--	--	--	--	--
	30	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	31	--	--	--	--	--	--	--	--	--	11	11	11	11	11	11	11	11	11	--	--	--	--	--	--
	Av.	1·3	1·3	1·3	1 3	1·3	1·3	1·9	2·0	2·4	3·5	4·9	5·8	5·5	6·3	7·3	8·2	7·3	6·4	4·0	1·8	1·4	1·4	1·4	1·4
	2y. Av.	1·2	1·6	1·3	1·4	1·4	1·9	2·7	3·7	4·1	5·3	5·8	6·7	6·8	7·3	7·7	7·8	7·6	6·9	4·8	3·0	2·2	2·2	1·9	1·6

Table VIII.—*Force of the Wind, Wallingford, Conn.*

	Days	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
JUNE, 1858.	1	--	--	--	--	--	--	--	--	--	--	11	12	11	11	--	--	--	--	--	--	--	--	--	--
	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	11	--	--	--	--	--
	4	--	--	--	--	--	--	--	--	--	10	11	11	11	11	14	17	17	17	17	17	11	11	17	17
	5	16	17	20	22	--	11	11	--	--	--	14	16	14	14	14	14	12	10	--	--	--	--	--	--
	6	--	--	--	--	--	--	10	12	--	11	14	18	22	25	28	30	31	34	30	25	22	17	10	--
	7	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	13	14	14	13	11	10	--	--	--
	8	--	--	--	--	--	--	--	--	--	--	--	--	11	11	13	13	11	10	11	--	--	--	--	--
	9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	10	11	11	11	--	--	--	--	--
	10	--	--	--	--	--	--	--	--	--	--	--	11	14	18	22	25	25	22	18	14	11	11	13	14
	11	11	--	--	--	--	--	--	14	21	18	14	11	11	13	11	--	13	13	--	--	10	9	9	8
	12	11	11	11	9	9	11	--	--	11	11	13	14	14	14	13	11	13	11	12	13	13	13	13	13
	13	13	13	13	11	13	13	12	11	11	11	11	11	--	--	--	--	--	--	--	--	--	--	--	--
	14	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	15	--	9	9	--	--	11	11	--	--	11	11	11	11	--	--	--	--	--	--	--	--	--	--	--
	16	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	17	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	18	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	--	--	--	--	--	--	--	--
	19	--	--	--	--	--	--	--	--	--	--	--	11	--	--	11	11	--	--	--	--	--	--	--	--
	20	--	--	--	--	--	--	--	--	--	--	--	--	--	9	13	12	--	--	--	--	--	--	--	--
	21	--	--	--	--	--	--	--	--	--	--	--	--	--	--	10	--	--	--	--	--	--	--	--	--
	22	--	--	--	--	--	--	--	--	--	--	11	--	--	--	--	--	--	--	--	--	--	--	--	--
	23	--	--	--	--	--	--	--	--	--	--	--	9	11	14	17	15	11	--	--	--	--	--	--	--
	24	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	11	14	--	--	--	--	--	--
	25	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	26	--	--	--	--	--	--	--	--	--	--	--	--	9	9	--	--	14	--	--	--	--	--	--	--
	27	--	--	--	--	--	--	--	--	--	--	--	--	--	--	9	--	--	9	--	--	--	--	--	--
	28	--	--	--	--	--	--	--	--	--	--	--	--	--	--	10	21	14	11	--	--	--	--	--	--
	29	--	--	--	--	--	--	--	--	--	8	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	30	--	--	--	--	--	--	11	--	--	--	--	--	16	21	13	11	11	--	--	--	--	--	--	--
	Av.	1·7	1·7	1·8	1·4	0·7	1·5	1·8	1·2	1·4	2·7	3·7	5·2	5·9	6·1	7·3	7·5	6·9	6·2	4·1	2·7	2·6	2·0	2·1	1·7
JUNE, 1859.	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	2	--	--	--	--	--	--	--	11	14	14	18	18	22	22	22	18	18	18	14	11	11	--	--	--
	3	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	11	11	11	11	--	--	14	--
	4	--	--	--	--	--	--	--	--	--	11	11	11	11	11	11	11	11	11	11	11	11	11	--	--
	5	11	14	11	11	11	11	14	14	14	14	14	22	22	22	18	18	11	11	--	--	--	--	--	--
	6	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	11	--	--	--	--	--	--
	7	--	--	--	--	--	--	--	--	--	11	11	11	11	11	11	11	14	14	11	11	11	--	--	--
	8	--	--	--	--	--	--	--	11	14	--	--	--	--	--	--	14	14	11	11	--	--	--	--	--
	9	--	--	11	11	--	--	11	11	14	14	14	11	18	11	11	14	11	11	--	--	--	--	--	--
	10	--	--	--	--	--	--	--	--	--	--	13	18	18	22	22	22	22	--	--	--	11	11	11	--
	11	--	--	--	--	--	--	--	--	11	12	14	14	11	11	11	11	11	11	--	--	--	--	--	--
	12	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	11	11	11	--	--	--	--
	13	--	--	--	--	--	11	11	11	11	11	11	11	11	11	11	11	11	11	--	--	--	--	--	--
	14	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	15	--	--	--	--	--	--	--	--	--	--	--	--	13	13	13	13	13	13	13	18	14	11	11	11
	16	11	11	11	11	11	11	11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	17	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	11	14	14	11
	18	11	11	11	--	--	--	--	14	14	14	--	--	11	14	14	14	14	14	11	11	--	--	--	--
	19	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	20	--	--	--	--	--	--	--	--	--	--	9	11	11	11	--	--	--	--	--	--	11	--	--	--
	21	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	22	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	23	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	24	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	25	--	--	--	--	--	--	--	--	--	--	--	--	11	11	18	18	18	18	18	11	11	--	--	--
	26	--	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	11	--	--	--	--	--
	27	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	--	--	--	--	--	--
	28	--	--	--	--	--	--	11	11	11	14	14	14	14	14	14	11	11	11	11	11	--	--	--	--
	29	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	--	--	11	--	--
	30	--	--	--	--	--	11	14	22	22	22	22	22	22	18	18	18	14	14	11	--	--	--	--	--
	Av	1·1	1·2	1·5	1·1	0·7	1·5	2·4	3·5	4·2	4·5	5·0	5·8	8·0	8·2	8·7	9·0	8·6	7·8	5·2	3·9	3·0	1·9	1·7	0·7
	2y.	1·4	1·4	1·6	1·2	0·7	1·5	2·1	2·3	2·8	3·6	4·3	5·5	6·9	7·3	8·0	8·2	7·7	7·0	4·6	3·3	2·8	2·0	1·9	1·2

Table VIII.—*Force of the Wind, Wallingford, Conn.*

Days	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
JULY, 1858.																								
1	--	--	--	--	--	--	--	--	--	--	--	16	18	18	14	20	11	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--	--	--	--	9	--	--	--	--	--	--	--	--	--	--	--	--
3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4	--	--	--	--	--	--	--	--	8	11	11	11	11	11	11	18	13	--	--	--	--	--	--	--
5	--	--	--	--	--	--	12	14	14	14	14	11	--	--	--	--	--	--	--	--	--	--	--	--
6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	13	--	--	--	--	--	--
7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	11	11	8	--	--	--	--	--
9	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	13	--	--	--	--	--	--	--	--
10	--	--	--	--	--	--	--	--	--	--	--	11	11	13	19	19	18	14	14	11	--	--	--	--
11	--	--	--	--	--	--	--	--	--	--	11	11	11	16	17	20	17	--	13	--	--	--	--	--
12	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
13	8	11	13	14	14	14	17	17	22	26	26	26	26	26	26	20	--	--	--	--	--	--	--	--
14	--	--	--	--	--	--	--	--	8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
15	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
16	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
17	--	--	--	--	--	--	--	--	--	--	--	--	--	8	11	11	11	8	--	--	--	--	--	--
18	--	--	--	--	--	--	--	--	--	--	--	8	--	--	--	--	--	--	--	--	--	--	--	--
19	--	--	--	--	--	--	--	--	8	8	--	--	8	--	--	8	--	--	--	--	--	--	--	--
20	--	--	--	--	--	--	--	--	--	--	--	--	--	--	13	9	--	--	--	--	--	--	--	--
21	--	--	--	--	--	--	--	--	--	--	--	11	--	8	11	11	12	11	--	--	--	--	--	--
22	--	--	24	--	--	--	--	--	--	--	--	--	12	--	30	--	--	--	--	--	--	8	--	--
23	--	--	--	--	--	--	--	--	--	11	11	15	11	11	11	--	--	--	--	--	--	13	--	--
24	--	--	--	--	--	--	--	11	14	14	14	14	14	14	14	14	14	18	19	11	--	--	--	--
25	--	--	--	--	--	--	--	8	11	17	16	9	--	--	--	--	--	--	--	--	--	--	--	--
26	--	--	--	--	--	--	--	--	--	--	--	11	11	11	13	14	14	14	13	--	--	--	--	--
27	--	--	--	--	--	--	8	11	11	16	19	18	21	17	17	17	15	12	--	--	--	--	--	--
28	--	--	--	--	--	--	--	11	11	11	17	17	18	18	18	18	14	9	--	--	--	--	--	--
29	--	--	--	--	--	--	--	--	--	--	--	--	11	14	11	--	--	--	--	--	--	--	--	--
30	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
31	--	--	--	25	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	--	--	--	--	--
Av.	0·3	0·4	1·2	1·3	0·5	0·5	1·2	2·3	3·5	4·1	4·5	7·1	6·6	6·7	8.7	7·5	5·2	3·6	2·5	0·7	0·0	0·7	0·0	0·0
JULY, 1859.																								
1	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	14	14	14	14	11	11	--	--
3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	14	--	--	--	--	14	14	14	14
4	14	14	14	14	11	11	11	14	14	14	11	11	11	11	11	11	11	11	11	--	--	--	--	--
5	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	--	--	--	--	--	--	--
6	--	--	--	--	--	--	--	--	--	--	11	11	11	11	--	--	--	--	--	--	--	--	--	--
7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	11	--	--	--	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	--	--	--	--	--	--
9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	--	--	--	--	--	--	--
10	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	11	--	--	--	--	--	--	--
11	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	--	--	--	--	--	--	--	--	--
Pressure no longer recorded.																								
Av.	1·3	1·3	1·3	1·3	1·0	1·0	1·0	1·3	1·3	1·3	2 0	5·0	7·0	7·0	8·0	9·3	7·3	3·3	2·3	1·3	2·3	2·3	1·3	1·3
2y	0·8	0·8	1·2	1·3	0·7	0·7	1·1	1·8	2·4	2·7	3·2	6·0	6·8	6·8	8·3	8·4	6·2	3·4	2·4	1·0	1·1	1·5	0·6	0·6

TABLE VIII.—*Force of the Wind, Wallingford, Conn.*

AUGUST, 1858.

Days	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
3	--	--	--	--	--	--	--	--	--	--	--	--	8	11	11	13	11	13	19	--	--	4	14	24
4	25	22	18	14	11	11	11	--	--	12	--	--	--	--	--	--	--	--	--	--	--	--	--	--
5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	6	12	--	--	--	--	--	--	--	--
6	--	--	--	--	--	--	--	--	--	11	11	13	21	18	28	29	24	13	--	--	--	--	--	--
7	--	--	--	--	--	--	--	--	10	14	14	11	11	9	--	--	--	--	--	--	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--	--	11	11	14	11	11	6	--	--	--	--	--	--	--
9	--	--	--	--	--	--	--	--	--	--	--	--	11	11	--	--	--	--	--	--	--	--	--	--
10	--	--	--	--	--	--	--	11	11	13	17	14	17	17	17	17	11	11	--	14	--	--	--	--
11	--	--	--	--	--	--	--	--	11	11	8	--	--	--	--	--	--	--	--	--	--	--	--	--
12	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
13	--	--	--	--	--	--	--	--	8	11	11	11	20	16	14	14	14	12	--	--	--	--	--	--
14	--	--	--	--	--	--	--	--	11	11	13	14	14	14	14	14	11	11	--	--	--	--	--	--
15	--	--	7	11	13	12	11	11	11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
16	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	--	--	--	--	--	--	--	--
17	--	--	--	--	--	--	--	--	--	--	--	--	--	11	--	13	--	--	--	--	--	--	11	8
18	--	--	--	--	--	--	--	--	11	11	11	11	17	17	17	17	17	17	14	11	22	--	--	--
19	--	--	--	--	--	--	--	16	16	26	26	18	22	26	23	18	18	13	--	--	--	--		--
20	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	11	--	--	--	--	--	--	--	6
21	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
22	--	--	--	--	--	--	--	--	11	11	--	--	14	14	14	14	11	11	--	--	--	--	11	10
23	--	--	8	--	--	--	--	18	26	26	26	33	40	32	28	29	22	--	--	--	--	--	--	--
24	--	--	--	--	--	--	--	--	--	--	--	11	--	--	--	11	--	--	--	--	--	--	--	--
25	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
26	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	14	--	--	--	--	--	--	-
27	--	--	--	--	--	--	--	--	--	--	--	--	11	21	21	21	21	18	--	--	18	18	18	14
28	--	--	--	--	--	--	--	--	--	--	--	11	16	16	12	11	11	11	9	--	--	11	11	11
29	--	--	--	--	--	--	--	--	--	--	--	9	11	11	15	18	18	18	--	--	--	--	--	--
30	--	--	--	--	--	--	--	--	--	9	11	11	11	11	--	11	--	--	--	--	--	--	--	--
31	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	--	--	--	--	--	--	--	--	--
Av.	0·8	0·7	1·1	0·8	0·8	0·7	0·7	1·8	4·4	5·4	5·1	6·1	9·3	9·7	8·9	9·9	6·7	4·8	1·4	0·8	1·3	1·1	2·1	2·4

Table VIII.—*Force of the Wind, Wallingford, Conn.*

Days	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
SEPTEMBER, 1857.																								
1	Observations begin 7.30 A. M., Sept. 7.																							
2																								
3																								
4																								
5																								
6																								
7	--	--	--	--	--	--	--	3	4	4	4	4	5	5	6	5	4	3	--	--	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	-	--	--	--	--	--	--	--	--	--
9	3	4	5	6	7	7	8	8	7	6	6	6	6	7	8	8	8	--	--	--	--	--	11	12
10	13	12	11	11	11	-	--	--	4	5	6	7	8	9	10	8	7	5	4	3	4	5	5	6
11	5	5	5	5	5	6	6	6	6	6	6	6	6	7	7	7	7	5	3	--	--	--	--	--
12	--	--	--	--	--	3	4	4	5	5	5	4	4	3	3	2	--	--	--	--	--	--	3	4
13	--	--	--	-	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
14	--	--	--	--	--	--	--	--	--	--	--	--	3	4	4	--	--	--	--	--	--	--	--	--
15	--	--	--	--	--	--	--	11	12	15	20	22	22	22	22	20	17	14	11	11	10	8	6	6
16	--	--	--	--	--	5	11	11	11	11	11	11	11	11	11	11	11	10	1	-	--	--	--	--
17	--	--	--	--	--	--	--	--	--	--	10	11	11	11	11	11	11	11	10	7	11	11	11	11
18	--	--	--	--	--	--	--	--	11	11	14	14	14	18	18	14	11	11	7	--	--	--	--	--
19	--	--	--	--	--	--	--	--	--	--	3	3	--	--	--	--	4	6	6	7	8	8	8	6
20	4	4	5	5	6	7	6	5	5	5	5	4	--	--	--	--	--	--	--	--	--	--	--	--
21	--	--	--	--	--	--	--	--	--	--	3	4	5	5	5	4	2	--	--	--	--	--	--	--
22	--	--	--	--	--	2	3	5	5	5	7	11	6	5	5	5	5	4	--	--	--	--	--	--
23	--	--	--	--	3	4	5	7	11	18	18	18	15	12	9	7	5	4	3	--	--	--	--	--
24	--	--	--	--	--	--	--	--	--	--	--	5	5	6	6	6	6	5	--	--	--	--	--	--
25	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
26	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3	4	4	4	3	--	--	--	--	--
27	--	--	--	--	--	--	--	--	--	--	--	--	3	3	4	4	3	2	--	--	--	--	--	--
28	--	--	--	--	12	12	15	14	3	4	4	4	4	4	3	2	11	11	11	10	--	--	--	--
29	--	--	--	-	5	12	12	12	14	11	18	18	14	14	13	11	8	8	11	8	7	5	--	--
30	--	--	--	--	--	--	--	--	--	--	3	4	4	4	3	3	3	3	--	--	-	--	--	--
Av.	1·0	1·0	1·1	1·1	2·0	2·4	2·9	3·6	4·1	4·4	6·0	6·5	6·1	6·2	6·3	5·5	5·3	4·4	2·9	1·9	1·7	1·5	1·8	1·9
SEPTEMBER, 1858.																								
1	--	--	--	--	--	26	26	25	--	--	11	11	11	11	12	--	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--	--	--	--	--	--	11	11	--	--	--	--	--	--	--	--	--
3	--	--	--	--	--	--	--	11	16	18	18	22	22	23	23	23	24	18	14	11	11	--	--	--
4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	-	--	--	--	--	--	--
5	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	--	--	--	--	--	--	--	--	--
6	--	--	--	--	--	--	--	--	12	18	18	18	18	21	21	21	21	14	--	--	--	--	--	--
7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
8	--	--	--	--	--	--	--	--	--	11	11	12	12	12	12	12	--	11	13	--	--	--	--	--
9	--	--	--	--	--	--	--	--	--		--	--	--	11	11	11	11	11	11	--	--	--	--	--
10	--	--	--	--	--	--	--	--	--	--	10	11	14	18	19	19	19	15	--	--	--	--	--	--
11	14	14	14	14	--	--	--	--	--	--	--	--	14	--	--	-	--	--	--	--	--	--	--	--
12	--	--	--	--	--	--	--	--	--	--	--	--	11	14	14	14	14	--	--	--	--	--	--	--
13	--	--	--	--	--	--	--	-	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
14	--	--	-	--	--	--	--	--	--	--	11	11	11	--	--	11	--	--	--	11	12	14	--	--
15	--	--	--	--	--	--	--	--	11	11	12	14	18	18	18	14	11	12	14	--	14	11	14	--
16	11	11	14	18	22	30	32	32	32	32	32	32	30	30	30	30	30	30	26	--	--	--	--	--
17	--	--	--	--	--	--	--	14	14	14	22	22	22	22	22	22	18	--	--	--	--	--	--	--
18	--	--	--	--	--	--	--	11	12	18	18	18	18	14	11	11	11	--	--	-	--	--	--	--
19	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
20	--	--	--	--	--	--	--	--	--	--	--	--	11	14	14	14	14	11	11	11	11	--	--	--
21	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	14	14	14	--	--	--	--	--	14
22	14	11	22	18	14	11	11	22	22	22	22	22	22	22	22	22	22	22	20	18	14	14	--	--
23	--	--	--	--	--	--	--	11	11	14	11	11	11	11	11	11	--	--	--	--	--	--	--	--
24	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
25	--	--	--	--	--	--	--	--	--	--	--	--	--	--	-	--	--	--	--	--	--	--	--	--
26	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
27	--	--	--	--	--	--	--	--	--	--	--	14	14	14	14	14	11	11	--	--	--	--	--	--
28	--	--	--	-	--	--	11	14	18	18	18	18	18	16	14	11	11	--	-	--	--	--	--	--
29	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	--	--	--	--	--	--	--	--	--
30	--	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	--	--	--	--	--	--
Av	1·3	1·2	1·7	1·7	1·2	2·2	2·7	4·7	4·9	5·9	7·1	7·9	10·0	10·5	10·8	9·5	8·1	6·0	3·6	1·7	2·1	1·3	0·5	0·5
2y.	1·1	1·1	1·4	1·4	1·6	2·3	2·8	4·1	4·5	5·1	6·5	7·2	8·0	8·3	8·5	7·5	6·7	5·2	3·2	1·8	1·9	1·4	1·1	1·2

Table VIII.—*Force of the Wind, Wallingford, Conn.*

OCTOBER, 1857.

Days	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
1	5	5	4	--	--	--	--	--	--	10	11	11	6	5	6	7	8	11	11	11	11	10	5	5
2	5	5	4	--	--	--	--	11	11	11	11	12	11	7	5	--	--	--	--	--	--	--	--	--
3	2	4	4	4	4	5	10	11	11	11	11	11	11	11	8	6	6	6	6	6	6	6	5	--
4	--	--	--	--	--	--	--	--	4	5	5	6	6	6	5	5	3	--	--	--	--	--	--	--
5	--	--	--	--	--	11	11	11	10	6	5	5	4	3	2	3	2	--	--	--	--	--	--	--
6	--	--	--	--	--	--	--	--	--	--	4	6	8	9	9	9	6	--	--	--	--	--	--	--
7	--	--	--	--	--	--	--	11	11	11	11	11	11	5	5	5	3	--	--	--	--	--	--	--
8	--	--	--	--	--	--	--	--	--	9	11	11	11	11	5	3	3	2	--	--	--	--	--	--
9	-	--	--	--	--	--	--	--	--	--	4	5	5	5	5	5	5	3	--	--	--	--	--	--
10	--	--	--	--	--	--	--	--	--	5	5	5	5	5	5	5	5	3	--	--	--	--	--	--
11	--	--	--	--	--	--	--	--	--	--	--	3	5	5	5	3	2	--	--	--	--	--	--	--
12	--	--	--	--	--	--	--	--	--	--	--	--	--	4	5	3	--	--	--	--	--	--	--	--
13	--	--	--	--	--	--	--	--	--	--	--	4	5	4	--	--	--	--	--	--	--	--	--	--
14	--	--	--	--	--	--	--	--	--	--	--	--	4	5	6	5	4	3	--	--	--	--	--	--
15	3	5	5	6	7	8	11	11	10	10	10	10	10	10	8	5	--	--	--	--	--	--	--	--
16	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	10	11	11
17	11	18	28	26	20	28	16	13	13	14	18	17	14	14	14	14	11	10	8	6	--	--	--	--
18	--	--	--	--	--	--	--	--	--	11	11	11	10	8	8	5	--	--	--	--	--	--	--	--
19	--	--	--	--	--	--	--	--	--	--	11	11	11	13	18	11	11	11	11	11	14	11	11	11
20	11	14	14	11	12	14	13	11	16	20	24	27	26	27	27	30	20	20	16	14	12	18	24	14
21	18	13	16	18	16	11	11	11	14	18	22	23	18	16	14	14	12	5	3	--	--	--	--	--
22	--	--	--	--	--	--	--	--	10	11	9	9	11	11	11	11	7	4	--	--	--	--	--	--
23	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3	--	12	12	--	--	--	--	--
24	--	--	-	--	--	--	--	--	--	--	--	--	12	12	11	11	11	11	11	11	11	11	11	12
25	13	12	16	11	11	11	11	11	11	11	11	11	11	11	11	11	10	8	11	11	9	8	9	11
26	14	11	11	14	15	12	11	11	11	11	11	11	14	11	11	11	13	12	11	11	9	11	14	18
27	18	18	18	17	17	17	17	17	17	16	14	14	22	23	18	18	18	14	14	14	14	14	14	14
28	12	11	11	11	11	11	11	11	11	11	11	6	5	4	2	--	--	--	--	--	--	--	--	--
29	--	--	--	--	--	--	--	-	--	--	--	--	--	--	--	--	11	11	11	11	11	11	11	7
30	4	4	2	--	--	--	--	--	11	11	11	9	9	10	9	5	--	11	12	--	--	--	--	--
31	--	--	--	--	--	--	--	--	--	--	--	--	--	-	--	--	--	--	--	--	--	--	--	--
Av.	3·7	4·0	4·3	3·8	3·7	4·1	4·0	4 5	5·5	6·8	7·8	8·1	8·5	8·2	7·5	6·7	5·5	5·1	4·4	3.4	3·2	3·5	3·7	3·3

OCTOBER, 1858.

Days	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
1	--	--	--	--	--	--	--	--	--	--	--	--	--	11	11	32	--	--	26	26	26	26	26	26
2	26	26	26	26	26	--	--	--	22	22	22	22	22	22	22	22	22	11	--	--	--	--	--	--
3	--	--	--	--	--	--	--	--	--	--	14	14	14	18	18	14	--	--	--	--	--	--	--	--
4	--	--	--	--	--	--	--	--	--	--	18	18	18	18	18	18	11	11	--	--	--	--	--	--
5	--	--	--	--	--	--	--	--	--	14	--	18	18	22	22	22	22	22	11	--	--	--	--	--
6	--	--	--	--	--	--	--	--	.	--	11	11	11	11	12	12	12	11	--	--	--	--	--	--
7	--	--	--	-	--	--	--	--	--	--	--	14	14	22	22	18	13	11	--	--	--	--	--	--
8	11	18	14	14	14	12	12	--	14	18	30	30	44	26	26	22	18	--	--	--	--	11	11	--
9	--	--	--	--	--	--	--	--	--	15	22	22	30	30	30	22	20	18	18	--	--	--	--	--
10	--	--	14	13	13	--	-	11	14	22	14	14	18	16	16	18	11	11	--	--	-	--	--	--
11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
12	--	--	--	--	--	--	--	--	--	11	11	11	11	12	14	16	18	14	12	11	11	10	10	--
13	--	--	--	--	11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
14	--	--	--	--	--	--	--	12	18	18	11	--	--	--	--	--	--	--	--	--	--	--	--	--
15	--	--	--	--	11	18	26	33	34	34	34	34	34	34	33	26	14	11	--	--	--	--	--	--
16	--	--	--	--	--	--	--	--	--	--	--	--	11	--	--	--	--	--	--	--	--	--	--	--
17	--	--	--	--	--	--	--	--	--	11	11	14	19	19	19	19	15	11	--	--	--	--	--	--
18	--	--	--	--	--	--	--	--	11	11	11	11	12	14	14	14	--	--	--	--	--	--	--	--
19	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	--	--	--	--	--	--	--	--	--
20	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	--	--	--	--	--	--
21	--	--	--	--	--	--	--	11	11	11	14	14	11	11	11	--	--	--	11	11	--	--	--	--
22	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
23	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	-	--	--	--	--	11	14	--	--
24	--	--	--	--	--	--	--	11	14	14	12	11	18	22	26	30	35	35	35	30	30	30	22	14
25	26	26	22	20	18	14	14	26	26	26	26	26	26	22	22	20	14	--	--	--	--	--	--	--
26	--	--	--	--	--	--	--	--	11	11	14	14	11	11	--	--	--	--	--	--	--	--	--	--
27	--	--	--	--	--	--	-	--	--	--	--	11	11	11	11	11	11	--	--	--	--	--	--	--
28	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	--	--	--	--	--	--	--	--	--
29	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	11	--	--	--	--	--	--	--
30	11	14	18	30	30	26	26	18	26	30	34	30	19	19	22	18	14	26	22	11	10	--	--	--
31	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	--	--	--	--	--	--	--
Av.	2·4	2·7	3·0	3·3	4·0	2·3	2·5	4·0	6·5	8·6	10·0	11·3	13·1	13·0	13·3	12·1	8·8	6·5	4·4	2·9	2·8	2·9	2·2	1·3
2y.	3·0	3·3	3·6	3·6	3·8	3·2	3·2	4·2	6·0	7·7	8·9	9·7	10·8	10·6	10·4	9·4	7·1	5·8	4·4	3·1	3·0	3·2	2·9	2·3

Table VIII.—*Force of the Wind, Wallingford, Conn.*

NOVEMBER, 1857.

Days	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
1	--	--	--	--	--	--	--	--	--	--	--	--	4	5	6	7	5	--	--	--	--	--	--	--
2	--	--	--	--	--	3	4	10	11	13	11	14	18	16	14	11	11	5	5	4	4	4	--	--
3	--	--	--	--	--	10	11	11	10	10	13	15	18	19	18	21	22	14	14	12	11	--	--	--
4	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	11	11	--	--	--	--	--	--	--
5	--	--	--	--	--	--	--	--	--	--	--	--	10	11	5	5	9	12	11	13	14	14	11	11
6	11	14	11	11	11	11	6	5	5	5	5	5	7	11	11	11	11	11	11	7	6	6	7	7
7	5	4	--	--	10	10	6	7	7	9	11	7	5	5	6	6	4	--	--	--	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--	3	4	5	10	10	6	6	7	7	5	9	10	--	--
9	--	--	--	--	--	--	--	--	11	11	14	14	14	14	14	13	13	11	11	11	11	11	11	11
10	11	11	11	11	11	11	12	10	11	7	7	11	11	14	12	16	14	12	14	11	7	3	--	--
11	--	--	--	--	--	--	--	--	--	10	11	6	6	7	9	7	4	--	--	--	--	--	--	--
12	--	--	--	--	--	--	--	--	--	--	9	11	11	11	11	11	11	12	10	6	5	5	5	6
13	--	--	--	--	--	--	--	--	--	--	--	--	--	9	10	7	6	6	7	5	--	--	--	--
14	--	--	--	--	--	--	--	9	11	11	14	16	18	19	18	18	18	18	20	18	11	11	5	--
15	5	11	11	11	6	6	5	5	8	8	11	11	11	11	11	9	4	--	--	--	--	--	--	--
16	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
17	--	--	--	--	--	--	--	--	--	--	4	6	7	9	10	11	5	8	7	--	--	--	11	11
18	--	--	--	--	--	--	--	--	--	--	10	11	11	12	12	12	11	5	--	--	--	--	--	--
19	--	--	--	--	--	--	--	--	5	11	12	13	13	13	18	18	18	22	19	18	18	22	22	16
20	4	8	11	11	11	11	11	11	10	14	12	11	13	14	14	18	17	18	17	14	11	8	6	4
21	2	3	4	5	6	8	9	11	11	11	14	14	12	11	11	11	11	11	11	12	4	--	3	3
22	7	11	12	10	5	4	3	5	10	11	11	11	14	11	11	11	--	--	--	--	--	--	--	--
23	--	--	--	--	2	4	6	11	15	19	23	26	30	29	26	22	18	10	14	10	16	13	12	11
24	12	15	11	12	15	15	11	11	11	11	11	11	11	11	11	10	10	8	7	10	11	11	11	11
25	10	10	11	14	14	15	20	11	28	29	30	28	28	26	26	22	14	13	11	--	--	--	--	--
26	--	--	--	--	--	--	--	--	--	--	--	2	3	5	10	11	7	4	--	--	--	--	--	--
27	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3	3	2	--	--	--	--	--	--	--
28	--	--	--	--	--	--	--	--	--	--	--	3	--	--	4	3	--	--	--	--	--	--	--	--
29	--	--	--	--	--	--	--	--	--	--	--	3	5	5	5	4	--	--	--	--	--	--	--	--
30	--	--	--	--	--	--	--	11	11	8	9	11	11	11	12	12	12	12	11	11	10	8	10	6
Av.	2·2	2·9	2·7	2·8	3·0	3·6	3·5	4·3	5·8	6·6	8·5	9·2	10·2	11·0	11·3	10·9	9·1	7·3	6·9	5·6	4·9	4·2	3·8	3·2

NOVEMBER, 1858.

Days	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
1	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--	--	14	14	14	14	14	11	11	11	14	14	14	14	14	14	14
3	14	14	14	14	14	14	14	14	14	14	14	22	22	20	18	18	18	18	18	18	18	14	14	14
4	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	11	11	11	11	11	11	11
5	11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
6	--	--	--	--	--	11	11	18	18	14	11	11	13	12	12	13	13	13	13	11	11	14	14	14
7	14	11	14	18	16	11	12	12	12	12	13	18	22	18	14	13	11	--	--	--	--	--	--	--
8	--	--	--	--	--	--	--	--	--	11	12	13	18	18	18	18	--	--	--	--	--	--	--	--
9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
10	--	--	--	--	--	--	--	--	--	--	--	12	12	14	14	12	14	--	--	--	--	--	--	--
11	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	--	--	--	--	--	--	--	--	--
12	--	--	11	11	--	--	--	--	--	--	11	18	18	18	18	11	10	--	--	--	--	--	--	--
13	--	--	--	--	--	--	--	--	--	--	--	--	11	--	--	--	--	--	--	--	--	--	--	--
14	--	--	--	--	--	--	--	--	--	--	26	30	30	26	22	18	--	--	--	--	--	--	--	--
15	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
16	18	--	--	--	--	--	--	--	--	--	--	11	11	14	14	14	14	12	--	--	16	11	--	--
17	--	--	--	--	11	22	--	--	14	14	16	12	12	20	30	35	26	26	26	12	--	--	--	--
18	--	--	--	--	--	--	--	--	--	--	--	10	10	--	11	11	--	--	--	--	--	--	--	--
19	--	--	11	--	--	--	--	--	--	11	11	14	18	22	22	22	22	22	22	22	22	22	11	11
20	11	--	11	14	11	--	--	--	--	--	11	12	14	14	11	11	--	--	--	--	--	--	--	--
21	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
22	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	10
23	10	16	22	22	22	22	22	22	22	25	25	25	18	18	18	18	18	18	14	10	--	--	--	--
24	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	12	11	11	14	14	11	14	11	13
25	18	18	18	16	11	22	18	13	11	18	22	34	34	30	30	28	22	22	22	26	26	26	22	14
26	11	13	14	18	22	11	14	18	18	22	30	30	30	30	30	30	30	22	14	11	14	14	18	22
27	12	18	11	11	11	18	14	14	14	13	11	12	14	14	14	13	11	11	10	--	--	--	--	--
28	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	14	14	14
29	14	14	14	14	14	11	13	13	11	11	--	--	14	--	--	--	--	--	--	--	--	--	--	--
30	--	--	--	--	--	--	--	--	--	--	--	--	14	30	30	26	22	22	22	22	22	22	14	14
Av.	4·9	3·9	5·1	5·1	4·9	5·2	4·4	4·6	4·9	6·4	8·0	10·8	12·8	12·3	12·8	12·0	8·9	7·8	7·0	6·1	5·9	5·9	4·8	5·0
2y.	3·5	3·4	3·9	3·9	3·9	4·4	3·9	4·4	5·3	6·5	8·2	10·0	11·5	11·6	12·0	11·4	9·0	7·5	7·0	5·8	5·4	5·0	4·3	4·1

Table VIII.—*Force of the Wind, Wallingford, Conn.*

December, 1857.

Days	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
1	3	4	3	--	--	11	14	17	18	16	12	10	--	--	11	11	--	11	11	11	11	8	10	11
2	--	--	--	--	--	--	--	--	--	--	--	--	5	9	5	5	3	--	--	--	--	--	--	--
3	11	8	6	4	--	--	--	--	--	11	13	17	21	19	18	16	13	11	5	--	--	--	--	--
4	--	--	--	--	--	--	--	--	11	14	18	19	18	14	14	11	9	--	--	--	--	--	--	--
5	--	--	--	--	--	--	--	--	--	--	--	--	5	11	6	5	5	5	6	9	11	5	--	--
6	4	4	5	6	7	8	8	4	--	--	--	--	--	11	11	11	11	11	11	11	9	11	11	11
7	11	11	7	5	4	--	--	--	--	-	7	11	11	11	6	2	--	--	--	-	--	--	--	--
8	--	--	--	--	--	--	--	--	--	2	11	11	10	6	5	3	--	--	--	--	--	--	--	--
9	3	3	4	4	5	5	5	6	8	9	6	6	5	6	6	9	9	8	8	8	8	7	7	9
10	11	8	8	9	10	7	6	6	8	10	13	14	15	14	14	11	11	10	10	10	10	10	16	17
11	16	18	15	13	11	11	11	11	11	18	22	16	14	19	17	20	14	11	14	12	12	11	11	13
12	13	12	9	4	--	--	--	--	--	--	--	--	3	7	9	7	--	--	--	--	--	--	--	--
13	--	--	--	--	--	--	--	--	--	11	11	13	9	7	7	9	11	8	6	5	5	6	7	7
14	4	4	5	5	5	6	6	6	6	6	6	6	7	8	5	3	--	--	--	--	--	--	--	--
15	--	--	--	--	--	--	--	--	--	--	--	--	3	6	7	5	5	5	5	3	--	--	--	--
16	--	--	--	--	--	--	--	--	--	--	--	4	5	5	4	3	--	--	--	--	--	--	--	--
17	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
18	--	--	4	8	11	11	14	22	30	28	13	11	11	11	17	14	11	15	15	17	17	12	11	14
19	13	14	15	15	11	12	13	11	11	13	16	18	15	14	17	11	5	4	5	6	7	4	--	--
20	--	--	--	--	--	--	2	6	9	11	11	11	11	11	11	11	11	6	5	2	--	--	--	--
21	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	9	9	--	--	--	--	4	3
22	2	4	6	11	13	13	7	3	--	--	--	--	--	11	11	11	13	17	22	18	26	26	26	13
23	8	7	7	10	7	8	10	9	10	12	12	11	11	11	11	11	11	9	8	10	10	8	11	8
24	7	12	11	11	11	11	10	9	8	14	14	12	11	11	10	13	16	14	14	11	15	11	11	11
25	10	8	7	8	9	7	6	6	7	7	8	8	8	8	8	9	11	9	8	6	5	5	5	5
26	3	4	4	3	4	5	6	6	6	6	6	5	5	5	5	5	7	11	11	11	11	11	11	11
27	11	8	5	--	--	--	--	--	--	--	--	--	--	--	2	2	1	--	--	--	--	--	--	--
28	--	--	--	--	--	--	--	11	13	10	9	12	11	7	5	5	5	3	--	--	--	--	--	--
29	--	--	--	--	--	--	--	--	--	--	--	--	-	3	4	4	5	5	5	5	5	5	5	5
30	5	5	5	4	4	4	5	5	6	5	5	5	5	5	5	3	--	--	--	--	--	--	4	5
31	11	16	22	22	22	19	12	14	14	14	11	16	7	9	11	11	10	9	8	8	8	9	10	10
Av.	4·7	4·8	4·8	4·6	4·3	4·5	4·4	4·9	5·7	7·0	7·2	7·6	7·3	8·4	8·5	7·8	6·6	6·2	5·7	5·3	5·5	4·8	5·2	5·0

December, 1858.

Days	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
1	11	22	26	22	18	--	--	11	11	11	22	14	11	11	11	--	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	-	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
3	--	--	--	--	--	--	--	--	--	--	--	11	--	--	--	--	--	--	--	--	--	--	--	--
4	--	--	--	--	13	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
6	--	--	--	--	--	--	--	--	--	--	11	11	11	11	11	--	--	--	--	--	--	--	--	--
7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--	12	14	14	13	12	12	12	12	12	12	12	12	.	--
9	--	--	--	--	--	--	--	--	26	26	26	26	26	26	26	26	14	--	--	--	--	--	--	--
10	--	11	11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
12	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
13	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
14	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	--	11
15	10	12	14	14	14	11	--	--	--	--	10	--	11	11	--	--	--	--	--	--	--	--	--	--
16	16	17	11	10	--	11	10	--	--	--	--	11	11	11	--	--	--	--	--	--	--	--	--	--
17	--	--	--	--	--	--	--	--	--	--	--	11	12	14	18	22	18	18	14	--	--	18	20	14
18	11	11	11	11	11	11	11	11	11	11	11	14	14	14	14	11	11	11	11	--	--	--	--	10
19	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
20	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
21	--	--	--	--	--	--	--	--	--	16	--	11	11	14	--	--	--	--	--	--	11	11	14	14
22	14	14	12	16	16	30	30	34	26	30	30	30	34	34	34	34	34	34	26	26	18		--	18
23	11	11	--	--	--	--	--	--	--	--	--	--	--	11	--	--	--	--	--	10	--	--	--	--
24	--	--	--	--	--	--	--	--	--	--	--	--	--	16	11	14	11	11	13	13	11	11	11	11
25	11	11	14	11	11	11	11	11	11	11	11	11	--	--	--	--	--	--	--	--	--	--	--	--
26	--	--	--	--	--	--	--	--	--	--	--	--	11	11	11	11	--	--	--	--	--	--	--	10
27	14	14	11	11	11	11	11	--	--		--	11	14	22	22	18	11	11	13	--	--	--	--	--
28	--	18	18	22	14	--	--	--	--	--	26	30	30	30	26	22	14	14	14	14	14	14	14	14
29	14	14	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	10	11	11
30	11	11	11	11	11	14	14	14	14	14	14	14	18	18	18	18	14	14	11	11	11	11	11	11
31	11	11	11	11	11	11	11	11	11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Av.	4·3	5·7	4·8	4·3	4·2	3·5	3·2	3·0	3·5	3·8	5·6	7·1	7·4	8.6	6·9	6·1	4·5	4·0	3·7	2·8	2·5	3·2	2·6	4·0
2y.	5.4	5·3	4·8	4·4	4·2	4·0	3.8	4·0	4·6	5·4	6·4	7·2	7·3	8·5	7·7	6·9	5·5	5·1	4·7	4·0	4·0	4·0	3·9	4·5

The curve lines upon Plate IX represent the mean force of the wind for each hour of the day, and each month of the year. The hour of the day is indicated at the top and bottom of the page. The space between the horizontal lines represents a difference of one ounce upon the pressure plate. Since the zero of pressure is different for each curve line, the absolute value of the horizontal lines could not be indicated upon the chart without creating confusion; but a reference to the average results in Table VIII, will readily indicate what the zero is. These curves exhibit strikingly to the eye the diurnal change in the wind's force.

The time of maximum pressure varies from 1 to 4 P. M.; occurring generally at 2 P. M. in winter; 3 P. M. in spring and autumn; and at 4 P. M. in summer. These hours, during the colder part of the year, correspond very closely with the time of maximum temperature, but during the warmer part of the year they occur from one to two hours later.

The average time of minimum pressure is 2 A. M., but varies from 10 P. M. to 7 A. M., between which hours the average change of pressure is quite small.

The general form of the curves of pressure at Wallingford is similar to that of the curves representing the observations at Girard College, Philadelphia, but the absolute pressure is different. Table IX affords a comparison of the extent of the diurnal change at the two places. Column second shows for each month the pressure for the hour when it was least at Wallingford, and column third the pressure at the hour when it was greatest. Column fourth shows the minimum pressure at Philadelphia, expressed in pounds per square foot, and column fifth shows the same numbers reduced to the standard of Wallingford, viz: ounces of pressure on a surface of 100 square inches. Columns 6 and 7 show the maximum pressure at Philadelphia similarly expressed. The results given for Philadelphia are the means of 2½ years of observations.

TABLE IX.—*Monthly Maxima and Minima of pressure at Wallingford and Philadelphia.*

	Wallingford.		Philadelphia.					Wallingford.		Philadelphia.			
Month	Min.	Max.	Minimum		Maximum		Month	Min.	Max.	Minimum		Maximum	
	oz.	oz.	lb.	oz.	lb.	oz.		oz.	oz.	lb.	oz.	lb.	oz.
Jan.	2·8	7·4	·59	6·6	1·54	17·1	July	0·6	8·4	·14	1·6	·66	7·3
Feb.	3·9	9·4	·60	6·7	1·36	15·1	Aug.	0·7	9·7	·15	1·7	·56	6·2
Mar.	4·7	13·5	·90	10·0	2·17	24·1	Sept.	1·1	8·5	·54	6·0	1·18	13·1
April	2·2	12·4	·39	4·3	1·53	17·0	Oct.	2·3	10·8	·46	5·1	1·42	15·8
May	1·2	7·8	·38	4·2	1·29	14·3	Nov.	3·4	12·0	·48	5·3	1·20	13·3
June	0·7	8·2	·22	2·4	1·17	13·0	Dec.	3·9	8·5	·54	6·0	1·22	13·6

The mean of the maxima for the year is nearly one-half greater at Philadelphia than at Wallingford; and the mean of the minima is more than double. The ratio of the maxima to the minima is nearly one-half greater at Wallingford than at Philadelphia.

Mean direction of the Wind's progress.

In considering the circulation of the atmosphere for the entire globe, it is important to know for each place, the average direction of the wind's *progress*, and this is not necessarily the same as the average direction of the wind, for its progress depends upon velocity as well as direction. If we could construct a polygon, all of whose sides but one should represent the successive directions of the wind for any assumed time, and the lengths of those sides should be proportional to the wind's force in these several directions, the remaining side ot the polygon would represent the direction and amount of the wind's progress for that time. In order to reduce the Wallingford observations upon this principle, the angles given in Table II, Part 1, were regarded as the directions of a ship's course, and the numbers representing the wind's force for the given hour and month, as shown in Table VIII, were regarded as the distances sailed. For these courses and distances, the Northings and Southings, Eastings and Westings for each hour were taken from a traverse table, and the total difference of latitude and departure for each month were computed. The resulting course was thence deduced by the principles of Trigonometry. The following table shows the results of this computation.

TABLE X.—*Mean direction of the Wind's progress.*

Month.	Direction.	Month.	Direction.	Month.	Direction.
January	N. 31°·8 W.	May	S. 40°·0 W.	September	N. 80°·6 W.
February	35·0	June	60·4	October	43·6
March	47·5	July	49·3	November	53·9
April	46·5	August	80·4	December	35·5

The mean direction of the wind's progress for the entire year is from a point N. 55°·8 W., being 4°·1 more southerly than the direction obtained without regarding the wind's force. The difference arises from the fact that the wind's force is generally greatest at that hour of the day when its direction is most southerly.

FALL OF RAIN AND SNOW AT WALLINGFORD, CONN., 1856–1870.

The observations on the fall of rain and snow began April, 1856, and continued to August, 1862. They were resumed in November, 1864, and are continuous to the close of 1870. The rain-gauge employed is a cylindrical metallic vessel 11¼ inches in diameter, and 8 inches deep. Near the middle of its height is a metallic diaphragm, designed to preserve the interior from objects falling upon the upper surface, while allowing the water to pass freely. It also prevents animals from drinking the fallen water. The gauge was placed on the surface of the ground, in the yard of Dr. Harrison's house, where there is a tolerably free exposure. To measure the amount of rain or melted snow there is a glass jar properly graduated to show inches, tenths and hundredths. The snow gauge is also 11¼ inches in diameter, and is two feet deep. It is placed on the top of a fence, at an elevation of about three feet from the surface of the ground, in a tolerably free exposure.

Table XI shows the total fall of rain and melted snow in inches for each month of the years observed; also the monthly means derived from twelve or fourteen years of observation, and the total annual fall of rain and snow. The average annual fall of rain and melted snow, derived from twelve and a half years of observations, is 51·26 inches; and this amount is distributed not very unequally through the different seasons, being in spring 13·78; summer 13·54; autumn 12·07; and winter 11·87 inches.

Table XI.—*Fall of rain and melted snow, in inches, Wallingford, Ct.*

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1856				4·10	6·85	3·07	2·93	11·68	3·22	1·98	2·67	6·61	
1857	4·39	2·08	2·47	7·11	7·76	3·23	8·29	5·62	3·17	5·88	2·06	5·79	57·85
1858	3·13	1·92	1·57	3·87	2·62	5·08	3·26	4·02	5·18	3·29	3·23	4·47	41·64
1859	6·94	4·24	8·45	3·76	4·73	6·25	2·58	6·12	5·63	1·91	2·49	4·01	57·11
1860	2·38	3·13	2·62	2·11	4·04	1·90	2·72	5·53	3·38	3·10	6·37	4·97	42·25
1861	4·07	2·90	5·02	5·83	5·67	3·68	2·85	5·66	4·61	2·40	4·47	1·77	48·93
1862	5·71	3·01	4·30	1·93	2·93	7·60	5·28						
1864											4·31	4·09	
1865	4·92	4·60	6·31	3·26	7·26	4·89	6·84	1·57	1·38	4·33	3·15	4·01	52·52
1866	1·71	6·48	3·41	2·89	5·80	4·31	3·28	4·21	6·17	3·35	4·96	4·38	50·95
1867	2·42	2·64	4·08	2·76	6·31	5·40	2·45	10·53	2·59	5·91	3·50	2·70	51·29
1868	4·55	1·69	2·66	5·58	7·79	3·67	2·44	7·27	8·40	0·93	4·31	2·47	51·76
1869	3·05	5·22	7·02	2·16	6·36	3·23	2·98	1·95	3·27	13·29	3·58	6·35	58·46
1870	6·38	5·19	5·60	6·21	1·39	3·12	2·96	2·11	1·40	5·37	3·43	2·19	45·35
Mean	4·14	3·59	4·46	3·97	5·35	4·26	3·76	5·52	4·03	4·31	3·73	4·14	51·26

Table XII shows the total fall of snow for each month in inches, also the monthly means and the total annual fall. The mean annual fall is 51·17 inches, and all this fell from November to April inclusive. Snow occasionally falls in October and May, but no such case occurred during the twelve and a half years embraced by these observations.

TABLE XII.—*Fall of snow, in inches, Wallingford, Conn.*

	January.	February.	March.	April.	November.	December.	Year.
1856				0	2½	12¾	
1857	27¾	2¾	10	0	0	6	46½
1858	4	5	13½	0	13	3	38½
1859	31	13	6	0	0	5½	55½
1860	11½	17½	0½	0½	0	10½	40½
1861	20	0	27	9	4	0	60
1862	16	19	4	0			
1864					2	16	
1865	11½	2	0	0	0	10	23½
1866	14½	5	3	0	0	10½	33
1867	26	16	16	0	6	14½	78½
1868	27	12½	15	15	0	12	81½
1869	5	13	13	0	2	15	48
1870	6	16	19	2	0	7	50
Mean	16·69	10·15	10·58	2·04	2·27	9·44	51·17

TABLE XIII.—*No. of days when rain or snow fell, Wallingford, Ct.*

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1856				7	13	9	9	10	7	5	8	9	
1857	12	8	8	8	13	9	10	10	5	9	6	12	110
1858	6	5	7	8	10	6	8	8	5	7	9	13	92
1859	8	12	8	6	9	13	5	7	8	4	6	8	94
1860	8	7	6	10	6	8	9	8	5	8	9	6	90
1861	11	6	9	9	8	10	9	6	6	8	7	4	93
1862	13	10	8	6	9	12	7						
1864											10	11	
1865	8	4	8	7	13	6	8	4	6	6	5	8	83
1866	5	7	4	6	10	9	7	10	11	5	6	7	87
1867	4	6	7	8	12	7	11	9	5	4	5	8	86
1868	8	11	5	7	9	7	4	7	10	7	6	4	85
1869	4	6	8	5	8	9	6	3	3	11	6	8	77
1870	17	6	5	7	8	9	6	7	4	7	5	7	88
Mean	8·66	7·33	6·92	7·23	9·85	8·77	7·62	7·42	6·25	6·75	7·33	8·08	92

Table XIII shows the number of days for each month of each year during which rain or snow fell. A day is here regarded as 24 consecutive hours. The record sometimes mentions rain or snow as having fallen during the day time, and also during the preceding or succeeding night. Such cases are counted as but one day, except when the duration of the fall exceeded twenty-four hours. In a few of the cases here enumerated, the amount of the rain or snow which fell was too small to be measured. From April, 1856, to August, 1862, the record was kept for the Smithsonian Institution, and in conformity with their instructions special care was taken to record the time of the beginning and end of each fall of rain and snow. In the subsequent observations, which were not made for the Smithsonian Institution, less care was observed to note the time of beginning and end of the periods of rain and snow. This may perhaps explain the fact that the total number of days when rain or snow fell during the years 1856 to 1862, exceeds the totals for the subsequent years. The average number of days each year when rain or snow falls is 92; or almost exactly one day in four. The greatest number of rainy days occurs in May, and the least in September. Comparing Table XIII with Table XI, we see that the amount of the rain for different months is not exactly proportional to the number of rainy days; for while during the three winter months the number of days of rain or snow is somewhat greater than for either of the other seasons, and is decidedly greater than for the autumn months, the amount of the precipitation is sensibly less.

The following Table shows the cases in which the fall of rain was unusually great. The extraordinary rain of October 3d and 4th, 1869, caused an extensive flood, which occasioned no little destruction of property.

TABLE XIV.—*Unusual falls of rain.*

Rain began.	Duration.	Am't in inches.	Rain began.	Am't in inches.
1856, Aug. 19, 4 P. M.	29 hours	3·30	1867, Oct. 29	3·72
1857, July 23, 3 A. M.	8 "	4·58	1868, Sept. 5	3·18
1857, Oct. 26, A. M.	— "	3·04	1869, Oct. 3	2·94
1858, Sept. 15, 8 P. M.	19 "	3·04	1869, Oct. 4	4·97
1862, June 3, 3 P. M.	13 "	3·29	1870, Apr. 18	2·85

The following Table shows the cases in which the fall of snow was unusually great.

TABLE XV.—*Unusual falls of snow.*

Snow began.	Duration.	Am't in inches.	Snow began.	Am't in inches.
1856, Dec. 22, 3 P. M.	24 hours	6	1866, Dec 26	6
1856, Dec. 23, 3 P. M.	18 "	5	1867, Jan. 17	12
1857, Jan. 3, A. M.	— "	8	1867, Jan. 21	6
1858, Feb. 19, 3 P. M.	28 "	5	1867, Feb. 20	5
1858, March 8, 3 P. M.	— "	10	1867, Feb. 21	10
1858, Nov. 28, 7 A. M.	— "	8	1867, Mar. 17	11
1859, Jan. 3, 8 P. M.	20 "	30*	1868, Jan. 21	6
1859, March 3, 3 P. M.	16 "	6	1868, Jan. 26	9
1860, Jan. 11, P. M.	— "	6	1868, Mar. 2	10
1860, Feb. 15, 5 P. M.	27 "	9	1868, Mar. 21	5
1860, Dec. 4, 10 A. M.	22 "	10	1868, Dec. 5	10
1861, March 20, P. M.	— "	10	1869, Jan. 1	5
1861, April 1, 5 P. M.	20 "	8	1869, Feb. 26	10
1862, Jan. 6, 3 A. M.	18 "	5	1869, Dec. 6	13
1864, Dec. 9, P. M.	— "	7	1870, Feb. 8	10
1864, Dec. 31,	— "	5	1870, Feb. 28	5
1865, Jan. 4,	— "	6	1870, Mar. 7	6
1866, Jan. 7,	— "	5	1870, Mar. 13	8
1866, Jan. 25,	— "	5	1870, Mar. 15	5

* This snow storm was one of unusual severity, and caused a general interruption of travel upon the railroads.

VII. Design for a Bridge across the East River, New York, at Blackwell's Island.

It is proper to say that the design for a bridge crossing the East River at Blackwell's Island, New York, described in the following paper, was intended only as a solution of a special problem in Engineering, applicable to long spans in certain localities; and that it does not assume to be more than a suggestion in connection with the actual execution of a bridge across the East River. It is intended to show that if objections to such a project shall arise on account of the popular apprehension of the defects of the ordinary suspension bridge, there is still a practical form of structure which may be employed with equal and perhaps greater advantage for bridges of long span.

The suspension system, although apparently the only one available beyond the limits of the straight girder and arch, presents inherent defects, which to say the least are a constant source of popular apprehension. It is, however, the only system possible for very great spans, and the object of the form of bridge which I wish to present, as particularly applicable to the case presented at Blackwell's Island, is to supply a link between the straight girder, or tube, and the suspension system. There is an interval in the lengths of spans beyond the practicable limits of the single girder, which I think this form of construction will fill with advantage in stability, strength, and stiffness over the suspension bridge, and advantage in economy over the simple girder.

The bridge at Blackwell's Island, when completed, must become a great thoroughfare between two populous districts, and should not only possess the elements of strength and stability, but of stiffness, or immobility, under passing loads, under the action of high winds, and under the influences of changes of temperature.

Blackwell's Island divides the East River at New York into two channels, each about 600 feet in width. At the location deemed most favorable for a high bridge, opposite 76th street, the east channel is 600 feet in width from high-water mark to high-water mark, the west channel being at the same point about 670 feet. This being a point at which the section of the water-way in depth is greater than it is either above or below, it will be practicable, if deemed desirable, to make both spans of the bridge 600 feet, one of the piers of the west channel being built a slight distance out from the shore line. With the spans first mentioned, however, all the piers may be built without expensive coffer-dams and with rock beds for foundations.

For these spans, taking into consideration also the great altitude of the roadway required (135 feet), it appears evident that single straight girders either of the lattice or tubular form are inapplicable, both on account of the excessive weight required and the difficulty of erecting them.

The system or design which I suggest is represented in elevation in sketch 1. The design may perhaps be appropriately classed with cantilever constructions, although differing in essential points from any existing structures of long span. It may be explained in detail by reference to sketch 2, which represents a half-span.

This sketch represents a half span of one of the channels. P represents the pier 150 feet long, 60 feet broad, and 135 feet high, built of masonry, but not necessarily solid throughout. A B represents the vertical elevation of a tubular chord or strut extending from A, the middle of the span, across the pier, and resting upon it, to B. There are three of these chords or struts, one at each side, and one in the middle of the breadth of the pier. These chords being designed to sustain *thrusts* only, will be about 4 feet square in cross section, of a tubular form, made of iron plates; and as the thrust towards the pier will increase uniformly from A, where it is 0, to the pier, the section of the material will be increased towards the pier by adding plates to the interior of the tubes.

Upon these three tubes or chords, and forming part of them, will be built three iron towers (T), firmly braced laterally to each other. These towers will be 150 feet high. A T and B T represent iron suspension or stay-rods, placed at distances of about 10 feet apart; each rod A T having a corresponding stay-rod B T. The lower ends of each pair of rods, A T and B T, are firmly attached to the tubes or chords and the upper ends to short pendulums, the design of which is to insure equality of strain in the corresponding rods A T and B T. At the points where the rods B T are attached to the tubes, anchoring-rods attached to the tube pass down into the pier through well-holes, at the bottom of which they are secured, by cross bars, to the masonry.

The widths of the towers at the base is such as to secure perfect stability. the downward thrusts always striking near the centre of the base of each tower. There are two sets of parallel rods A T, and two sets B T, in pairs, for each tube or chord, making six sets of 17 each, or 102 rods A T and 102 rods B T. The rods for the outer tubes are $2\frac{3}{4}$ inches diameter, and those for the inner tube $3\frac{1}{2}$ inches diameter. These latter being heavier, because double weight, or half the weights of both roadways will be borne by the middle system of rods.

The rods are all kept from deflection under the action of their own weight by braces, shown best in sketch 2. The object of this will be explained in the proper place.

It will now be seen that the structure A T B, consisting of the lower chords, the towers and the stay-rods (all of wrought iron) constitute a homogeneous structure entirely independent of the pier, but resting upon it—the pier, through the anchoring rods, forming the counterweight, which prevents the overturning of the half-span when it is loaded.

This structure is first to be examined *under the action of its own weight.*

1. The horizontal chord from A to D is sustained by the stay-rods A T, and there will be developed in this chord neither a bending movement nor shearing force, or rather the shearing force will be distributed equally along the chord at the points of suspension, and the only strains or stresses that need be taken into account in this chord are the thrusts which increase uniformly from A to D. In a strut of this length the yielding under pressure is apt to take place by bending. The bending cannot take place laterally, because the three horizontal chords are firmly braced by diagonals in this direction. Neither can the bending take place downwards at any point; and the only yielding that can occur will be from the rising of the middle of the chord. To counteract this tendency, a light truss shown in the drawing is placed upon each chord, forming part of it. These trusses form at the same time the side railings or guards of the bridge.

The tension or stay-rods A T will evidently sustain all the permanent load, including their own weights, this load being transferred to the pier through the action of the counter-rods B T and the anchoring-rods. The tensions of these rods will all be equal, if we neglect the weights of the rods; and the stresses upon the lower chords, the tower, and any stay-rod, will be relatively as the sides of the right-angled triangle formed by the stay-rod, the chord at bottom, and the tower. For the longer rods the upper joints or sections should be increased slightly in diameter, since they have to bear, as a part of the permanent load, their own weights. Under this condition of things no cross strain can come upon the tower, and the thrusts will diminish uniformly from the top to the bottom.

2. If the lower chord be *uniformly loaded*, the same principles and reasoning apply. If loaded at separate points, it will be observed that the strains arising from any load will be transmitted through the stay-rods nearest it directly to the anchoring-rods in the pier; and thus it will be impossible for several loads to concentrate their effects upon any one, two, or three sets of rods. This condition will give stiffness, or freedom from vertical vibration, under moving loads. The only vertical oscillation that can arise under these circumstances will occur from the stretching of the rods under the tensions brought upon them. This will be so small in amount as to be inappreciable. In some suspension bridges this elasticity of stay-rods is a dangerous element, however, because the shorter rods may be stretched beyond their limits of elasticity, from the greater extension of the longer rods. This circumstance has not usually been taken into account in suspension bridges, and frequent disasters have occurred from the unaccountable giving way of the stay-rods. Long rods will stretch more than short rods, of the same diameter, in the exact proportion to their greater length, and even more on account of their additional weight; and if two such rods of greatly unequal lengths support equal loads, this element of elasticity should be taken into account. There are two modes of doing this; one is to increase the diameter of the longer rods with especial reference to this stretching, and the other to permit the platform of the bridge to yield to accommodate itself to the increased length of the rods. This plan is adopted in the construction under consideration. The stay-rods being all parallel, and not being all brought from the top of the tower, the stretching of the rods under passing loads will increase from the pier, where it is nothing, outward to the point A, and this end being unattached, all the points of suspension from the pier outward may move in proportion to the stretching of the rods, in small arcs of circles having a common center at the pier. Thus the movement of the platform so adjusts itself that the limits of elasticity will be reached at the same instant in all the stay-rods; and no injurious bending or shearing strain can be thrown upon the platform near the pier.

3. *Action under change of Temperature.*—This is one of the most important considerations in all iron bridges of long span. In this structure it is evident that the only effect of change of temperature will be to cause an outward or inward movement of the points A and B, and an upward or downward movement of the point T, without disturbing the lines of direction or causing a movement of sliding horizontally on the pier, the structure A T B being homogeneous and inde-

pendent of the pier. No deflections and no hurtful sliding movements are therefore possible from change of temperature. In the suspension bridge both of these consequences follow a change of temperature. To secure this important condition, perfectly, the deflections of the stay-rods by their own weights are prevented by a system of braces shown in sketch 2, the only object of which is to keep the stay-rods in right lines, and thus preserve the true triangular structure. The weight of these supporting braces adds only about 12 tons to each span of 600 feet.

4. The lateral stability of the structure is provided for by diagonal bracing between the horizontal chords and between the three iron towers; and also by light ties of wire rope between the stay-rods. The above description refers to a half-span of 300 feet. To complete the span another similar structure is erected on the opposite side, as shown in sketch 1, the ends of the half chords at A *not being joined together*, but an opening of 4½ inches being left for the free movement from expansion. This opening is covered by the string pieces of the road-way and by light slip joints along the sides, which act merely as guards.

To erect this bridge the opposite piers are first built up, during the erection of which the materials for the superstructure are made ready. These will be in duplicate, as the half spans are precisely similar. When the piers are completed, the half spans are built by first erecting about ten, twenty or thirty feet of the towers. Proportionate lengths of the chords are then built outward, overhanging the river, and the suspension and stay-rods attached. Another section of the tower is then built up, and a second section of the chords added. By this process the successive sections may be tested as the work progresses, and the lines of the structure perfectly adjusted. The stay-rods are made in sections or parts, united by screw turn buckles for this purpose, and thus the whole of a half span may be built out until the two half spans meet. An important feature in this process is that the strains encountered in the erection are precisely those which the structure will afterwards be subjected to, and no abnormal strains are brought to bear by uniting the half spans.

It will be seen on inspection that the complete structure is analogous to a combination of two large fixed derricks or cranes, examples of which have been so thoroughly tested in this country in the use of the famous Bishop's Derrick, which has been subjected to the most severe tests. In this bridge, however, there are arrangements of detail which do not occur in any existing structure, as far as I can learn. The roadway is supported upon light trussed beams thrown across between the chords about nine feet apart. These beams have a depth of four feet, and a span of about 23 feet, and are built of T and angle iron. Upon these the string pieces of the roadways are laid. It is unnecessary to describe the manner of building the approaches, as they are independent of the spans. To recapitulate the advantages of this construction. They are—

1. Simplicity.
2. The avoidance of cross strains in all pieces of the bridge.
3. Freedom of expansion and contraction from change of temperature, by which deflections and sliding motions are avoided.
4. Stability and strength, with the least amount of material.
5. Freedom from vertical oscillations from passing loads or high winds.
6. Lateral stiffness from the horizontal diagonal bracing of the towers and chords.
7. The distribution of strains among a large number of stay-rods, and the parallelism and independent connections of these rods.
8. The avoidance of separate anchoring abutments distinct from the piers.
9. Facility of construction and facilities for testing the strength as the work progresses.

An application of this system of construction might be made with great advantage at the crossing of the Niagara River, where the present suspension bridge is built. Sketch 3 represents the valley or gorge of the Niagara River at this point spanned by such a structure. The present suspension bridge is thrown across between two points of the crest B B, distant from each other about 800 feet, while the width of the river at the water level, 250 feet below, is only 382 feet. If from the water's edge piers were erected of masonry to the height of the crests, on each side, giving the proper batter, these piers would be about 400 feet apart at the top. This is not a long span. The longest tube of the Menai bridge is 460 feet, and trains cross that at full speed. It would be very easy to construct each half span from A to B on the land, in the prolongation of the bridge, and when these half spans should be completed to push them out until they should meet in mid-channel; then to unite them firmly as a single girder. This girder might have the tubular form, and the bridge would then possess all the elements of strength and stiffness of the Menai bridge, with the additional security of the counterbalanced half spans.

VIII. On the Mean Direction and Force of the Wind at New Haven, Conn.; from an extended series of Observations reduced by Francis E. Loomis, Ph.D., Professor of Physics in Cornell University, Ithaca, N. Y.

Direction of the Wind.

A meteorological journal has been kept at New Haven since 1779, and is well nigh continuous to the present time. These observations are the result of the labors of a large number of individuals, and the system of observation has been repeatedly changed. Nearly every observer made some record of the direction of the wind, but on account of the looseness of many of the observations and the frequent change of the hours of observation, it is difficult to deduce from them satisfactory results. There are, however, two series of observations made with such care that the results deduced from them are thought to be of considerable value.

The first series of observations extends from 1804 to 1820. These observations were made by Rev. J. Day, D.D., at that time Professor of Natural Philosophy in Yale College; but the direction of the wind was estimated only for the eight cardinal points of the compass. The observations were made three times a day, and recorded under the headings M., N. and E., abbreviations for morning, noon and evening; and they are supposed to have been made at about the same time as the observations of temperature, viz: sunrise, 1 P. M. and 10 P. M. The direction of the wind was probably indicated by an ordinary vane on some church spire in the immediate vicinity of Yale College.

The second series of observations extends from 1844 to 1852, during which time the observations were made five times a day, and the directions were estimated to 32 points of the compass. The observers were Col. Enos Cutler and Mr. Francis Bradley. Occasionally during the summer months the observations were suspended, so that while for certain months the records are pretty complete for eight or nine years, for other months the records are complete for only five years.

The hours of observation were not perfectly uniform, but did not vary greatly from 6 and 10 A. M., 2, 6 and 10 P. M. The mean hours of observation for the different years are stated in the Transactions of the Connecticut Academy, Vol. I, Part I, page 225, etc. It is presumed that the direction of the wind was derived from a vane placed upon some convenient church spire, and it is probable that the same vane was not employed throughout the entire series of observations.

TABLE I.—*Direction of the Wind, New Haven, Conn.*, 1804–1820.

North.

	Jan. M.	Jan. N.	Jan. E.	Feb. M.	Feb. N.	Feb. E.	March. M.	March. N.	March. E.
1804	7	5	5	4	6	2	9	4	4
1805	4	4	3	4	1	0	8	0	1
1806	4	3	6	0	1	2	4	0	1
1807	4	3	2	4	1	2	11	3	5
1808	5	3	6	4	1	1	3	3	1
1809	7	5	5	3	1	1	2	1	3
1810	2	0	2	6	2	1	3	0	0
1811	6	2	5	2	0	0	3	2	2
1812	3	2	1	2	1	1	4	3	3
1813	4	2	2	4	3	2	7	2	0
1814	7	6	2	8	1	0	4	0	0
1815	7	5	3	6	7	3	2	2	1
1816	6	3	3	4	0	0	5	3	3
1817	5	3	0	5	2	6	9	4	6
1818	8	9	7	8	3	1	13	7	6
1819	6	3	4	5	5	3	8	4	4
1820	10	6	4	4	6	2	9	5	4
Sum	95	64	60	73	41	27	104	43	44

Northwest.

	January. M.	January. N.	January. E.	February. M.	February. N.	February. E.	March. M.	March. N.	March. E.
1804	15	14	13	12	12	14	15	15	15
1805	11	8	13	11	11	13	4	5	7
1806	10	10	12	9	10	10	15	17	18
1807	11	14	15	10	13	12	9	13	13
1808	9	14	11	7	8	6	9	7	6
1809	10	8	10	7	11	8	11	9	10
1810	14	10	10	8	11	12	11	10	10
1811	11	13	15	3	4	8	9	4	7
1812	7	8	15	10	8	11	13	12	10
1813	12	8	12	6	6	7	9	7	13
1814	10	11	14	6	6	13	12	9	12
1815	9	7	9	12	8	13	10	7	8
1816	7	4	6	7	4	5	7	6	9
1817	6	7	16	6	3	5	9	5	8
1818	5	3	4	4	3	4	0	1	4
1819	3	8	7	4	6	8	5	7	9
1820	1	7	9	4	2	6	4	5	6
Sum	151	154	191	126	126	155	152	139	165

West.

	Jan. M.	Jan. N.	Jan. E.	Feb. M.	Feb. N.	Feb. E.	March. M.	March. N.	March. E.
1804	2	4	2	5	2	0	2	3	2
1805	3	3	1	6	3	2	0	1	0
1806	1	2	2	5	2	1	3	1	0
1807	6	5	3	7	2	3	8	7	5
1808	6	2	2	4	4	3	4	1	1
1809	5	6	4	7	1	3	2	5	4
1810	4	3	2	3	2	3	5	3	5
1811	1	3	1	4	3	2	1	3	1
1812	8	10	4	3	6	2	0	2	1
1813	2	2	3	4	3	2	1	2	0
1814	5	5	5	1	5	1	2	3	1
1815	4	5	3	2	1	2	0	2	1
1816	5	8	5	5	8	8	3	1	1
1817	8	6	3	4	5	4	0	3	3
1818	7	7	7	5	8	6	3	3	6
1819	7	2	2	7	5	6	6	4	6
1820	11	8	7	3	5	4	4	3	3
Sum	85	81	56	75	65	52	44	47	40

Southwest.

	Jan. M.	Jan. N.	Jan. E.	Feb. M.	Feb. N.	Feb. E.	March. M.	March. N.	March. E.
1804	4	2	6	5	6	5	3	1	2
1805	9	11	11	4	5	8	7	5	6
1806	6	7	6	8	11	12	3	5	7
1807	7	6	8	1	2	4	0	2	1
1808	2	4	5	6	9	9	6	8	10
1809	5	5	11	3	6	9	7	8	7
1810	6	8	8	3	5	4	3	8	4
1811	2	2	3	5	5	5	7	7	9
1812	7	3	5	3	4	4	2	3	4
1813	8	10	10	8	9	8	2	5	7
1814	6	8	6	9	5	7	8	7	5
1815	5	4	6	3	4	4	5	7	8
1816	5	4	8	9	6	8	5	6	7
1817	5	8	4	6	7	8	3	3	6
1818	5	4	7	6	5	8	3	4	2
1819	6	8	8	6	3	6	5	3	5
1820	4	4	7	9	6	8	5	8	10
Sum	92	98	119	94	98	117	74	90	100

South.

	Jan. M.	Jan. N.	Jan. E.	Feb. M.	Feb. N.	Feb. E.	March. M.	March. N.	March. E.
1804	0	0	0	2	1	4	0	4	3
1805	0	1	2	0	4	2	2	5	4
1806	0	0	0	1	1	1	0	2	1
1807	0	1	0	0	3	0	0	0	0
1808	3	2	4	0	1	2	0	4	5
1809	0	1	0	0	1	0	0	3	0
1810	0	1	1	1	2	1	0	1	1
1811	0	0	0	0	0	0	1	2	0
1812	0	3	0	0	0	2	2	5	4
1813	2	4	0	0	0	2	0	2	1
1814	0	0	0	0	7	3	1	6	6
1815	2	2	2	1	3	1	6	7	4
1816	2	3	2	1	5	2	2	4	3
1817	1	2	3	1	2	0	0	7	0
1818	2	2	0	2	2	2	5	10	5
1819	3	4	4	0	5	2	1	4	1
1820	0	2	0	0	2	*2	4	4	4
Sum	15	28	18	9	39	26	24	70	42

Southeast.

	January. M.	January. N.	January. E.	February. M.	February. N.	February. E.	March. M.	March. N.	March. E.
1804	1	3	0	0	1	2	0	3	2
1805	1	1	0	1	1	1	3	8	9
1806	0	0	0	0	0	1	0	1	0
1807	0	0	1	0	0	2	1	2	4
1808	2	3	0	2	0	0	3	4	3
1809	1	1	0	0	2	2	1	3	4
1810	1	3	2	1	4	3	0	5	3
1811	0	1	0	0	0	1	0	8	7
1812	0	2	3	1	4	3	1	0	1
1813	1	2	2	0	3	0	1	1	0
1814	0	0	0	1	0	1	3	5	5
1815	1	1	2	0	0	0	1	1	3
1816	0	1	1	0	3	3	0	1	0
1817	0	1	3	0	0	0	1	1	4
1818	0	0	1	0	0	1	1	1	0
1819	0	1	2	1	0	0	0	0	1
1820	0	1	1	0	0	0	0	2	0
Sum	8	21	18	7	18	20	16	46	46

East.

	Jan. M.	Jan. N.	Jan. E.	Feb. M.	Feb. N.	Feb. E.	March. M.	March. N.	March. E.
1804	0	1	1	0	0	0	1	0	1
1805	0	0	0	0	0	0	0	2	0
1806	0	0	0	2	0	1	3	2	2
1807	0	1	0	0	3	0	1	3	0
1808	0	0	1	0	1	3	2	2	2
1809	0	0	0	0	0	0	2	0	1
1810	0	1	2	0	0	0	0	0	2
1811	0	0	0	0	0	0	0	3	1
1812	0	1	0	0	0	1	0	1	1
1813	0	0	0	0	0	2	1	1	0
1814	0	0	0	0	0	0	0	0	0
1815	0	2	2	0	0	2	0	2	2
1816	0	0	1	1	3	1	0	1	2
1817	0	2	0	1	2	0	1	3	0
1818	0	1	0	0	3	2	0	0	0
1819	0	0	0	0	2	1	1	2	0
1820	1	1	0	1	3	3	0	0	0
Sum	1	10	7	5	17	16	12	22	14

Northeast.

	Jan. M.	Jan. N.	Jan. E.	Feb. M.	Feb. N.	Feb. E.	March. M.	March. N.	March. E.
1804	2	2	4	1	1	2	1	1	2
1805	3	3	1	2	3	2	7	5	4
1806	10	9	5	3	3	0	3	3	2
1807	3	1	2	6	4	5	1	1	3
1808	4	3	1	6	5	5	4	2	3
1809	3	5	1	8	6	5	6	2	2
1810	4	5	4	6	2	4	9	4	6
1811	11	10	7	14	16	12	10	2	4
1812	6	2	3	10	6	5	9	5	7
1813	2	3	2	6	4	5	10	11	10
1814	3	1	4	3	4	3	1	1	2
1815	3	5	4	4	5	3	7	3	4
1816	6	8	5	2	0	2	9	9	6
1817	6	2	2	5	7	5	8	5	4
1818	4	5	5	3	4	4	6	5	8
1819	6	5	4	5	2	2	5	7	5
1820	4	2	3	8	5	4	5	4	4
Sum	80	71	57	92	77	68	101	70	76

North.

	April. M.	April. N.	April. E.	May. M.	May. N.	May. E.	June. M.	June. N.	June. E.
1804	10	0	4	3	0	3	8	3	3
1805	5	2	1	4	1	1	5	1	1
1806	5	2	3	5	2	1	6	0	0
1807	8	2	2	9	1	1	8	1	3
1808	5	2	3	2	0	5	3	0	0
1809	6	2	1	3	1	2	5	3	4
1810	4	1	2	5	2	4	6	1	1
1811	5	1	1	5	2	3	5	1	2
1812	2	1	2	9	2	3	6	0	2
1813	6	4	2	6	3	2	9	2	0
1814	6	3	4	4	0	0	12	4	1
1816	4	4	1	3	4	0	3	2	2
1816	6	5	2	6	1	1	9	4	1
1817	0	3	2	4	2	2	5	2	1
1818	13	8	5	9	2	5	8	5	2
1819	13	8	8	9	2	3	9	4	5
1820	8	3	4	3	3	6	8	1	0
Sum	106	51	47	89	28	42	115	34	28

Northwest.

	April. M.	April. N.	April. E.	May. M.	May. N.	May. E.	June. M.	June. N.	June. E.
1804	8	11	10	2	1	1	10	5	4
1805	6	9	11	7	6	9	4	5	9
1806	10	13	11	3	4	2	3	3	5
1807	4	7	9	5	7	9	4	4	6
1808	7	7	7	7	8	4	7	8	4
1809	9	9	10	8	4	8	3	2	4
1810	6	4	4	8	10	11	3	4	3
1811	9	7	7	7	5	7	4	7	6
1812	10	6	5	9	11	8	12	7	12
1813	4	2	6	6	3	6	3	5	3
1814	3	2	5	9	9	9	4	1	4
1816	9	4	9	13	8	10	6	6	8
1816	9	8	13	3	5	7	5	5	11
1817	11	4	10	2	4	4	4	2	7
1818	5	4	6	4	5	4	2	1	11
1819	4	7	7	5	4	4	1	3	5
1820	3	5	5	3	1	1	4	5	6
Sum	117	109	135	101	95	104	79	73	108

West.

	April. M.	April. N.	April. E.	May. M.	May. N.	May. E.	June. M.	June. N.	June. E.
1804	4	2	3	1	0	1	0	1	2
1805	4	2	2	3	1	1	2	0	1
1806	4	3	3	2	1	4	0	1	2
1807	5	3	3	2	3	1	4	3	3
1808	1	0	0	3	0	3	5	0	0
1809	1	1	0	6	6	4	1	1	0
1810	1	0	0	3	2	1	2	1	2
1811	0	0	1	1	0	0	4	3	0
1812	0	0	0	1	0	0	0	1	0
1813	2	2	2	2	2	1	4	0	1
1814	0	0	0	1	1	2	1	1	2
1816	0	0	0	1	1	2	5	3	0
1816	4	2	2	5	3	0	3	4	0
1817	4	2	5	0	1	0	1	2	0
1818	2	3	4	4	5	3	3	4	1
1819	3	1	4	2	3	2	3	1	4
1820	3	2	2	0	1	0	4	1	1
Sum	38	23	31	37	30	25	42	27	19

Southwest.

	April. M.	April. N.	April. E.	May. M.	May. N.	May. E.	June. M.	June. N.	June. E.
1804	1	1	4	5	3	7	3	6	11
1805	4	5	6	7	8	10	8	7	6
1806	2	2	5	3	3	6	9	9	12
1807	2	3	5	8	7	12	6	8	12
1808	5	6	7	4	7	5	8	8	13
1809	6	8	9	3	3	6	8	6	9
1810	5	6	8	8	6	4	6	6	8
1811	1	1	5	4	9	10	6	8	9
1812	1	3	7	2	0	2	4	9	9
1813	6	1	6	4	4	6	6	5	10
1814	10	4	10	3	1	2	1	1	3
1816	7	5	6	5	3	7	12	5	10
1816	3	4	7	8	4	9	5	4	8
1817	7	9	6	4	1	7	8	3	10
1818	3	2	4	4	7	5	9	4	6
1819	2	4	1	3	3	5	8	10	8
1820	5	3	4	3	3	9	6	7	11
Sum	70	67	100	78	72	112	113	106	155

South.

	April. M.	April. N.	April. E.	May. M.	May. N.	May. E.	June. M.	June. N.	June. E.
1804	0	3	2	3	9	5	1	2	1
1805	4	3	2	3	7	5	3	10	8
1806	0	3	0	7	8	8	1	8	3
1807	2	5	2	1	6	3	0	5	2
1808	1	3	5	2	4	5	0	8	5
1809	0	3	3	2	8	5	0	2	4
1810	0	4	3	1	4	1	2	6	1
1811	3	7	2	2	5	3	1	4	2
1812	2	6	4	2	6	2	2	3	3
1813	1	9	3	0	2	2	1	5	5
1814	3	12	4	4	9	10	3	9	6
1815	2	10	7	1	5	3	1	9	7
1816	3	6	4	1	12	6	2	7	3
1817	1	8	2	5	10	7	2	11	3
1818	1	5	3	3	6	5	6	15	8
1819	1	5	2	1	5	1	6	9	6
1820	2	9	5	6	10	6	3	10	6
Sum	26	101	53	44	116	77	34	123	73

Southeast.

	April. M.	April. N.	April. E.	May. M.	May. N.	May. E.	June. M.	June. N.	June. E.
1804	1	8	6	4	14	9	3	8	5
1805	2	5	3	3	6	3	5	5	4
1806	0	3	2	1	8	2	3	7	6
1807	1	4	5	1	2	0	3	4	1
1808	1	6	4	3	7	5	1	3	1
1809	3	2	3	3	5	4	7	13	8
1810	7	8	5	1	2	5	5	6	10
1811	2	8	8	1	5	3	2	4	7
1812	8	13	10	3	6	9	3	6	3
1813	2	8	8	3	10	5	4	10	6
1814	1	5	4	3	4	4	5	9	8
1815	1	1	0	0	4	4	3	3	3
1816	2	3	1	1	0	5	0	3	0
1817	2	2	4	3	9	7	1	3	5
1818	1	1	2	1	1	2	1	1	0
1819	1	0	1	1	2	4	2	1	0
1820	0	2	2	2	4	3	1	5	2
Sum	35	79	68	34	89	74	49	91	69

East.

	April. M.	April. N.	April. E.	May. M.	May. N.	May. E.	June. M.	June. N.	June. E.
1804	2	1	1	3	0	3	3	3	2
1805	0	1	0	0	1	0	0	2	1
1806	0	0	1	0	1	4	1	1	2
1807	1	5	0	2	0	1	0	1	0
1808	1	2	1	4	1	2	0	0	1
1809	2	1	0	1	2	0	1	0	0
1810	0	0	2	0	2	1	1	0	0
1811	1	1	1	0	0	2	0	0	2
1812	0	0	0	0	0	1	1	2	1
1813	2	0	0	0	0	3	1	2	0
1814	1	0	1	2	5	0	0	1	2
1815	1	2	1	0	2	2	0	1	0
1816	0	0	0	3	2	0	1	0	3
1817	1	1	0	1	1	1	1	4	2
1818	1	1	1	2	2	3	0	0	1
1819	1	3	4	1	3	4	0	2	2
1820	1	2	1	4	2	2	1	1	3
Sum	15	20	14	23	24	29	11	20	22

Northeast.

	April. M.	April. N.	April. E.	May. M.	May. N.	May. E.	June. M.	June. N.	June. E.
1804	4	4	0	10	4	2	2	2	2
1805	5	3	5	4	1	2	3	0	0
1806	9	4	5	10	4	4	7	1	0
1807	7	1	4	3	5	4	5	4	3
1808	9	4	3	6	4	2	6	3	6
1809	3	4	4	5	2	2	5	3	1
1810	7	7	6	5	3	4	5	6	5
1811	9	5	5	11	5	3	8	3	2
1812	7	1	2	5	6	6	2	2	0
1813	7	4	3	10	7	6	2	1	5
1814	6	4	2	5	2	4	4	4	4
1815	6	4	6	8	4	3	0	1	0
1816	3	2	1	4	4	3	5	3	4
1817	4	1	0	12	3	3	8	3	2
1818	4	6	5	4	3	4	1	0	0
1819	5	2	2	9	9	7	1	0	0
1820	8	4	7	10	7	4	3	0	1
Sum	103	60	60	121	73	63	67	36	35

North.

	July M.	July N.	July E.	August M.	August N.	August E.	Sept. M.	Sept. N.	Sept. E.
1804	5	0	1	8	3	1	7	2	2
1805	11	0	1	--	--	--	7	6	4
1806	3	2	0	7	1	5	9	5	4
1807	3	0	1	3	3	2	10	7	8
1808	4	1	3	6	1	1	3	0	0
1809	7	0	3	5	4	0	9	2	5
1810	3	0	0	6	5	4	10	3	4
1811	4	3	2	10	1	1	3	5	3
1812	6	2	0	6	1	3	3	1	1
1813	1	0	1	4	3	0	4	2	2
1814	6	0	1	8	2	2	8	2	2
1815	4	1	0	8	2	0	8	3	2
1816	13	5	2	10	2	1	10	4	5
1817	9	2	1	12	3	2	9	4	3
1818	7	0	1	13	3	5	15	7	4
1819	11	1	3	14	5	3	11	4	5
1820	5	0	4	7	1	0	10	0	1
Sum	102	17	24	127	40	30	136	57	55

Northwest.

	July M.	July N.	July E.	August M.	August N.	August E.	Sept. M.	Sept. N.	Sept. E.
1804	7	5	9	5	3	9	8	6	11
1805	2	6	5	--	--	--	6	1	4
1806	8	2	9	8	3	5	2	3	5
1807	5	3	4	6	3	3	9	9	8
1808	8	3	4	7	6	5	8	4	9
1809	8	5	7	4	5	8	10	8	7
1810	5	3	4	6	4	5	6	3	5
1811	5	3	6	5	5	9	6	5	9
1812	10	4	8	0	4	6	13	6	12
1813	10	4	8	12	5	8	12	11	13
1814	5	6	7	6	8	9	5	5	6
1815	5	3	4	5	6	10	6	5	6
1816	6	3	10	5	6	8	6	3	8
1817	3	2	4	2	2	8	8	4	6
1818	5	5	7	2	4	8	2	5	10
1819	0	1	4	1	0	4	3	1	2
1820	3	0	0	8	3	9	8	5	5
Sum	95	58	100	82	67	114	118	84	126

West.

	July M.	July N.	July E.	August M.	August N.	August E.	Sept. M.	Sept. N.	Sept. E.
1804	3	3	1	1	1	0	2	2	1
1805	3	2	0	--	--	--	2	1	0
1806	4	3	2	1	1	0	2	0	1
1807	4	2	1	3	1	2	4	1	1
1808	2	3	0	3	2	1	6	3	3
1809	4	3	3	1	1	0	6	0	1
1810	2	3	3	2	0	0	1	1	0
1811	3	1	0	2	2	2	4	0	0
1812	4	0	0	6	2	2	1	3	1
1813	2	1	1	0	4	0	0	0	0
1814	7	5	3	1	0	2	1	1	0
1815	4	1	2	1	2	1	2	3	2
1816	0	4	1	0	1	0	1	2	2
1817	2	1	3	3	1	3	5	4	3
1818	5	4	0	3	3	1	2	6	3
1819	2	2	1	1	0	0	2	3	1
1820	1	1	1	3	3	0	3	0	2
Sum	52	39	22	31	24	14	44	30	21

Southwest.

	July M.	July N.	July E.	August M.	August N.	August E.	Sept. M.	Sept. N.	Sept. E.
1804	11	8	14	7	6	9	7	6	8
1805	12	15	20	--	--	--	7	9	12
1806	8	10	11	7	11	10	7	7	6
1807	8	9	16	5	7	12	3	4	6
1808	6	7	11	4	6	14	7	10	5
1809	4	6	11	9	5	11	3	13	14
1810	6	8	14	7	5	12	5	7	12
1811	7	9	13	9	4	13	8	9	12
1812	1	6	8	2	3	3	5	5	6
1813	13	12	14	13	8	16	6	5	5
1814	7	6	15	9	4	6	8	6	8
1815	6	11	13	4	1	7	7	4	12
1816	5	6	9	7	5	9	3	3	6
1817	7	8	8	5	7	5	5	6	12
1818	4	4	7	3	6	7	6	2	4
1819	12	6	13	8	4	9	4	2	8
1820	11	5	11	4	3	8	5	6	11
Sum	128	136	208	103	85	151	96	104	147

South.

	July M.	July N.	July E.	August M.	August N.	August E.	Sept. M.	Sept. N.	Sept. E.
1804	2	2	1	2	2	0	0	2	1
1805	1	5	4	--	--	--	1	8	3
1806	1	8	5	1	6	4	1	5	2
1807	3	11	4	0	7	5	0	5	6
1808	1	4	2	0	5	3	2	5	6
1809	0	7	1	2	7	6	0	3	1
1810	1	5	1	3	6	4	1	6	2
1811	1	8	3	1	12	1	1	4	0
1812	5	11	5	4	5	3	0	5	2
1813	0	5	2	0	7	4	3	7	3
1814	4	9	4	5	10	7	0	4	1
1815	6	10	7	2	10	2	1	9	2
1816	2	9	5	4	8	8	1	7	3
1817	5	12	8	2	11	9	0	8	3
1818	4	12	10	2	9	6	0	3	4
1819	2	14	7	1	16	9	3	10	5
1820	6	18	9	3	12	9	1	12	8
Sum	44	150	78	32	133	80	15	103	52

Southeast.

	July M.	July N.	July E.	August M.	August N.	August E.	Sept. M.	Sept. N.	Sept. E.
1804	3	10	5	1	9	8	2	8	3
1805	0	2	1	--	--	--	1	2	3
1806	1	2	1	3	4	6	1	5	2
1807	4	6	4	4	5	2	1	3	0
1808	4	7	5	0	4	3	0	6	4
1809	0	5	2	1	6	3	0	1	1
1810	3	10	5	1	7	1	0	3	1
1811	2	5	3	2	6	4	0	4	3
1812	0	6	7	3	9	8	1	4	2
1813	2	6	3	0	2	2	2	2	5
1814	1	4	1	1	5	3	3	4	4
1815	4	3	4	2	7	3	1	1	0
1816	1	2	3	1	5	3	0	0	0
1817	2	5	5	2	4	2	0	2	1
1818	1	5	2	0	2	2	0	3	1
1819	0	4	2	0	1	1	2	4	2
1820	1	5	4	0	6	2	1	5	1
Sum	29	87	57	21	82	53	15	57	33

East.

	July M.	July N.	July E.	August M.	August N.	August E.	Sept. M.	Sept. N.	Sept. E.
1804	0	2	0	1	3	0	0	0	1
1805	0	0	0	--	--	--	0	0	0
1806	1	2	1	0	1	0	0	1	0
1807	0	0	0	1	1	1	0	0	0
1808	0	2	4	0	0	0	1	0	0
1809	0	1	0	2	0	0	0	0	0
1810	0	0	0	0	0	0	0	0	0
1811	0	1	2	0	1	1	0	0	0
1812	0	0	1	3	1	1	0	0	1
1813	1	1	0	0	1	1	0	0	0
1814	0	1	0	0	1	1	0	0	1
1815	0	1	1	3	2	4	0	0	0
1816	0	1	0	1	1	2	0	1	0
1817	0	0	0	0	0	0	0	0	0
1818	2	0	2	1	1	0	0	1	1
1819	2	2	1	0	1	1	1	3	4
1820	1	0	2	0	1	0	0	0	1
Sum	7	14	14	12	15	12	2	6	9

Northeast.

	July M.	July N.	July E.	August M.	August N.	August E.	Sept. M.	Sept. N.	Sept. E.
1804	0	1	0	6	4	4	4	4	3
1805	2	1	0	--	--	--	6	3	4
1806	5	2	2	4	4	1	8	4	7
1807	4	0	1	9	4	4	3	1	1
1808	6	4	2	11	7	4	3	2	3
1809	8	4	4	7	3	3	2	3	1
1810	11	2	4	6	4	5	7	7	6
1811	9	1	2	2	0	0	8	3	3
1812	5	2	2	7	6	5	7	6	5
1813	2	2	2	2	1	0	3	3	2
1814	1	0	0	1	1	1	5	7	4
1815	2	1	0	6	1	4	5	5	6
1816	4	1	1	3	3	0	9	10	6
1817	3	1	1	5	3	2	3	2	2
1818	3	1	2	7	3	2	5	3	3
1819	2	1	0	6	4	4	4	3	3
1820	3	2	0	6	2	3	2	2	1
Sum	70	26	23	88	50	42	84	68	60

North.

	Oct. M.	Oct. N.	Oct. E.	Nov. M.	Nov. N.	Nov. E.	Dec. M.	Dec. N.	Dec. E.
1804	5	2	2	5	1	1	7	7	3
1805	5	2	2	5	3	3	0	0	1
1806	11	5	7	7	3	8	7	3	6
1807	9	4	4	3	5	1	3	2	1
1808	8	2	2	4	2	3	2	2	1
1809	5	1	1	4	3	2	7	5	4
1810	7	4	3	1	0	0	2	0	0
1811	6	4	1	6	1	4	3	1	1
1812	3	2	2	4	1	1	4	2	1
1813	1	3	1	9	6	4	4	2	2
1814	1	2	2	10	4	2	6	4	4
1815	5	1	0	6	5	4	6	3	1
1816	7	1	1	8	7	1	2	3	2
1817	13	5	3	7	5	1	7	5	3
1818	11	2	4	3	3	3	10	7	6
1819	8	5	1	14	8	3	8	5	4
1820	12	6	9	9	6	2	7	8	5
Sum	117	51	45	105	63	43	85	59	45

Northwest.

	Oct. M.	Oct. N.	Oct. E.	Nov. M.	Nov. N.	Nov. E.	Dec. M.	Dec. N.	Dec. E.
1804	11	8	12	7	10	11	6	9	12
1805	2	6	6	7	9	9	15	11	14
1806	9	8	11	9	8	9	4	8	7
1807	9	8	9	8	8	14	5	6	6
1808	6	8	10	5	6	6	10	10	9
1809	2	3	3	9	9	11	6	7	12
1810	9	6	7	5	8	4	8	10	14
1811	4	1	2	10	13	11	12	11	14
1812	13	8	12	14	11	12	13	10	12
1813	13	12	15	8	4	7	19	19	8
1814	19	13	13	6	5	8	4	10	13
1815	6	3	6	4	5	6	4	4	10
1816	8	7	10	6	4	11	8	5	7
1817	7	10	11	6	7	10	8	8	9
1818	3	6	6	7	6	8	7	7	13
1819	8	7	8	1	4	8	5	11	11
1820	6	6	7	7	10	10	7	8	9
Sum	135	120	148	119	127	155	141	154	190

West.

	Oct. M.	Oct. N.	Oct. E.	Nov. M.	Nov. N.	Nov. E.	Dec. M.	Dec. N.	Dec. E.
1804	2	3	4	4	5	4	7	5	4
1805	10	3	1	3	0	1	3	4	4
1806	2	2	1	2	2	0	5	6	6
1807	2	2	6	9	6	5	7	5	4
1808	0	2	1	4	2	4	3	5	5
1809	2	0	1	2	2	3	3	4	1
1810	1	3	2	3	0	5	5	6	3
1811	3	1	2	3	3	3	6	5	2
1812	2	1	1	6	8	5	7	10	8
1813	3	1	2	3	3	1	0	1	0
1814	0	0	0	2	0	0	5	8	2
1815	0	2	2	4	1	2	13	8	7
1816	3	4	1	2	3	2	2	4	0
1817	3	0	3	8	5	6	4	3	5
1818	5	1	2	5	3	1	7	7	5
1819	6	4	5	6	4	4	8	5	6
1820	5	2	2	4	2	6	6	4	4
Sum	49	31	36	70	49	52	91	90	66

Southwest.

	Oct. M.	Oct. N.	Oct. E.	Nov. M.	Nov. N.	Nov. E.	Dec. M.	Dec. N.	Dec. E.
1804	7	10	8	9	8	9	8	5	8
1805	5	11	15	6	9	9	8	11	10
1806	2	4	6	3	4	7	8	4	6
1807	8	10	6	3	8	6	9	7	11
1808	5	4	6	10	12	8	4	6	7
1809	5	9	11	4	6	5	7	5	7
1810	8	9	14	6	8	7	6	7	6
1811	8	12	17	7	5	5	6	5	7
1812	6	9	6	2	3	6	3	3	1
1813	5	7	6	6	9	9	6	4	4
1814	4	2	5	4	5	10	12	7	11
1815	7	6	9	8	7	13	5	8	8
1816	5	6	7	8	5	11	13	7	15
1817	5	8	8	3	0	5	5	6	5
1818	6	7	6	12	11	13	4	7	5
1819	7	8	11	4	8	7	7	6	7
1820	4	6	6	3	2	2	4	3	6
Sum	97	128	147	98	110	132	115	101	124

South.

	Oct. M.	Oct. N.	Oct. E.	Nov. M.	Nov. N.	Nov. E.	Dec. M.	Dec. N.	Dec. E.
1804	0	2	0	0	1	1	0	1	0
1805	1	2	1	1	2	2	3	3	0
1806	2	4	3	1	3	3	0	2	2
1807	0	1	2	0	0	0	0	4	0
1808	3	4	3	0	0	0	0	0	0
1809	1	2	1	0	0	1	2	1	2
1810	0	2	2	0	0	0	1	0	0
1811	1	1	0	0	1	0	1	1	0
1812	4	5	4	3	4	3	1	2	2
1813	0	2	3	1	1	2	0	0	1
1814	1	3	0	4	6	1	0	0	0
1815	1	4	2	3	7	2	0	3	1
1816	2	5	5	2	6	2	2	8	3
1817	2	7	4	2	8	3	1	2	3
1818	3	12	9	0	2	1	0	0	0
1819	1	5	3	2	1	0	1	1	0
1820	1	1	2	3	7	5	1	1	0
Sum	23	62	44	22	49	26	13	29	14

Southeast.

	Oct. M.	Oct. N.	Oct. E.	Nov. M.	Nov. N.	Nov. E.	Dec. M.	Dec. N.	Dec. E.
1804	1	1	2	2	2	1	1	1	1
1805	0	2	1	1	1	0	0	0	1
1806	0	1	1	0	1	1	1	2	0
1807	0	2	1	0	0	0	0	3	3
1808	0	5	3	0	3	2	1	2	3
1809	2	5	5	0	2	1	0	2	1
1810	1	4	1	1	3	3	0	0	0
1811	1	4	2	1	3	4	0	3	3
1812	2	5	6	1	2	3	0	1	2
1813	6	4	2	1	1	4	0	0	1
1814	1	6	4	0	1	3	1	1	0
1815	0	2	1	0	0	1	1	1	1
1816	0	3	4	0	2	0	0	2	0
1817	0	0	0	1	2	2	0	1	0
1818	0	0	2	0	1	2	0	0	0
1819	1	2	2	1	1	4	0	0	0
1820	0	3	3	1	1	1	0	0	0
Sum	15	49	40	10	26	32	5	19	16

East.

	Oct. M.	Oct. N.	Oct. E.	Nov. M.	Nov. N.	Nov. E.	Dec. M.	Dec. N.	Dec. E.
1804	0	1	0	0	0	1	0	1	0
1805	0	2	1	0	1	0	0	0	1
1806	0	1	0	1	2	2	0	0	0
1807	0	0	0	0	0	0	1	1	1
1808	1	0	0	0	1	2	1	1	0
1809	0	2	1	0	0	0	0	0	0
1810	0	0	0	2	4	3	1	0	0
1811	1	1	0	0	1	0	0	0	0
1812	0	1	0	0	0	0	1	2	2
1813	1	2	2	0	2	0	0	0	0
1814	1	0	0	1	4	1	0	0	0
1815	0	1	0	0	1	0	0	0	0
1816	3	1	0	1	0	1	0	0	0
1817	0	0	0	1	2	0	1	1	0
1818	0	0	0	1	1	0	0	0	0
1819	0	0	0	0	1	0	0	0	1
1820	0	1	0	0	1	0	0	2	0
Sum	7	13	4	7	21	10	5	8	5

Northeast.

	Oct. M.	Oct. N.	Oct. E.	Nov. M.	Nov. N.	Nov. E.	Dec. M.	Dec. N.	Dec. E.
1804	5	4	3	3	3	2	2	2	3
1805	8	3	4	7	5	6	2	2	0
1806	5	6	2	7	7	0	6	6	4
1807	3	4	3	7	3	4	6	3	5
1808	8	6	6	7	4	4	10	5	6
1809	14	9	8	11	8	7	6	7	4
1810	5	3	2	12	7	8	8	8	8
1811	7	7	7	3	3	3	3	5	4
1812	1	0	0	0	1	0	2	1	3
1813	2	0	0	2	4	3	2	5	5
1814	2	0	2	3	5	5	3	1	1
1815	4	4	3	5	4	2	2	4	3
1816	3	4	3	3	3	2	4	2	4
1817	1	1	2	2	1	3	5	5	6
1818	3	3	1	2	3	2	3	3	2
1819	0	0	1	2	3	4	2	3	2
1820	3	6	2	3	1	4	6	5	7
Sum	74	60	49	79	65	59	72	67	67

TABLE II.—*Direction of the Wind, New Haven, Conn.*

JANUARY.

	N.					N. by W.					N.N.W.					N.W. by N.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1845	3	2	1	2	3	5	4	2	2	1	3	3	2	1	1	1	1	0	0	0
1846	0	0	0	1	2	0	0	2	1	1	1	0	1	1	1	1	1	0	1	1
1847	4	4	0	0	0	0	1	0	0	0	0	0	1	0	0	1	1	3	3	3
1848	1	1	1	2	2	3	3	1	2	2	1	1	0	0	0	0	1	0	0	0
1849	3	5	1	2	2	1	1	3	4	4	0	0	0	0	0	1	0	0	0	0
1850	3	3	1	2	2	0	1	0	0	0	0	1	2	0	0	0	0	0	0	0
1851	2	3	2	3	3	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0
1852	4	5	2	1	2	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0
Sum	20	23	8	13	16	11	13	9	10	9	5	5	6	2	2	4	4	3	4	4

	N.W.					N.W. by W.					W.N.W.					W. by N.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1845	5	3	7	6	7	3	4	2	2	2	0	0	1	0	0	1	0	1	1	1
1846	8	10	8	5	5	3	6	5	4	4	2	0	2	2	2	0	1	1	1	0
1847	6	3	4	7	7	1	2	4	2	2	0	0	0	1	1	2	1	2	1	1
1848	3	6	5	4	4	1	1	0	3	3	0	0	1	0	0	0	0	0	1	1
1849	7	5	7	7	8	1	0	3	2	1	0	2	1	0	0	0	1	0	0	0
1850	6	4	5	4	5	2	2	3	2	1	0	0	1	1	1	1	0	0	2	2
1851	2	4	1	2	2	0	1	1	0	0	3	0	4	1	1	2	1	1	1	1
1852	4	4	3	6	6	0	0	3	0	0	0	0	0	0	0	3	1	2	3	3
Sum	41	39	40	41	44	11	16	21	15	13	5	2	10	5	5	9	5	7	10	9

	W.					W. by S.					W.S.W.					S.W. by W.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1845	0	1	1	1	1	1	1	1	2	1	1	2	0	1	1	1	1	0	0	0
1846	3	1	0	1	0	1	0	0	1	1	1	1	0	1	1	0	0	0	0	0
1847	5	5	3	2	2	1	2	0	2	2	0	0	0	0	0	1	0	0	1	1
1848	0	1	3	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0
1849	1	2	0	1	1	0	0	0	1	1	0	0	0	0	0	3	3	0	0	0
1850	2	0	1	3	3	1	2	0	0	0	0	0	0	0	0	0	1	0	1	1
1851	4	6	5	5	5	1	0	0	1	1	0	1	1	0	0	0	1	1	1	1
1852	5	4	3	3	2	1	2	1	2	2	0	0	0	1	1	1	0	0	1	1
Sum	20	20	16	16	14	6	7	2	9	8	2	5	2	3	3	7	6	1	4	4

	S.W.					S.W. by S.					S.S.W.					S. by W.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1845	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1846	2	1	2	3	5	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0
1847	2	3	4	2	3	0	1	1	2	0	0	0	0	0	0	0	0	0	0	0
1848	3	3	2	6	7	0	0	0	0	0	0	0	0	1	0	0	1	2	1	0
1849	5	4	7	6	6	1	0	0	0	0	0	0	0	0	0	0	2	1	2	2
1850	5	7	3	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1851	4	1	4	4	4	0	1	1	0	0	1	2	0	1	1	1	1	3	3	3
1852	3	6	8	3	3	0	0	0	1	1	0	0	0	1	1	0	0	0	0	0
Sum	25	26	31	28	33	1	3	3	3	1	1	2	0	3	2	1	5	6	6	5

	S.					S. by E.					S.S.E.					S.E. by S.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1845	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1846	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
1847	0	0	0	1	1	0	0	2	1	1	1	0	0	0	0	0	0	0	0	0
1848	0	0	2	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	1	1
1849	3	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1850	0	1	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
1851	1	2	2	2	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1852	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Sum	4	3	6	5	6	1	3	3	2	2	2	0	1	0	0	0	0	0	1	1

	S.E.					S.E. by E.					E.S.E.					E. by S.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1845	0	0	0	0	2	1	1	1	3	1	0	0	1	0	0	0	0	0	0	0
1846	1	1	0	0	1	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0
1847	1	0	1	1	2	0	1	2	1	1	0	0	1	0	0	0	1	0	0	0
1848	0	0	2	2	2	0	1	3	0	0	2	0	1	1	2	1	0	0	0	0
1849	0	0	0	1	1	0	0	1	0	0	0	0	1	1	1	0	0	0	1	1
1850	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1
1851	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
1852	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Sum	3	1	5	4	8	1	3	8	6	4	2	0	4	3	4	2	1	0	2	2

	E.					E. by N.					E.N.E.					N.E. by E.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1845	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
1846	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1847	1	1	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0
1848	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0
1849	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1850	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2
1851	1	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1852	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	3	2	3	3	2	1	0	1	1	1	0	0	0	1	1	1	1	2	3	2

	N.E.					N.E. by N.					N.N.E.					N. by E.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1845	1	0	1	0	1	2	3	2	4	2	1	2	3	3	1	1	2	3	2	3
1846	0	1	0	0	1	1	1	5	5	3	1	1	0	1	1	4	4	2	2	1
1847	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	2	2	3
1848	7	5	4	3	4	3	2	1	1	1	0	0	0	1	0	3	1	2	1	1
1849	2	1	1	0	0	1	2	3	2	2	0	1	0	0	0	1	1	1	0	0
1850	5	5	4	6	6	0	0	2	1	1	1	1	0	0	0	3	3	2	1	1
1851	5	4	1	0	0	0	0	1	1	1	0	0	0	0	0	3	1	2	2	3
1852	4	2	3	3	3	1	2	1	1	1	0	2	2	1	1	4	1	2	2	2
Sum	25	19	14	12	15	8	10	15	15	11	3	7	5	6	3	23	17	16	12	14

FEBRUARY.

	N.					N. by W.					N.N.W.					N.W. by N.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1845	1	2	2	0	0	2	1	0	1	1	4	4	1	4	4	0	0	0	0	0
1846	2	2	1	1	1	0	2	0	1	0	2	1	1	0	0	1	1	0	2	1
1847	2	1	0	1	1	0	1	0	0	0	0	0	1	2	2	1	1	0	0	0
1848	6	4	2	1	1	0	1	1	0	0	0	0	1	1	1	0	1	1	0	0
1849	2	2	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
1850	4	2	3	5	4	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
1851	4	5	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1852	5	4	2	1	2	1	1	0	0	0	0	0	1	2	2	0	0	0	0	0
Sum	26	22	13	12	12	3	6	3	4	3	6	5	5	9	9	2	3	1	2	1

	N.W.					N.W. by W.					W.N.W.					W. by N.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1845	5	4	7	5	7	0	1	3	1	2	1	1	1	1	0	0	0	1	2	0
1846	7	4	6	6	7	1	3	3	4	6	1	0	0	0	0	1	0	1	0	0
1847	6	5	5	6	6	0	1	1	1	1	0	0	1	0	0	1	1	2	1	1
1848	3	4	8	10	10	4	3	2	4	4	1	3	1	1	1	2	0	1	1	1
1849	4	4	3	3	4	2	1	1	1	1	1	0	1	2	1	0	1	1	0	0
1850	2	3	1	2	3	2	1	3	2	2	0	1	0	0	0	1	2	3	2	3
1851	3	6	3	3	3	0	0	0	0	0	2	1	0	1	1	0	0	1	1	1
1852	4	5	5	4	5	0	0	0	0	0	0	1	0	1	0	0	2	5	3	4
Sum	34	35	38	39	45	9	10	13	13	16	6	7	4	6	3	5	6	15	10	10

	W.					W. by S.					W.S.W.					S.W. by W.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1845	0	0	1	1	0	2	1	0	0	1	0	1	0	0	0	0	0	0	1	0
1846	1	1	2	0	0	2	1	0	0	0	0	1	0	0	0	0	1	2	1	1
1847	2	3	3	2	2	0	0	0	0	0	0	0	0	1	1	1	0	0	1	0
1848	0	3	2	1	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0
1849	0	1	0	0	0	1	0	0	1	1	0	0	0	0	0	1	0	0	1	1
1850	5	2	4	3	2	0	0	0	0	0	1	2	1	1	1	3	2	0	0	0
1851	1	0	4	2	1	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0
1852	2	1	2	4	3	1	0	0	1	1	0	0	0	0	0	2	0	0	0	0
Sum	11	11	18	13	9	6	2	1	2	4	2	4	1	2	2	9	3	2	4	2

	S.W.					S.W. by S.					S.S.W.					S. by W.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1845	0	0	0	2	1	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0
1846	4	3	2	4	4	0	0	2	0	0	0	0	0	1	1	0	0	0	0	0
1847	2	3	2	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1848	1	1	1	3	3	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
1849	1	4	3	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1850	5	3	1	4	4	0	1	1	1	1	1	0	0	1	1	0	0	3	0	0
1851	3	4	4	7	7	0	0	0	0	0	0	0	1	0	0	0	1	1	1	1
1852	6	8	6	6	5	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Sum	22	26	19	30	28	1	1	3	1	2	1	1	1	3	2	0	1	5	1	1

	S.					S. by E.					S.S.E.					S.E. by S.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1845	2	1	2	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
1846	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1847	0	0	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1848	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1849	0	0	2	1	0	0	0	1	1	1	0	1	0	0	0	0	0	0	0	0
1850	0	3	4	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1851	2	4	4	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1852	1	1	3	3	5	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	5	9	17	11	12	0	1	1	1	1	0	1	0	1	0	0	0	0	0	0

	S.E.					S.E. by E.					E.S.E.					E. by S.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1845	1	0	0	0	0	4	3	3	2	4	0	0	0	0	0	0	1	0	0	0
1846	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1847	0	0	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1848	0	0	0	0	0	0	0	1	2	2	0	0	0	0	0	0	1	0	1	1
1849	0	0	2	0	2	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
1850	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1851	3	2	1	0	1	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0
1852	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	5	2	6	3	5	4	3	4	4	6	0	0	2	1	1	1	2	0	1	1

	E.					E. by N.					E.N.E.					N.E. by E.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1845	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
1846	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
1847	1	2	0	1	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
1848	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
1849	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0
1850	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
1851	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1852	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	1	5	1	2	1	0	0	0	0	1	0	0	3	0	0	1	2	1	3	1

	N.E.					N.E. by N.					N.N.E.					N. by E.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1845	0	1	1	2	2	0	1	2	1	1	1	0	1	0	0	4	5	1	3	3
1846	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	3	4	4	4
1847	2	1	1	1	0	2	1	2	1	1	1	1	1	0	0	7	7	6	6	6
1848	2	4	3	3	3	3	1	2	1	1	1	0	0	0	0	4	2	0	0	0
1849	5	6	6	7	8	3	3	4	4	4	1	2	0	0	0	5	2	2	2	2
1850	2	3	1	1	1	1	1	0	0	0	1	0	0	0	0	0	2	1	1	1
1851	5	4	4	4	5	0	0	0	0	0	1	0	0	0	0	3	0	0	1	1
1852	2	1	2	2	2	1	0	0	0	0	0	0	0	0	0	3	4	2	1	0
Sum	20	21	19	21	22	11	8	11	8	8	7	4	3	1	1	28	25	16	18	17

MARCH.

Year	N. 6h	N. 10h	N. 2h	N. 6h	N. 10h	N by W. 6h	N by W. 10h	N by W. 2h	N by W. 6h	N by W. 10h	N.N.W. 6h	N.N.W. 10h	N.N.W. 2h	N.N.W. 6h	N.N.W. 10h	N.W. by N. 6h	N.W. by N. 10h	N.W. by N. 2h	N.W. by N. 6h	N.W. by N. 10h
1844	8	8	6	6	6	1	2	1	1	2	2	1	0	0	1	1	2	1	0	0
1845	0	2	1	0	0	1	0	1	1	1	1	1	0	1	1	0	0	0	0	0
1846	4	3	1	1	1	1	2	0	2	3	0	0	1	0	0	3	1	2	2	3
1847	1	2	2	2	1	1	1	0	0	0	3	1	0	1	1	0	0	0	0	1
1848	4	1	2	2	2	1	2	0	1	1	1	1	1	1	1	0	1	2	1	1
1849	1	1	1	2	3	3	2	2	1	1	0	0	0	0	0	1	0	1	0	0
1850	4	6	5	0	2	0	1	0	0	0	0	0	1	0	0	0	0	0	1	1
1851	4	4	1	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1852	4	3	1	2	4	1	1	1	1	0	0	2	0	1	0	0	0	0	2	2
Sum	30	30	20	18	22	9	11	5	7	8	7	6	3	4	4	5	4	6	6	8

Year	N.W. 6h	N.W. 10h	N.W. 2h	N.W. 6h	N.W. 10h	N.W. by W. 6h	N.W. by W. 10h	N.W. by W. 2h	N.W. by W. 6h	N.W. by W. 10h	W.N.W. 6h	W.N.W. 10h	W.N.W. 2h	W.N.W. 6h	W.N.W. 10h	W. by N. 6h	W. by N. 10h	W. by N. 2h	W. by N. 6h	W. by N. 10h
1844	2	0	1	0	1	1	0	3	2	2	0	1	0	0	0	0	1	0	1	2
1845	7	6	4	6	6	4	1	4	3	4	1	0	0	1	1	1	0	0	2	2
1846	5	5	6	6	5	2	4	2	2	1	0	0	0	0	0	1	1	2	1	0
1847	4	6	5	6	9	4	2	5	4	3	0	0	1	1	1	2	3	3	2	1
1848	4	6	7	7	8	1	0	1	0	0	1	0	0	0	0	1	1	0	0	0
1849	3	4	5	5	4	1	1	0	1	1	0	1	0	0	0	1	0	0	0	0
1850	7	6	4	7	9	2	0	1	1	1	0	0	0	1	1	4	4	4	3	2
1851	5	6	8	4	4	0	0	1	0	0	0	0	0	1	0	1	0	0	1	2
1852	7	4	4	5	6	0	0	0	0	0	0	0	0	0	0	3	1	0	0	0
Sum	44	43	44	46	52	15	8	17	13	12	2	2	1	4	3	14	11	9	10	9

Year	W. 6h	W. 10h	W. 2h	W. 6h	W. 10h	W. by S. 6h	W. by S. 10h	W. by S. 2h	W. by S. 6h	W. by S. 10h	W.S.W. 6h	W.S.W. 10h	W.S.W. 2h	W.S.W. 6h	W.S.W. 10h	S.W. by W. 6h	S.W. by W. 10h	S.W. by W. 2h	S.W. by W. 6h	S.W. by W. 10h
1844	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	3	3	1	2	0
1845	0	0	0	1	0	2	2	3	0	0	0	2	0	0	0	0	0	0	0	0
1846	1	0	0	1	1	0	0	1	0	1	0	0	0	0	0	1	1	0	2	1
1847	3	3	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
1848	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
1849	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0
1850	3	3	3	2	2	0	0	0	0	0	1	0	1	2	2	0	1	1	1	0
1851	1	2	0	2	3	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1
1852	1	0	2	2	2	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0
Sum	11	8	5	10	10	3	4	4	1	2	1	3	2	2	2	5	8	2	7	2

Year	S.W. 6h	S.W. 10h	S.W. 2h	S.W. 6h	S.W. 10h	S.W. by S. 6h	S.W. by S. 10h	S.W. by S. 2h	S.W. by S. 6h	S.W. by S. 10h	S.S.W. 6h	S.S.W. 10h	S.S.W. 2h	S.S.W. 6h	S.S.W. 10h	S. by W. 6h	S. by W. 10h	S. by W. 2h	S. by W. 6h	S. by W. 10h
1844	2	2	5	6	5	0	0	0	0	0	0	1	0	0	0	1	0	0	1	1
1845	3	4	1	2	2	0	0	1	3	3	0	0	0	0	0	0	0	3	0	0
1846	3	3	3	4	5	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
1847	3	1	4	2	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1848	1	1	2	4	4	0	0	0	1	0	0	0	1	3	3	1	1	2	1	1
1849	0	1	1	1	1	0	0	0	0	0	0	1	1	0	0	1	1	1	3	2
1850	3	1	3	6	4	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1
1851	6	6	8	5	3	0	1	1	0	0	1	1	2	1	0	1	1	1	3	3
1852	1	2	4	4	3	0	0	0	0	0	0	0	0	2	2	0	1	2	2	0
Sum	22	21	31	34	30	1	3	3	5	4	1	3	4	6	5	4	5	10	10	8

Year	S. 6h	S. 10h	S. 2h	S. 6h	S. 10h	S. by E. 6h	S. by E. 10h	S. by E. 2h	S. by E. 6h	S. by E. 10h	S.S.E. 6h	S.S.E. 10h	S.S.E. 2h	S.S.E. 6h	S.S.E. 10h	S.E. by S. 6h	S.E. by S. 10h	S.E. by S. 2h	S.E. by S. 6h	S.E. by S. 10h
1844	1	0	1	1	1	1	2	0	0	0	0	0	3	1	1	0	2	1	0	0
1845	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
1846	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
1847	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
1848	1	4	6	3	3	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
1849	1	1	5	4	5	0	1	0	1	1	0	1	1	1	1	0	0	0	0	0
1850	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
1851	2	1	2	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1852	1	2	5	1	4	0	1	2	2	1	0	0	1	0	1	0	0	0	0	0
Sum	7	10	20	14	19	2	6	4	5	3	0	1	6	2	3	0	2	2	1	0

Year	S.E. 6h	S.E. 10h	S.E. 2h	S.E. 6h	S.E. 10h	S.E. by E. 6h	S.E. by E. 10h	S.E. by E. 2h	S.E. by E. 6h	S.E. by E. 10h	E.S.E. 6h	E.S.E. 10h	E.S.E. 2h	E.S.E. 6h	E.S.E. 10h	E. by S. 6h	E. by S. 10h	E. by S. 2h	E. by S. 6h	E. by S. 10h
1844	1	1	1	3	3	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1
1845	2	5	7	5	4	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1
1846	0	1	1	1	0	2	1	1	2	2	0	0	1	0	0	0	1	1	0	0
1847	0	0	1	3	2	0	1	3	1	1	0	0	0	0	0	0	0	0	0	0
1848	0	2	3	2	3	0	1	0	0	0	1	1	0	0	0	1	0	0	0	0
1849	1	2	2	2	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
1850	0	0	0	1	2	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0
1851	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1852	0	2	1	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	4	13	16	20	18	5	8	6	4	5	1	1	1	0	0	2	1	1	2	2

Year	E. 6h	E. 10h	E. 2h	E. 6h	E. 10h	E. by N. 6h	E. by N. 10h	E. by N. 2h	E. by N. 6h	E. by N. 10h	E.N.E. 6h	E.N.E. 10h	E.N.E. 2h	E.N.E. 6h	E.N.E. 10h	N.E. by E. 6h	N.E. by E. 10h	N.E. by E. 2h	N.E. by E. 6h	N.E. by E. 10h
1844	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
1845	0	0	0	0	0	2	0	1	1	1	0	1	0	0	0	0	0	0	0	0
1846	0	0	1	1	2	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
1847	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
1848	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
1849	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	2	1	1
1850	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
1851	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1852	2	1	1	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0
Sum	6	2	2	2	3	4	1	3	3	3	0	1	1	0	0	2	1	3	2	2

Year	N.E. 6h	N.E. 10h	N.E. 2h	N.E. 6h	N.E. 10h	N.E. by N. 6h	N.E. by N. 10h	N.E. by N. 2h	N.E. by N. 6h	N.E. by N. 10h	N.N.E. 6h	N.N.E. 10h	N.N.E. 2h	N.N.E. 6h	N.N.E. 10h	N. by E. 6h	N. by E. 10h	N. by E. 2h	N. by E. 6h	N. by E. 10h
1844	2	4	5	5	3	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0
1845	1	1	0	0	1	2	2	1	1	1	0	2	1	0	0	3	1	1	2	2
1846	1	1	1	1	1	2	1	0	1	0	0	0	1	0	0	2	3	2	1	2
1847	3	3	3	2	3	0	0	0	0	0	0	1	0	0	0	5	5	2	2	2
1848	5	2	3	3	3	2	4	1	0	0	2	0	0	0	0	0	1	0	0	0
1849	7	4	3	4	4	4	3	2	1	2	0	0	0	0	0	5	3	2	3	2
1850	3	5	3	1	3	0	0	0	0	0	1	1	1	0	1	1	0	2	4	0
1851	5	4	2	2	2	1	1	1	1	1	0	0	1	1	1	4	2	1	2	3
1852	3	2	2	2	2	0	0	0	0	0	1	2	0	0	0	4	2	2	0	0
Sum	30	26	22	20	22	11	11	5	4	4	5	6	4	1	2	24	17	13	15	11

APRIL.

Direction	Hour	1844	1845	1846	1847	1848	1849	1851	Sum
N.	6h	2	3	1	2	3	1	0	12
	10h	2	3	3	0	1	0	1	10
	2h	2	0	1	1	0	1	1	6
	6h	0	1	1	0	2	1	1	6
	10h	1	0	1	1	2	0	1	6
N. by W.	6h	3	1	1	0	3	0	0	8
	10h	3	1	1	0	0	1	0	6
	2h	2	0	1	0	0	1	0	4
	6h	5	1	0	2	0	2	0	10
	10h	2	3	0	0	0	2	0	7
N.N.W.	6h	1	3	2	1	0	0	0	7
	10h	0	2	1	0	1	1	0	5
	2h	0	1	0	0	0	1	0	2
	6h	0	2	0	0	0	1	0	3
	10h	0	1	0	0	0	1	0	2
N.W. by N.	6h	0	0	2	1	1	1	0	5
	10h	0	0	1	0	2	1	0	4
	2h	1	0	0	0	1	1	0	3
	6h	0	0	1	0	1	0	0	2
	10h	1	0	1	0	1	0	0	3
N.W.	6h	2	4	4	7	7	6	3	33
	10h	1	6	2	7	7	6	5	34
	2h	1	4	4	7	8	5	1	30
	6h	1	4	5	8	7	8	2	35
	10h	0	6	5	9	10	9	2	41
N.W. by W.	6h	1	3	0	1	2	2	1	10
	10h	1	2	1	3	0	0	0	7
	2h	0	6	0	1	1	0	1	9
	6h	1	4	0	1	1	0	1	8
	10h	1	3	0	1	0	0	1	6
W.N.W.	6h	1	0	0	0	0	0	0	1
	10h	0	0	0	0	0	1	0	1
	2h	0	0	0	0	0	0	2	2
	6h	0	0	0	0	0	0	1	1
	10h	1	0	0	0	0	0	0	1
W. by N.	6h	0	0	0	1	0	0	1	2
	10h	0	0	0	0	0	0	2	2
	2h	1	0	0	0	0	1	1	3
	6h	0	0	0	0	1	0	1	2
	10h	0	0	0	0	1	0	0	1

Direction	Hour	1844	1845	1846	1847	1848	1849	1851	Sum
W.	6h	0	0	0	1	0	1	1	3
	10h	1	0	1	0	0	1	0	3
	2h	0	0	1	0	0	0	2	3
	6h	0	0	1	0	0	1	0	2
	10h	0	0	1	2	0	1	2	6
W. by S.	6h	0	0	2	0	0	2	0	4
	10h	0	0	0	0	0	2	0	2
	2h	0	0	1	0	0	2	0	3
	6h	0	0	0	1	0	1	0	2
	10h	0	0	0	0	0	1	0	1
W.S.W.	6h	0	0	1	0	0	1	0	2
	10h	0	0	0	0	0	0	0	0
	2h	0	0	0	0	0	0	0	0
	6h	0	0	0	0	0	0	0	0
	10h	0	0	0	0	0	0	0	0
S.W. by W.	6h	0	1	0	1	1	1	0	4
	10h	1	0	0	3	0	0	0	4
	2h	2	0	0	1	0	0	0	3
	6h	1	0	1	0	0	0	0	2
	10h	0	0	2	1	0	0	0	3
S.S.W.	6h	2	3	3	3	1	0	2	14
	10h	2	2	3	3	1	1	2	14
	2h	2	2	3	8	3	1	2	21
	6h	2	2	7	4	4	1	6	26
	10h	3	2	7	2	4	2	4	24
S.W. by S.	6h	1	0	2	0	0	0	0	3
	10h	1	3	1	1	0	0	1	7
	2h	1	4	6	0	0	0	1	12
	6h	1	4	2	4	0	1	1	13
	10h	1	3	2	5	0	0	1	12
S.S.W.	6h	0	0	0	0	0	0	0	0
	10h	1	0	1	1	0	0	0	3
	2h	0	1	0	0	0	0	1	2
	6h	0	0	0	0	0	0	0	0
	10h	0	0	0	0	0	0	0	0
S. by W.	6h	0	0	1	0	0	0	0	1
	10h	0	0	1	2	4	3	1	11
	2h	1	0	0	0	3	2	4	10
	6h	1	0	1	0	2	1	3	8
	10h	1	0	0	0	1	1	2	5

Direction	Hour	1844	1845	1846	1847	1848	1849	1851	Sum
S.	6h	0	0	1	0	1	1	0	3
	10h	1	1	0	2	1	2	1	8
	2h	0	0	2	1	3	5	3	14
	6h	2	0	0	0	2	3	2	9
	10h	2	1	1	0	1	3	2	10
S. by E.	6h	0	0	2	0	0	0	0	2
	10h	1	1	1	0	4	0	0	7
	2h	3	1	3	2	1	1	0	11
	6h	2	0	6	0	2	0	0	10
	10h	1	0	6	0	2	0	0	9
S.S.E.	6h	1	0	0	0	1	0	0	2
	10h	1	0	0	0	1	0	0	2
	2h	3	0	1	0	2	1	1	8
	6h	1	0	1	1	1	0	0	4
	10h	0	0	0	1	0	0	0	1
S.E. by S.	6h	0	0	0	0	0	0	0	0
	10h	0	0	0	0	1	1	0	2
	2h	0	0	1	0	1	0	0	2
	6h	0	1	0	0	1	0	0	2
	10h	0	1	0	0	1	0	0	2
S.E.	6h	2	3	0	3	4	1	2	15
	10h	4	1	3	1	2	3	3	17
	2h	3	3	3	2	5	4	2	22
	6h	4	4	0	1	4	6	4	23
	10h	6	3	1	1	5	5	4	25
S.E. by E.	6h	1	1	2	1	0	2	1	8
	10h	3	2	2	3	0	1	0	11
	2h	1	2	2	0	0	1	0	6
	6h	1	1	1	2	0	2	0	7
	10h	1	2	1	1	0	2	0	7
E.S.E.	6h	0	0	1	0	0	1	0	2
	10h	0	0	2	0	0	1	0	3
	2h	0	0	0	0	0	0	0	0
	6h	1	0	2	0	0	1	0	4
	10h	2	0	1	0	0	1	0	4
E. by S.	6h	1	0	0	0	0	0	0	1
	10h	1	2	1	0	0	0	0	4
	2h	2	2	0	1	0	0	2	7
	6h	3	1	0	0	0	0	1	5
	10h	1	1	0	0	0	0	1	3

Direction	Hour	1844	1845	1846	1847	1848	1849	1851	Sum
E.	6h	0	0	1	0	0	0	0	1
	10h	1	0	0	1	0	1	4	7
	2h	1	0	0	0	0	2	0	3
	6h	0	0	1	0	0	1	1	3
	10h	1	0	1	0	0	1	1	4
E. by N.	6h	0	1	1	1	0	0	0	3
	10h	0	1	2	0	0	1	0	4
	2h	0	0	0	0	0	0	0	0
	6h	0	1	0	0	0	0	0	1
	10h	0	1	0	0	0	0	0	1
E.N.E.	6h	2	0	1	1	0	1	0	5
	10h	0	1	0	0	1	1	0	3
	2h	0	0	0	0	0	0	0	0
	6h	0	0	0	0	0	0	0	0
	10h	0	0	0	0	0	0	0	0
N.E. by E.	6h	1	0	0	0	0	0	0	1
	10h	0	0	0	0	0	0	0	0
	2h	0	0	0	1	0	0	0	1
	6h	1	0	0	0	0	0	0	1
	10h	0	0	0	0	0	0	0	0
N.E.	6h	5	1	0	2	3	5	6	22
	10h	2	0	0	1	3	0	7	13
	2h	2	1	0	3	1	0	3	10
	6h	1	3	0	4	1	0	5	14
	10h	2	2	0	3	1	0	5	13
N.E. by N.	6h	0	1	0	4	3	0	0	8
	10h	0	2	1	0	0	1	0	4
	2h	0	2	0	1	0	0	0	3
	6h	0	0	0	1	0	0	0	1
	10h	0	0	0	1	0	0	0	1
N.N.E.	6h	0	0	1	0	0	1	1	3
	10h	0	0	1	0	0	1	1	3
	2h	0	0	1	0	0	0	2	3
	6h	0	0	0	1	0	0	1	2
	10h	2	0	0	1	0	0	2	5
N. by E.	6h	3	5	1	0	0	3	12	24
	10h	1	0	1	1	1	0	2	6
	2h	0	1	0	0	1	1	1	4
	6h	1	1	0	0	1	0	0	3
	10h	0	1	0	1	1	1	2	6

MAY.

Year	N. 6h	N. 10h	N. 2h	N. 6h	N. 10h	N. by W. 6h	N. by W. 10h	N. by W. 2h	N. by W. 6h	N. by W. 10h	N.N.W. 6h	N.N.W. 10h	N.N.W. 2h	N.N.W. 6h	N.N.W. 10h	N.W. by N. 6h	N.W. by N. 10h	N.W. by N. 2h	N.W. by N. 6h	N.W. by N. 10h
1844	2	0	4	2	3	1	3	0	0	0	0	1	0	0	0	1	1	0	1	0
1845	2	2	1	1	2	4	1	0	3	6	1	1	2	0	0	3	0	0	2	0
1846	1	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1
1847	3	2	1	0	1	2	1	1	1	2	0	0	0	0	0	0	0	0	0	0
1848	0	0	0	1	1	1	2	0	0	0	0	0	0	0	0	1	0	0	0	0
1849	3	3	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0
Sum	11	7	6	4	8	9	8	2	4	8	2	3	2	0	0	5	1	1	4	1

Year	N.W. 6h	N.W. 10h	N.W. 2h	N.W. 6h	N.W. 10h	N.W. by W. 6h	N.W. by W. 10h	N.W. by W. 2h	N.W. by W. 6h	N.W. by W. 10h	W.N.W. 6h	W.N.W. 10h	W.N.W. 2h	W.N.W. 6h	W.N.W. 10h	W. by N. 6h	W. by N. 10h	W. by N. 2h	W. by N. 6h	W. by N. 10h
1844	6	2	3	5	6	1	1	0	0	0	0	0	0	0	0	0	1	1	0	0
1845	1	2	2	3	4	4	1	4	2	2	0	0	0	0	0	1	2	0	0	0
1846	3	2	2	3	3	1	0	1	0	1	0	0	0	0	0	1	1	1	0	0
1847	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1
1848	6	6	4	3	5	1	1	2	1	0	0	0	0	0	0	0	0	0	0	0
1849	3	2	3	3	6	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Sum	19	14	15	17	24	8	4	7	3	3	0	0	1	1	0	2	4	2	1	1

Year	W. 6h	W. 10h	W. 2h	W. 6h	W. 10h	W. by S. 6h	W. by S. 10h	W. by S. 2h	W. by S. 6h	W. by S. 10h	W.S.W. 6h	W.S.W. 10h	W.S.W. 2h	W.S.W. 6h	W.S.W. 10h	S.W. by W. 6h	S.W. by W. 10h	S.W. by W. 2h	S.W. by W. 6h	S.W. by W. 10h
1844	0	1	0	0	0	1	0	2	0	1	0	0	0	0	0	0	1	0	1	0
1845	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0
1846	2	2	0	1	2	0	0	6	1	0	0	0	0	0	0	0	0	0	0	0
1847	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
1848	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
1849	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	1
Sum	3	3	2	1	3	1	0	3	2	1	0	1	0	0	0	2	2	0	3	2

Year	S.W. 6h	S.W. 10h	S.W. 2h	S.W. 6h	S.W. 10h	S.W. by S. 6h	S.W. by S. 10h	S.W. by S. 2h	S.W. by S. 6h	S.W. by S. 10h	S.S.W. 6h	S.S.W. 10h	S.S.W. 2h	S.S.W. 6h	S.S.W. 10h	S. by W. 6h	S. by W. 10h	S. by W. 2h	S. by W. 6h	S. by W. 10h
1844	5	5	10	10	10	0	0	1	1	1	2	0	1	0	0	0	1	0	0	0
1845	4	6	6	7	7	1	0	2	3	2	0	0	1	0	0	2	0	0	0	0
1846	0	0	3	2	1	2	2	1	1	2	1	0	0	1	0	0	0	0	0	1
1847	1	0	1	2	4	0	0	0	1	0	1	0	0	0	0	1	1	0	1	0
1848	5	1	3	6	6	1	1	1	0	0	0	0	3	1	1	0	3	2	3	1
1849	2	2	3	4	1	0	0	0	0	0	0	0	0	0	0	0	1	0	2	2
Sum	17	14	26	31	29	4	3	5	6	5	4	0	5	2	1	3	6	2	6	4

Year	S. 6h	S. 10h	S. 2h	S. 6h	S. 10h	S. by E. 6h	S. by E. 10h	S. by E. 2h	S. by E. 6h	S. by E. 10h	S.S.E. 6h	S.S.E. 10h	S.S.E. 2h	S.S.E. 6h	S.S.E. 10h	S.E. by S. 6h	S.E. by S. 10h	S.E. by S. 2h	S.E. by S. 6h	S.E. by S. 10h
1844	1	0	0	0	1	0	1	1	1	1	0	0	0	1	0	1	3	1	1	0
1845	1	1	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1846	3	1	2	2	2	0	2	1	1	1	0	0	1	1	0	0	0	1	1	0
1847	0	2	7	2	3	1	2	2	1	1	1	0	0	0	0	0	1	0	1	0
1848	2	6	5	2	2	0	3	2	3	3	0	1	0	1	1	2	0	0	0	0
1849	2	5	6	5	5	0	1	2	0	1	0	1	1	1	1	0	0	0	0	0
Sum	9	15	21	11	13	1	10	9	6	7	1	2	2	4	2	3	4	2	3	0

Year	S.E. 6h	S.E. 10h	S.E. 2h	S.E. 6h	S.E. 10h	S.E. by E. 6h	S.E. by E. 10h	S.E. by E. 2h	S.E. by E. 6h	S.E. by E. 10h	E.S.E. 6h	E.S.E. 10h	E.S.E. 2h	E.S.E. 6h	E.S.E. 10h	E. by S. 6h	E. by S. 10h	E. by S. 2h	E. by S. 6h	E. by S. 10h
1844	7	7	5	7	6	1	1	0	1	1	0	0	0	0	0	1	0	1	0	1
1845	0	6	4	5	5	1	1	2	1	0	1	0	0	0	0	0	1	1	0	1
1846	1	3	6	1	1	0	6	3	5	4	0	1	0	1	1	2	2	2	1	2
1847	1	1	5	5	5	0	0	0	2	1	0	2	0	0	0	0	2	0	0	0
1848	1	1	3	4	5	0	0	2	1	0	2	1	0	0	0	0	1	0	0	0
1849	1	4	6	3	4	0	0	0	2	0	0	0	0	0	0	0	0	2	0	0
Sum	11	22	29	25	26	2	8	7	12	6	3	4	0	1	1	3	6	6	1	4

Year	E. 6h	E. 10h	E. 2h	E. 6h	E. 10h	E. by N. 6h	E. by N. 10h	E. by N. 2h	E. by N. 6h	E. by N. 10h	E.N.E. 6h	E.N.E. 10h	E.N.E. 2h	E.N.E. 6h	E.N.E. 10h	N.E. by E. 6h	N.E. by E. 10h	N.E. by E. 2h	N.E. by E. 6h	N.E. by E. 10h
1844	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1845	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
1846	6	3	5	6	6	2	1	0	0	0	1	0	0	0	0	0	0	0	0	0
1847	0	1	1	1	0	2	1	1	2	1	0	0	0	0	0	1	1	0	0	0
1848	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
1849	2	0	1	2	1	1	0	0	0	0	1	0	0	2	1	0	1	0	0	0
Sum	9	5	9	10	8	6	2	1	3	1	2	0	0	2	1	1	3	0	0	0

Year	N.E. 6h	N.E. 10h	N.E. 2h	N.E. 6h	N.E. 10h	N.E. by N. 6h	N.E. by N. 10h	N.E. by N. 2h	N.E. by N. 6h	N.E. by N. 10h	N.N.E. 6h	N.N.E. 10h	N.N.E. 2h	N.N.E. 6h	N.N.E. 10h	N. by E. 6h	N. by E. 10h	N. by E. 2h	N. by E. 6h	N. by E. 10h
1844	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
1845	1	1	0	1	1	2	2	2	1	0	0	1	0	0	0	1	1	1	1	1
1846	0	2	1	1	1	0	1	1	1	1	2	0	0	0	0	2	1	0	0	0
1847	11	6	5	8	3	0	0	0	0	0	0	2	1	0	2	4	4	3	2	2
1848	5	1	0	3	3	1	0	1	0	0	1	0	0	0	0	1	1	1	0	0
1849	4	4	4	5	6	6	4	0	0	0	0	0	0	0	0	4	1	0	0	0
Sum	21	15	10	18	14	9	7	4	2	1	3	3	1	0	2	12	9	5	3	3

JUNE.

Year	N. 6h	N. 10h	N. 2h	N. 6h	N. 10h	N. by W. 6h	N. by W. 10h	N. by W. 2h	N. by W. 6h	N. by W. 10h	N.N.W. 6h	N.N.W. 10h	N.N.W. 2h	N.N.W. 6h	N.N.W. 10h	N.W. by N. 6h	N.W. by N. 10h	N.W. by N. 2h	N.W. by N. 6h	N.W. by N. 10h
1844	2	1	1	1	2	7	2	0	1	0	0	1	0	0	0	0	0	0	1	1
1845	2	0	1	0	2	5	1	0	0	1	2	0	1	3	2	1	1	0	0	0
1846	3	1	1	1	1	0	1	0	1	1	1	1	0	0	0	1	1	0	0	0
1847	1	1	2	1	2	7	1	0	1	1	2	3	1	1	1	0	0	0	1	0
1848	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	8	4	5	3	8	20	5	0	3	3	5	5	2	4	3	2	2	0	2	1

Year	N.W. 6h	N.W. 10h	N.W. 2h	N.W. 6h	N.W. 10h	N.W. by W. 6h	N.W. by W. 10h	N.W. by W. 2h	N.W. by W. 6h	N.W. by W. 10h	W.N.W. 6h	W.N.W. 10h	W.N.W. 2h	W.N.W. 6h	W.N.W. 10h	W. by N. 6h	W. by N. 10h	W. by N. 2h	W. by N. 6h	W. by N. 10h
1844	0	3	4	1	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
1845	1	3	5	3	3	0	4	1	0	1	1	1	1	1	1	1	0	0	0	0
1846	5	2	3	3	4	1	2	0	0	0	0	0	0	0	0	1	1	1	0	0
1847	3	6	0	2	4	0	0	0	1	1	0	0	0	1	0	0	2	0	0	0
1848	8	6	5	7	7	0	0	0	0	0	1	0	2	1	1	0	1	1	0	0
Sum	17	20	17	16	19	1	6	1	1	2	2	1	3	3	2	3	5	2	0	0

Year	W. 6h	W. 10h	W. 2h	W. 6h	W. 10h	W. by S. 6h	W. by S. 10h	W. by S. 2h	W. by S. 6h	W. by S. 10h	W.S.W. 6h	W.S.W. 10h	W.S.W. 2h	W.S.W. 6h	W.S.W. 10h	S.W. by W. 6h	S.W. by W. 10h	S.W. by W. 2h	S.W. by W. 6h	S.W. by W. 10h
1844	2	0	0	0	0	1	1	1	0	0	1	1	0	0	0	1	0	0	0	1
1845	2	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	2	1	2	1
1846	1	0	1	1	4	0	1	1	1	0	0	0	0	1	0	0	1	1	1	0
1847	2	1	2	2	3	1	0	2	3	0	0	0	0	0	0	0	0	0	0	0
1848	0	1	1	2	2	0	2	1	1	0	1	1	1	0	0	0	0	0	2	2
Sum	7	3	5	6	10	2	4	5	6	1	3	2	1	1	0	1	3	2	5	4

Year	S.W. 6h	S.W. 10h	S.W. 2h	S.W. 6h	S.W. 10h	S.W. by S. 6h	S.W. by S. 10h	S.W. by S. 2h	S.W. by S. 6h	S.W. by S. 10h	S.S.W. 6h	S.S.W. 10h	S.S.W. 2h	S.S.W. 6h	S.S.W. 10h	S. by W. 6h	S. by W. 10h	S. by W. 2h	S. by W. 6h	S. by W. 10h
1844	3	2	7	11	9	1	4	2	0	1	0	0	0	0	0	1	1	0	1	1
1845	6	3	7	6	7	4	3	2	4	4	1	0	0	0	1	0	0	1	2	2
1846	0	0	2	2	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1
1847	1	1	1	1	2	0	1	0	0	0	0	0	1	2	0	2	2	4	3	4
1848	5	2	3	3	4	2	1	0	0	0	1	0	0	0	0	1	1	1	3	2
Sum	15	8	20	23	23	8	10	5	5	6	2	0	1	2	1	4	5	7	10	10

Year	S. 6h	S. 10h	S. 2h	S. 6h	S. 10h	S. by E. 6h	S. by E. 10h	S. by E. 2h	S. by E. 6h	S. by E. 10h	S.S.E. 6h	S.S.E. 10h	S.S.E. 2h	S.S.E. 6h	S.S.E. 10h	S.E. by S. 6h	S.E. by S. 10h	S.E. by S. 2h	S.E. by S. 6h	S.E. by S. 10h
1844	0	0	3	2	4	2	1	2	2	1	0	0	1	1	0	0	0	0	0	1
1845	0	0	1	0	0	0	2	1	1	0	0	0	1	1	0	0	1	0	0	0
1846	3	1	2	2	2	1	2	2	1	0	3	1	5	2	3	0	0	1	0	0
1847	0	4	4	6	3	1	2	6	0	0	2	1	2	0	0	0	0	0	0	0
1848	1	5	8	3	5	0	2	4	1	1	0	1	1	3	0	0	0	0	0	0
Sum	4	10	18	13	14	4	9	15	5	2	5	3	10	7	3	0	1	1	0	1

Year	S.E. 6h	S.E. 10h	S.E. 2h	S.E. 6h	S.E. 10h	S.E. by E. 6h	S.E. by E. 10h	S.E. by E. 2h	S.E. by E. 6h	S.E. by E. 10h	E.S.E. 6h	E.S.E. 10h	E.S.E. 2h	E.S.E. 6h	E.S.E. 10h	E. by S. 6h	E. by S. 10h	E. by S. 2h	E. by S. 6h	E. by S. 10h
1844	5	6	7	8	8	0	2	1	0	0	1	0	0	0	0	0	0	0	0	0
1845	0	0	2	2	1	0	3	2	0	0	0	0	1	1	1	0	0	0	0	0
1846	0	1	1	1	0	2	2	3	6	7	0	0	0	0	0	0	1	1	0	0
1847	1	1	2	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1848	2	1	0	1	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Sum	8	9	12	14	14	2	7	6	7	7	1	0	1	1	1	0	1	1	0	1

Year	E. 6h	E. 10h	E. 2h	E. 6h	E. 10h	E. by N. 6h	E. by N. 10h	E. by N. 2h	E. by N. 6h	E. by N. 10h	E.N.E. 6h	E.N.E. 10h	E.N.E. 2h	E.N.E. 6h	E.N.E. 10h	N.E. by E. 6h	N.E. by E. 10h	N.E. by E. 2h	N.E. by E. 6h	N.E. by E. 10h
1844	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1845	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
1846	3	1	2	3	3	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
1847	0	0	0	0	1	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0
1848	0	0	0	0	0	0	1	0	0	0	1	1	1	1	1	0	0	0	0	0
Sum	3	1	2	3	4	1	2	0	0	0	2	3	2	1	1	0	1	0	0	0

Year	N.E. 6h	N.E. 10h	N.E. 2h	N.E. 6h	N.E. 10h	N.E. by N. 6h	N.E. by N. 10h	N.E. by N. 2h	N.E. by N. 6h	N.E. by N. 10h	N.N.E. 6h	N.N.E. 10h	N.N.E. 2h	N.N.E. 6h	N.N.E. 10h	N. by E. 6h	N. by E. 10h	N. by E. 2h	N. by E. 6h	N. by E. 10h
1844	1	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	2	1	0	0
1845	0	1	1	0	1	2	0	0	1	0	1	0	0	1	0	0	2	0	0	0
1846	0	0	0	0	1	2	1	0	1	0	2	0	0	0	0	0	5	1	1	0
1847	4	2	1	1	0	0	0	0	0	0	0	1	0	0	0	1	1	0	1	0
1848	5	3	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Sum	10	6	3	1	3	6	3	0	2	0	3	1	0	1	0	1	10	2	3	0

JULY.

	N.					N. by W.					N.N.W.					N.W. by N.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	4	3	1	1	3	4	2	1	2	1	0	0	0	2	1	0	0	0	1	1
1845	4	2	0	1	1	2	0	0	0	0	2	1	0	2	2	1	3	1	1	2
1846	1	0	1	0	0	0	0	0	0	0	1	0	1	0	0	1	0	1	1	1
1848	4	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0
1849	3	3	4	1	0	2	1	0	0	0	0	0	0	0	0	1	1	0	0	0
Sum	16	8	6	4	4	9	3	1	2	1	3	1	1	4	3	4	5	2	3	4

	N.W.					N.W. by W.					W.N.W.					W. by N.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	2	2	4	1	1	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0
1845	5	4	3	5	3	2	3	9	2	4	0	0	0	0	0	0	2	0	0	0
1846	2	6	2	2	5	1	3	1	2	2	1	1	0	0	0	1	2	0	0	0
1848	3	2	2	1	3	1	3	0	1	0	0	0	0	1	0	0	0	1	0	0
1849	3	1	3	1	2	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0
Sum	15	15	14	10	14	4	9	10	5	6	2	1	1	1	0	2	6	2	0	0

	W.					W. by S.					W.S.W.					S.W. by W.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	2	0	0	1	1	0	1	2	2	1	0	0	0	0	0	0	0	0	0	0
1845	1	0	1	0	0	5	0	1	0	0	0	0	0	3	2	1	1	1	3	2
1846	1	2	1	2	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
1848	0	1	0	1	1	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0
1849	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1
Sum	5	4	2	5	3	6	1	3	2	2	0	0	1	3	2	2	1	2	5	3

	S.W.					S.W. by S.					S.S.W.					S. by W.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	8	4	7	4	7	1	0	1	1	0	0	1	1	2	1	0	0	2	5	3
1845	2	4	4	3	4	2	0	3	1	2	1	0	0	2	3	0	0	2	1	2
1846	2	1	6	6	4	0	0	1	0	1	0	0	0	0	0	1	0	2	2	1
1848	3	1	5	7	8	0	0	0	0	0	1	0	0	0	0	2	4	6	5	6
1849	2	0	1	2	2	4	3	1	2	0	0	0	0	0	0	0	1	3	3	3
Sum	17	10	23	22	25	7	3	6	4	3	2	1	1	4	4	3	5	15	16	15

	S.					S. by E.					S.S.E.					S.E. by S.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	0	1	3	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
1845	0	0	0	2	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
1846	0	0	1	0	0	3	1	0	0	2	1	1	1	2	2	0	0	1	1	1
1848	1	3	5	4	2	0	2	2	2	2	0	1	1	0	0	0	0	0	2	1
1849	2	7	7	7	3	0	1	2	1	0	0	0	0	0	0	1	2	2	0	0
Sum	3	11	16	13	7	3	4	6	4	5	1	2	2	2	2	1	2	3	3	2

	S.E.					S.E. by E.					E.S.E.					E. by S.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	3	8	5	5	6	2	0	0	0	0	0	0	0	0	0	0	0	1	1	0
1845	0	3	2	3	1	2	4	3	0	0	0	0	0	1	1	0	0	0	0	0
1846	1	0	2	0	1	1	2	2	4	2	0	0	0	1	1	0	0	0	1	0
1848	1	3	2	1	0	1	0	4	2	2	0	1	0	1	2	1	1	0	0	0
1849	1	0	4	4	3	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0
Sum	6	4	15	13	11	6	6	9	7	5	0	1	0	3	4	1	1	1	3	0

	E.					E. by N.					E.N.E.					N.E. by E.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	0	2	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1845	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
1846	4	4	2	3	2	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
1848	0	2	1	0	0	1	1	0	1	0	0	0	0	0	0	0	1	0	0	1
1849	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Sum	4	9	5	3	2	1	2	0	1	0	2	1	0	0	0	0	1	0	1	2

	N.E.					N.E. by N.					N.N.E.					N. by E.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	1	4	0	2	2	0	1	0	0	0	0	0	0	0	0	2	1	0	1	2
1845	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
1846	2	2	1	1	1	0	1	0	0	0	0	0	0	1	0	5	4	4	2	4
1848	6	2	1	1	2	2	0	0	0	0	0	0	0	0	0	1	2	0	0	0
1849	2	4	0	0	1	3	1	1	2	1	0	0	0	0	0	2	2	0	1	0
Sum	11	14	2	4	6	5	3	1	2	1	0	1	0	1	0	10	10	4	4	6

AUGUST.

	N.					N. by W.					N.N.W.					N.W. by N.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	0	1	1	0	0	4	2	1	2	2	0	0	0	0	0	0	0	1	0	0
1845	2	2	0	1	0	1	2	1	0	0	0	1	1	1	1	0	0	0	1	1
1846	2	1	2	1	1	3	1	1	2	0	1	1	0	1	0	1	1	0	0	0
1847	1	2	0	3	2	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0
1848	5	4	1	0	0	2	1	1	0	0	0	0	0	0	0	0	0	1	1	1
1849	5	2	1	1	0	0	0	0	0	0	2	1	1	1	1	1	0	0	0	0
Sum	15	12	5	6	3	11	6	5	5	2	3	3	2	3	2	2	1	2	2	2

	N.W.					N.W. by W.					W.N.W.					W. by N.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	4	4	4	5	7	0	0	0	0	0	0	0	1	0	0	0	1	3	1	0
1845	3	3	2	2	2	0	1	2	0	0	0	0	0	0	0	3	1	0	0	0
1846	3	3	1	1	2	1	1	0	2	2	0	0	1	0	0	0	1	1	0	0
1847	0	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1848	5	4	3	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1849	4	2	2	3	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	19	18	14	15	19	2	2	2	2	2	0	0	2	0	0	3	3	4	1	0

	W.					W. by S.					W.S.W.					S.W. by W.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1845	2	0	0	1	1	1	0	0	0	0	0	0	0	1	1	2	0	0	0	0
1846	1	2	3	1	2	1	0	0	1	1	2	0	0	1	0	0	0	0	0	0
1847	0	0	0	1	0	1	0	0	1	0	0	0	1	1	1	2	1	0	0	0
1848	0	1	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
1849	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1
Sum	4	4	4	4	4	4	1	0	2	1	3	0	1	3	2	5	2	0	0	1

	S.W.					S.W. by S.					S.S.W.					S. by W.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	6	3	6	7	7	1	0	0	1	0	0	1	0	0	0	2	0	2	2	3
1845	1	0	3	6	6	0	1	2	1	1	1	0	0	2	2	1	0	0	0	1
1846	0	0	2	3	2	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0
1847	4	1	2	3	2	0	2	3	1	2	1	2	2	1	1	0	2	2	4	1
1848	3	2	1	4	3	0	0	2	0	0	0	0	0	0	0	1	1	1	2	2
1849	0	0	1	5	6	1	1	1	1	1	0	0	0	1	1	1	1	3	3	2
Sum	14	6	15	28	26	2	4	9	4	4	2	3	2	4	5	5	4	9	11	9

	S.					S. by E.					S.S.E.					S.E. by S.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	1	1	2	3	2	2	1	0	0	0	0	0	0	0	0	0	1	0	0	0
1845	2	0	0	1	1	0	1	1	0	0	0	0	1	2	1	0	2	0	0	0
1846	2	0	0	3	4	1	2	2	2	2	4	2	1	4	3	0	1	0	1	0
1847	3	6	5	3	2	0	0	2	0	0	0	0	1	1	0	0	0	0	0	0
1848	0	6	11	7	8	0	0	4	2	1	0	2	1	0	0	1	1	0	0	0
1849	1	8	12	4	4	0	0	1	1	1	0	0	0	0	0	2	1	3	1	1
Sum	9	21	30	21	21	3	4	10	5	4	4	4	4	7	4	3	6	3	2	1

	S.E.					S.E. by E.					E.S.E.					E. by S.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	3	8	6	6	6	0	0	0	1	0	0	0	0	0	0	0	1	1	0	1
1845	0	3	7	3	3	1	5	7	1	2	0	1	0	1	0	1	0	0	2	4
1846	0	0	6	1	2	1	2	3	0	1	0	0	0	1	1	1	0	0	0	1
1847	0	0	0	2	2	0	0	0	1	0	0	0	0	1	1	0	1	1	0	0
1848	1	2	4	3	4	0	0	0	2	1	0	0	0	2	2	0	0	0	0	0
1849	2	5	4	8	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	6	18	27	23	24	2	7	10	8	4	0	1	0	5	4	2	2	2	2	6

	E.					E. by N.					E.N.E.					N.E. by E.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	1	1	2	2	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1845	2	1	1	0	1	4	1	0	0	0	1	0	0	0	0	0	0	0	0	0
1846	0	1	1	2	1	2	1	1	0	0	0	0	0	0	0	1	2	0	0	0
1847	2	0	1	1	0	2	2	0	0	0	0	0	0	0	0	0	1	0	0	0
1848	0	0	0	1	1	0	0	0	0	0	0	1	0	1	1	0	1	0	0	0
1849	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	5	4	5	6	5	11	4	1	0	0	1	1	0	1	1	1	4	0	0	0

	N.E.					N.E. by N.					N.N.E.					N. by E.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	3	2	0	1	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
1845	2	0	1	1	1	0	2	1	0	1	0	1	0	1	0	1	3	1	0	1
1846	1	3	0	1	1	0	0	0	0	0	1	1	0	1	2	2	5	1	2	2
1847	6	5	2	2	1	3	3	0	2	1	1	0	0	0	0	1	1	1	0	0
1848	5	3	0	1	2	3	1	1	1	0	0	0	0	0	0	3	1	0	0	0
1849	2	4	1	0	1	2	1	0	0	0	2	1	1	1	1	4	2	0	1	1
Sum	19	17	4	6	7	8	7	2	3	2	4	3	1	3	3	11	14	6	3	4

SEPTEMBER.

Direction	Hour	1844	1845	1846	1847	1849	Sum
N.	6h	4	0	0	1	3	8
	10h	7	1	0	2	1	11
	2h	3	1	1	1	0	6
	6h	0	1	0	1	3	5
	10h	2	1	1	1	3	8
N. by W.	6h	4	2	0	1	0	7
	10h	2	0	3	0	0	5
	2h	0	0	1	0	0	1
	6h	5	1	1	0	0	7
	10h	1	1	1	0	0	6
N.N.W.	6h	0	4	1	1	0	6
	10h	0	2	4	1	0	7
	2h	0	2	2	2	1	7
	6h	0	1	3	2	0	6
	10h	0	1	4	2	0	7
N.W. by N.	6h	0	2	0	0	0	2
	10h	1	1	0	0	0	2
	2h	0	1	0	0	1	2
	6h	0	0	0	0	0	0
	10h	0	2	0	0	0	0
N.W.	6h	0	6	2	2	5	15
	10h	2	10	2	4	3	21
	2h	4	8	1	3	4	20
	6h	1	5	1	3	3	13
	10h	1	3	1	2	3	10
N. W. by W.	6h	0	3	2	1	0	6
	10h	0	0	0	0	2	2
	2h	0	2	1	0	3	6
	6h	0	4	1	0	0	5
	10h	0	3	1	0	0	1
W.N.W.	6h	0	0	0	1	0	1
	10h	0	0	0	1	0	1
	2h	0	0	0	0	0	0
	6h	0	0	1	0	0	1
	10h	0	0	0	0	0	0
W. by N.	6h	0	2	1	0	0	3
	10h	1	2	1	0	0	4
	2h	1	0	1	0	0	2
	6h	0	1	0	0	0	1
	10h	0	1	1	0	0	2
W.	6h	2	1	5	0	3	11
	10h	2	0	3	1	0	6
	2h	1	0	1	1	0	3
	6h	1	0	2	0	3	6
	10h	0	1	3	0	2	6
W. by S.	6h	0	1	2	2	1	6
	10h	1	0	2	0	2	5
	2h	0	0	1	0	0	1
	6h	0	2	0	2	1	5
	10h	0	2	0	2	0	4
W.S.W.	6h	0	1	0	0	0	1
	10h	0	0	0	0	0	0
	2h	0	0	0	0	0	0
	6h	0	0	0	1	0	1
	10h	0	0	0	1	0	1
S.W. by W.	6h	0	0	0	0	2	2
	10h	0	1	1	0	1	3
	2h	0	0	0	1	0	1
	6h	0	0	0	0	1	1
	10h	0	0	0	0	1	1
S.W.	6h	2	1	1	1	1	6
	10h	0	2	1	0	2	5
	2h	1	2	6	2	2	13
	6h	2	3	9	2	3	19
	10h	3	3	7	2	4	19
S.W. by S.	6h	0	1	2	2	0	5
	10h	0	1	1	0	0	2
	2h	0	1	1	1	1	4
	6h	1	0	1	0	0	2
	10h	0	0	1	0	0	1
S.S.W.	6h	1	0	0	1	0	2
	10h	0	0	0	3	0	3
	2h	0	1	0	1	0	2
	6h	0	1	0	2	1	4
	10h	0	1	0	2	1	4
S. by W.	6h	1	1	0	0	0	2
	10h	0	0	0	0	1	1
	2h	1	1	1	3	4	10
	6h	3	1	0	1	1	6
	10h	3	1	0	1	0	5
S.	6h	3	1	0	0	0	4
	10h	0	0	1	2	2	5
	2h	3	1	2	2	4	12
	6h	3	3	1	2	1	10
	10h	4	3	1	2	1	11
S. by E.	6h	1	0	2	0	0	3
	10h	0	1	1	0	0	2
	2h	0	2	2	0	0	4
	6h	2	0	1	0	0	3
	10h	1	0	1	0	0	2
S.S.E.	6h	0	0	0	0	0	0
	10h	0	0	0	0	0	0
	2h	0	1	0	0	0	1
	6h	0	0	0	0	0	0
	10h	0	0	0	0	0	0
S.E. by S.	6h	0	0	0	0	0	0
	10h	0	0	0	0	0	0
	2h	0	1	1	0	0	2
	6h	0	0	0	0	0	0
	10h	0	1	0	0	0	1
S.E.	6h	2	2	1	0	0	5
	10h	2	2	1	1	2	8
	2h	7	2	3	4	5	21
	6h	2	2	2	2	6	14
	10h	2	3	2	2	6	15
S.E. by E.	6h	0	0	1	0	0	1
	10h	1	2	2	0	0	5
	2h	0	4	1	0	0	5
	6h	0	3	1	0	0	4
	10h	0	0	1	0	0	1
E.S.E.	6h	0	0	0	0	0	0
	10h	0	1	0	1	0	2
	2h	0	0	0	1	0	1
	6h	1	2	0	2	0	5
	10h	1	2	0	2	0	5
E. by S.	6h	0	1	0	0	0	1
	10h	0	0	0	0	1	1
	2h	0	0	0	0	0	0
	6h	1	0	0	0	1	2
	10h	1	0	0	0	1	2
E.	6h	2	1	0	0	0	3
	10h	1	0	0	1	1	3
	2h	1	0	1	0	0	2
	6h	1	0	1	0	1	3
	10h	1	0	1	0	1	3
E. by N.	6h	1	0	0	0	0	1
	10h	0	0	0	1	0	1
	2h	0	0	0	0	0	0
	6h	0	0	0	0	0	0
	10h	1	1	0	0	0	2
E.N.E.	6h	0	0	0	2	0	2
	10h	1	0	0	1	0	2
	2h	0	0	0	0	0	0
	6h	0	0	0	2	0	2
	10h	0	0	0	2	0	2
N.E. by E.	6h	0	0	0	0	0	0
	10h	0	0	0	0	0	0
	2h	0	0	0	1	0	1
	6h	0	0	0	0	0	0
	10h	0	0	0	0	0	0
N.E.	6h	4	0	1	6	4	15
	10h	5	1	3	7	2	18
	2h	7	0	1	5	3	16
	6h	5	0	1	5	3	14
	10h	4	0	1	6	3	14
N.E. by N.	6h	0	0	2	5	4	11
	10h	1	0	1	2	7	11
	2h	0	0	0	2	1	3
	6h	0	0	1	1	1	3
	10h	0	0	1	1	1	3
N.N.E.	6h	0	0	1	4	1	6
	10h	0	2	1	2	1	6
	2h	0	0	0	0	0	0
	6h	0	0	0	2	0	2
	10h	0	0	0	2	0	2
N. by E.	6h	3	0	3	0	6	12
	10h	3	1	2	0	1	7
	2h	1	0	2	0	1	4
	6h	2	0	3	0	1	6
	10h	2	0	2	0	1	5

OCTOBER.

	N.					N. by W.					N.N.W.					N.W. by N.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	3	3	2	1	1	4	2	0	2	1	1	1	0	0	0	0	0	0	0	0
1845	2	3	2	1	1	1	2	1	1	1	1	1	0	0	0	0	0	0	0	0
1846	4	4	4	1	2	3	0	1	1	0	2	2	0	0	0	0	0	0	2	2
1847	4	4	1	3	4	0	1	2	1	1	1	0	1	2	2	0	0	0	0	0
1848	4	2	0	1	0	3	2	2	2	2	2	0	0	0	0	0	0	0	0	0
1849	7	3	5	4	4	1	0	0	0	0	0	6	0	0	0	0	0	0	0	0
Sum	24	19	14	11	12	12	7	6	7	5	7	4	1	2	2	0	0	0	2	2

	N.W.					N.W. by W.					W.N.W.					W. by N.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	3	3	4	3	4	1	1	2	2	2	0	0	0	0	0	1	1	2	3	2
1845	7	5	5	3	3	5	2	2	5	5	0	0	0	0	0	0	0	0	0	0
1846	5	5	2	4	4	4	3	3	2	2	0	0	0	0	0	2	0	0	1	1
1847	2	2	2	0	0	0	0	0	0	0	1	2	0	2	2	0	0	0	0	0
1848	2	5	4	5	4	0	1	1	0	0	2	1	0	0	0	0	0	1	0	0
1849	3	3	2	2	3	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0
Sum	22	23	19	17	18	11	8	8	9	9	3	3	0	2	2	3	2	3	4	3

	W.					W. by S.					W.S.W.					S.W. by W.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	1	4	3	1	2	1	0	1	1	0	0	0	0	0	0	0	0	1	0	0
1845	1	0	1	0	0	1	1	1	1	1	0	1	0	0	0	0	0	0	1	1
1846	1	1	0	1	1	1	0	0	1	1	0	0	0	0	0	1	0	0	0	0
1847	2	0	3	1	1	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0
1848	2	1	1	1	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
1849	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Sum	8	6	9	5	6	3	1	2	3	2	1	2	0	0	1	1	2	3	1	1

	S.W.					S.W. by S.					S.S.W.					S. by W.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	3	1	2	3	3	1	0	1	0	0	0	0	1	0	1	1	0	0	0	0
1845	1	2	4	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1846	0	4	5	3	4	0	0	2	2	2	0	0	0	0	0	0	0	1	0	0
1847	1	2	2	3	3	0	1	1	1	1	0	0	0	0	0	2	2	1	1	1
1848	0	1	1	1	0	0	0	0	0	0	2	1	0	1	1	0	0	0	2	1
1849	2	3	2	6	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	7	13	16	19	20	1	1	4	3	3	2	1	1	1	2	3	2	2	3	2

	S.					S. by E.					S.S.E.					S.E. by S.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	0	0	0	1	2	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0
1845	1	1	1	2	1	0	0	1	1	1	0	0	0	0	0	0	0	1	0	0
1846	0	0	1	1	1	1	1	2	2	2	0	0	0	0	0	1	0	0	0	0
1847	0	0	4	2	1	0	1	1	1	1	0	1	2	0	0	0	0	0	0	0
1848	0	3	3	1	0	0	0	1	0	0	1	1	0	0	0	0	1	0	0	0
1849	1	1	4	4	2	0	0	1	0	0	0	0	0	0	0	0	1	1	1	1
Sum	2	5	13	11	7	2	4	6	4	4	1	2	2	0	0	1	2	2	1	1

	S.E.					S.E. by E.					E.S.E.					E. by S.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	4	3	4	6	4	0	0	2	1	2	1	1	1	1	1	0	0	0	0	0
1845	2	1	2	0	0	0	0	5	5	5	1	2	0	1	1	1	1	0	1	1
1846	0	2	2	2	1	2	3	2	2	2	0	0	0	0	0	0	0	0	0	0
1847	0	0	1	4	4	0	0	0	0	0	0	0	2	4	4	0	0	0	0	0
1848	0	0	3	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1849	1	2	3	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
Sum	7	8	15	14	12	2	3	9	8	9	2	3	3	6	6	1	1	1	2	2

	E.					E. by N.					E.N.E.					N.E. by E.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
1845	3	2	4	3	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
1846	1	0	1	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0
1847	0	1	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1
1848	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1849	1	0	2	2	3	0	0	0	3	2	0	0	0	0	0	0	0	0	0	0
Sum	6	3	7	6	7	0	0	0	5	4	0	1	1	0	0	0	1	0	1	1

	N.E.					N.E. by N.					N.N.E.					N. by E.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	2	3	1	1	2	0	1	0	2	2	1	0	1	0	0	2	1	3	2	2
1845	0	3	0	0	0	2	0	0	2	2	0	1	0	0	0	2	2	1	1	1
1846	2	3	2	1	2	0	1	1	2	2	0	0	0	0	0	1	2	2	1	1
1847	6	8	3	1	1	4	1	0	1	1	8	2	2	1	1	0	1	1	1	1
1848	1	4	1	0	0	1	0	1	1	1	5	5	4	0	1	4	1	1	2	2
1849	3	3	4	2	2	5	4	2	1	1	0	3	0	1	1	5	5	3	2	2
Sum	14	24	11	5	7	12	7	4	9	9	14	11	7	2	3	11	12	11	9	9

NOVEMBER.

	N.					N. by W.					N.N.W.					N.W. by N.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	1	2	0	0	0	3	2	2	2	2	1	2	1	1	0	1	0	0	0	0
1815	0	0	0	0	0	1	0	1	1	1	0	2	0	0	0	3	2	3	1	1
1846	1	3	1	1	2	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0
1847	3	0	2	1	1	1	5	1	3	2	0	0	1	3	3	0	0	0	0	0
1848	5	1	2	2	2	1	1	0	0	2	0	0	0	0	0	2	1	0	0	0
1849	3	3	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0
1850	5	7	3	3	4	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
Sum	18	16	8	7	9	9	10	6	7	8	1	4	3	4	3	6	3	3	2	1

	N.W.					N.W. by W.					W.N.W.					W. by N.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	4	3	7	6	5	2	4	0	1	1	0	1	0	0	1	3	5	2	1	2
1815	8	4	5	3	5	5	3	3	4	5	2	1	0	1	0	0	0	1	2	0
1846	3	3	3	4	4	2	0	0	2	1	1	2	1	1	2	1	0	1	0	0
1847	4	7	7	4	7	0	2	1	1	1	1	0	0	0	0	1	1	1	0	0
1848	5	6	8	7	8	1	0	1	0	0	0	1	2	1	0	1	1	0	0	0
1849	3	4	3	3	3	2	1	2	1	1	0	0	0	0	0	0	0	1	2	2
1850	3	1	4	2	3	0	0	0	0	0	0	1	1	0	0	0	1	1	2	1
Sum	30	28	37	29	35	12	10	7	9	9	4	6	4	3	3	6	8	7	7	5

	W.					W. by S.					W.S.W.					S.W. by W.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	6	2	0	3	3	0	2	2	0	0	0	0	0	1	1	0	0	0	0	0
1845	3	4	2	3	2	3	0	1	0	0	0	0	0	0	0	0	2	0	1	1
1846	1	3	4	1	2	0	1	0	0	0	0	0	0	0	0	0	0	0	2	1
1847	1	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	1
1848	0	1	1	2	2	0	0	1	0	0	0	1	1	1	1	2	1	0	1	1
1849	3	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	3	2	1	1
1850	3	2	3	4	4	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0
Sum	17	14	11	16	14	4	4	5	2	2	0	1	1	3	3	3	6	5	6	5

	S.W.					S.W. by S.					S.S.W.					S. by W.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	2	0	2	2	2	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1
1845	0	4	4	4	5	0	1	3	1	1	0	0	0	1	1	0	0	0	0	0
1846	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1847	4	4	5	4	4	0	0	0	1	1	0	0	0	0	0	3	2	0	1	1
1848	3	4	4	6	5	0	2	0	0	0	0	0	1	1	1	0	1	3	0	0
1849	1	2	3	5	5	0	0	1	0	0	0	0	0	1	1	1	0	4	3	2
1850	2	1	3	5	4	0	0	0	0	0	0	0	0	0	0	2	2	2	0	0
Sum	14	16	22	26	25	0	3	4	3	3	0	0	1	3	3	6	5	9	5	4

	S.					S. by E.					S.S.E.					S.E. by S.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	1	1	1	1	2	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0
1845	2	1	1	3	3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1846	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
1847	2	1	5	4	4	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
1848	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
1849	1	0	1	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1850	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	7	4	9	13	14	0	1	3	2	1	0	0	0	0	0	0	1	1	0	0

	S.E.					S.E. by E.					E.S.E.					E. by S.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	1	0	1	2	2	0	0	3	1	1	0	0	0	0	0	0	0	0	0	0
1845	0	1	0	0	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0
1846	0	0	1	1	1	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0
1847	0	0	1	2	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
1848	1	3	0	1	1	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0
1849	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1	1
1850	0	0	0	1	1	0	1	1	1	1	0	0	0	1	1	0	0	0	0	0
Sum	2	4	3	7	7	2	1	8	4	4	1	0	1	2	1	1	1	1	1	1

	E.					E. by N.					E.N.E.					N.E. by E.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0
1845	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1846	1	1	2	3	2	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
1847	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	1	0	0
1848	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1849	0	2	1	1	1	0	0	0	0	0	0	0	0	0	0	2	2	2	1	1
1850	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	1	3	3	6	5	1	2	1	1	1	1	1	1	0	0	2	4	3	1	1

	N.E.					N.E. by N.					N.N.E.					N. by E.				
	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h	6h	10h	2h	6h	10h
1844	1	0	0	0	0	1	2	1	2	1	0	0	2	2	2	3	2	3	3	3
1845	0	0	1	0	0	2	2	1	0	3	0	0	1	0	0	1	2	1	1	1
1846	2	5	6	1	1	1	4	2	0	7	2	3	2	0	0	7	2	3	3	4
1847	1	2	1	2	2	3	2	0	0	0	0	0	0	0	0	2	1	1	0	0
1848	1	1	1	0	0	6	4	2	0	0	0	0	0	0	0	1	2	0	4	4
1849	7	5	4	5	6	1	0	0	0	0	0	0	1	0	0	2	2	1	1	1
1850	9	4	8	6	5	0	0	0	0	0	2	5	0	0	0	4	4	1	2	3
Sum	21	17	21	14	14	17	14	6	2	11	4	8	6	2	2	20	15	10	14	16

DECEMBER.

Direction	Hour	1844	1845	1846	1847	1848	1849	1850	1851	Sum
N.	6h	4	3	2	2	2	2	7	3	25
N.	10h	4	3	2	0	1	2	4	2	18
N.	2h	3	1	1	3	0	2	3	3	16
N.	6h	0	0	0	2	2	3	3	4	14
N.	10h	1	0	1	2	2	4	5	4	19
N. by W.	6h	2	3	1	1	1	1	0	1	10
N. by W.	10h	4	2	0	1	1	1	1	2	12
N. by W.	2h	2	2	1	1	2	0	1	2	11
N. by W.	6h	3	3	2	0	3	2	1	1	15
N. by W.	10h	2	3	2	0	3	1	1	1	13
N.N.W.	6h	0	2	0	0	0	0	0	0	2
N.N.W.	10h	0	2	2	0	0	0	1	3	8
N.N.W.	2h	0	1	0	0	0	0	2	1	4
N.N.W.	6h	1	2	0	0	1	0	0	2	6
N.N.W.	10h	0	1	0	0	1	0	0	2	4
N.W. by N.	6h	0	1	2	1	0	1	0	1	6
N.W. by N.	10h	0	3	3	0	0	1	0	1	8
N.W. by N.	2h	0	2	1	0	1	0	0	0	4
N.W. by N.	6h	0	4	3	0	1	0	0	0	8
N.W. by N.	10h	0	3	3	0	1	0	0	0	7
N.W.	6h	4	5	9	2	0	4	2	6	32
N.W.	10h	5	6	7	2	1	5	0	5	31
N.W.	2h	5	5	11	2	3	6	3	4	39
N.W.	6h	5	2	8	5	0	3	4	4	31
N.W.	10h	5	3	5	4	0	3	4	4	28
N.W. by W.	6h	5	4	3	0	5	1	0	1	19
N.W. by W.	10h	4	0	4	2	1	2	0	0	13
N.W. by W.	2h	5	4	4	2	2	2	0	0	19
N.W. by W.	6h	1	7	5	3	1	2	0	0	19
N.W. by W.	10h	2	6	5	2	1	2	0	0	18
W.N.W.	6h	0	1	1	0	1	0	1	0	4
W.N.W.	10h	0	2	0	0	1	0	0	1	4
W.N.W.	2h	0	2	0	1	1	0	0	1	5
W.N.W.	6h	0	0	1	0	1	0	1	0	3
W.N.W.	10h	0	0	1	0	1	0	0	0	2
W. by N.	6h	3	1	1	1	0	3	2	1	12
W. by N.	10h	1	2	1	1	0	1	3	1	10
W. by N.	2h	1	2	0	1	0	3	1	3	11
W. by N.	6h	0	2	0	0	0	3	1	2	8
W. by N.	10h	1	2	0	1	0	3	1	3	11
W.	6h	2	2	2	0	0	6	3	5	20
W.	10h	3	2	3	0	0	4	6	5	23
W.	2h	1	3	3	1	1	5	4	3	21
W.	6h	3	2	1	1	0	4	3	4	18
W.	10h	1	3	3	1	0	5	3	4	20
W. by S.	6h	2	3	2	2	0	2	1	1	13
W. by S.	10h	2	0	1	0	0	2	1	3	9
W. by S.	2h	2	1	1	0	0	3	1	2	10
W. by S.	6h	4	2	1	2	0	1	0	0	10
W. by S.	10h	4	1	2	1	0	0	0	0	8
W.S.W.	6h	0	0	0	2	0	0	0	0	2
W.S.W.	10h	0	1	1	1	0	0	0	0	3
W.S.W.	2h	0	0	2	1	0	0	0	0	3
W.S.W.	6h	0	0	2	0	0	0	0	2	4
W.S.W.	10h	0	0	1	0	0	0	0	2	3
S.W. by W.	6h	1	0	0	1	0	1	2	2	7
S.W. by W.	10h	0	1	0	0	3	1	1	0	6
S.W. by W.	2h	0	0	0	0	2	0	2	1	5
S.W. by W.	6h	0	0	0	1	1	2	2	2	8
S.W. by W.	10h	0	1	0	2	1	2	2	1	9
S.W.	6h	1	1	2	4	5	2	1	2	18
S.W.	10h	0	1	1	5	3	2	3	2	17
S.W.	2h	2	1	1	5	1	1	4	4	19
S.W.	6h	1	1	3	5	3	3	3	3	22
S.W.	10h	2	2	2	5	3	4	3	3	24
S.W. by S.	6h	0	0	0	0	0	0	0	0	0
S.W. by S.	10h	0	0	0	0	0	0	0	1	1
S.W. by S.	2h	0	0	1	0	0	0	0	0	1
S.W. by S.	6h	1	0	0	0	1	0	2	0	4
S.W. by S.	10h	1	0	0	0	1	0	2	0	4
S.S.W.	6h	0	0	0	1	0	0	0	0	1
S.S.W.	10h	0	0	0	2	0	0	0	0	2
S.S.W.	2h	1	0	0	0	0	0	0	1	2
S.S.W.	6h	0	0	0	1	0	0	0	0	1
S.S.W.	10h	0	0	0	1	0	0	0	0	1
S. by W.	6h	0	0	0	0	0	0	0	0	0
S. by W.	10h	0	0	0	2	0	1	0	0	3
S. by W.	2h	0	0	0	1	1	0	0	0	2
S. by W.	6h	1	0	0	1	0	0	0	0	2
S. by W.	10h	0	0	0	1	0	0	0	0	1
S.	6h	0	0	0	1	0	0	0	0	1
S.	10h	0	0	0	0	0	0	0	0	0
S.	2h	0	0	0	4	1	1	0	1	7
S.	6h	0	0	0	5	4	0	0	1	10
S.	10h	0	0	0	5	2	0	0	1	8
S. by E.	6h	0	0	0	0	0	0	0	0	0
S. by E.	10h	0	0	0	0	0	0	0	0	0
S. by E.	2h	0	0	0	2	2	0	0	0	4
S. by E.	6h	0	0	0	0	0	0	0	0	0
S. by E.	10h	0	0	0	0	0	0	0	0	0
S.S.E.	6h	0	0	0	0	0	0	0	0	0
S.S.E.	10h	0	0	0	0	0	0	0	0	0
S.S.E.	2h	0	0	0	1	1	0	0	0	2
S.S.E.	6h	0	0	0	1	0	0	0	0	1
S.S.E.	10h	0	0	0	1	0	0	0	0	1
S.E. by S.	6h	0	0	0	0	0	0	0	0	0
S.E. by S.	10h	0	0	0	0	0	0	0	0	0
S.E. by S.	2h	0	0	0	0	0	0	0	0	0
S.E. by S.	6h	0	0	0	0	0	0	0	0	0
S.E. by S.	10h	0	0	0	0	0	0	0	0	0
S.E.	6h	1	0	0	0	0	0	0	0	1
S.E.	10h	1	0	0	3	3	0	0	0	7
S.E.	2h	0	0	0	1	1	1	0	0	3
S.E.	6h	0	0	0	0	1	1	2	1	5
S.E.	10h	1	0	0	0	3	1	2	1	8
S.E. by E.	6h	2	0	0	0	0	0	0	0	2
S.E. by E.	10h	2	0	0	0	1	0	0	0	3
S.E. by E.	2h	1	0	0	0	0	0	0	0	1
S.E. by E.	6h	1	1	0	0	0	0	0	0	2
S.E. by E.	10h	3	1	0	0	0	0	0	0	4
E.S.E.	6h	0	0	0	0	0	0	0	0	0
E.S.E.	10h	0	0	0	0	0	0	0	0	0
E.S.E.	2h	0	0	0	0	0	0	0	0	0
E.S.E.	6h	0	0	0	0	1	0	0	0	1
E.S.E.	10h	0	0	0	0	1	0	0	0	1
E. by S.	6h	0	0	0	0	2	0	0	0	2
E. by S.	10h	0	0	0	0	0	0	0	0	0
E. by S.	2h	0	0	0	0	0	0	0	0	0
E. by S.	6h	0	0	0	0	1	0	0	0	1
E. by S.	10h	0	0	0	0	1	0	0	0	1
E.	6h	0	0	0	1	0	0	1	0	2
E.	10h	0	0	0	0	0	0	1	0	1
E.	2h	0	0	0	1	0	0	0	0	1
E.	6h	0	0	0	1	0	0	0	0	1
E.	10h	0	0	0	1	0	0	0	0	1
E. by N.	6h	0	0	1	0	0	0	0	0	1
E. by N.	10h	0	0	1	0	0	0	0	0	1
E. by N.	2h	1	0	0	0	0	1	0	0	2
E. by N.	6h	0	0	0	0	0	0	0	0	0
E. by N.	10h	0	0	0	0	0	0	0	0	0
E.N.E.	6h	0	0	0	0	0	0	0	0	0
E.N.E.	10h	0	0	0	0	0	0	0	0	0
E.N.E.	2h	0	0	0	0	0	0	0	0	0
E.N.E.	6h	0	0	0	0	0	0	0	0	0
E.N.E.	10h	0	0	0	0	0	0	0	0	0
N.E. by E.	6h	0	0	0	0	1	0	0	0	1
N.E. by E.	10h	0	0	0	0	0	2	0	0	2
N.E. by E.	2h	0	0	0	0	0	0	0	0	0
N.E. by E.	6h	0	0	0	0	0	1	0	0	1
N.E. by E.	10h	0	0	0	0	0	0	0	0	0
N.E.	6h	0	1	1	7	6	6	7	2	30
N.E.	10h	2	0	0	7	8	5	4	0	26
N.E.	2h	1	0	1	2	9	5	5	0	23
N.E.	6h	0	0	2	2	7	6	4	0	21
N.E.	10h	1	0	2	2	7	6	4	0	22
N.E. by N.	6h	2	1	1	0	1	0	0	0	5
N.E. by N.	10h	2	2	2	1	2	0	0	0	9
N.E. by N.	2h	2	2	2	1	2	0	0	1	10
N.E. by N.	6h	1	0	3	0	1	0	0	0	5
N.E. by N.	10h	1	0	3	0	1	0	0	0	5
N.N.E.	6h	1	3	0	1	0	0	2	3	10
N.N.E.	10h	0	2	0	2	1	0	5	1	11
N.N.E.	2h	1	2	0	1	0	0	3	2	9
N.N.E.	6h	1	3	0	1	0	0	3	3	11
N.N.E.	10h	1	3	0	1	0	0	3	3	11
N. by E.	6h	1	0	3	4	7	2	2	3	22
N. by E.	10h	0	2	3	2	5	2	1	4	19
N. by E.	2h	4	2	2	0	1	1	2	2	14
N. by E.	6h	7	2	0	1	2	0	2	2	16
N. by E.	10h	5	2	1	1	2	0	1	2	14

In order to determine the mean direction of the wind for each of the hours of observation for each month of the year, the number of times that each direction occurred during the month for each of the hours of observation was counted, and the sum of the corresponding numbers for the entire period of years was taken. These numbers are given in Table I, pages 270–273, and Table II, pages 274–285.

The mean direction of the wind for each of the hours of observation was obtained by solving a traverse in which the number of times that each wind was recorded was regarded as the distance traveled. The mean direction of the wind thus obtained for each of the hours of observation, and for each month of the year, is given in Table III. The angles are reckoned from the North point around the circle through the West and South.

Table III also shows the ratio of the wind's progressive motion in its mean direction to the total distance traveled, for each hour of observation. These numbers were obtained as follows: Having computed the mean direction of the wind for each hour, the absolute length of the line indicating its direction was computed trigonometrically, and the number representing this line was divided by the number of observations for that hour, without regard to direction. When these ratios are large it shows that the direction of the wind was comparatively steady; when the ratios are small it shows that the direction of the wind was extremely variable.

If we compare the direction of the wind as deduced from the first series of observations with the direction as deduced from the second series, we shall find considerable discrepancies. Table IV, Part 1, shows the result of such a comparison. From the month of October to the month of March inclusive, the directions in the first series are more westerly in every instance, except for March at 6 P. M. During the remaining six months of the year the two series present still greater discrepancies. These differences are larger than was anticipated, and are not easily explained. The observations of the second series were principally made at a station about half a mile nearer the harbor than the first series; but this circumstance does not seem sufficient to account for so large differences as appear in the results.

It is suspected that in the first series of observations the direction of the wind recorded for M. and E. was not designed to give the direction noticed at any fixed hour, but rather the *prevalent direction* for the forenoon and afternoon. Such a result, deduced, as it probably was, not from several recorded observations, but from casual observations of the vane loosely preserved in the memory, could not claim much precision; and that no great precision was aimed at is shown by the fact that the winds were only recorded for eight points of the compass. There is no doubt that the second series of observations is more reliable than the first, for the directions were estimated to thirty-two points of the compass, and the precise time of each observation was carefully stated.

TABLE III.—Hourly Means.—First Series.

Direction of the Wind, New Haven, Conn., 1804–1820.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
M.	48·3°	46·7°	29·2°	19·7°	14·2°	50·5°	64·4°	29·7°	33·6°	41·4°	46·3°	57·1°
N.	58·9	65·5	76·8	139·2	173·4	163·8	160·4	169·8	127·4	94·3	67·8	63·3
E.	60·7	69·6	61·5	82·0	133·1	133·1	132·4	124·5	87·0	87·4	73·8	63·1

Ratio of the Wind's progressive motion in its mean direction to the total distance traveled. New Haven, Conn., 1804–1820.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
M.	0·492	0·445	0·424	0·336	0·240	0·215	0·279	0·294	0·436	0·419	0·416	0·481
N.	0·409	0·319	0·205	0·088	0·159	0·309	0·466	0·263	0·169	0·227	0·278	0·428
E.	0·469	0·368	0·275	0·184	0·135	0·294	0·435	0·299	0·277	0·347	0·369	0·477

Hourly Means.—Second Series.

Direction of the Wind, New Haven. Conn., 1844–1852.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
6 A.M.	37·5°	29·1°	22·6°	7·1°	346·1°	51·9°	42·9°	358·9°	21·1°	8·8°	25·0°	33·3°
10	43·4	31·7	29·0	42·7	246·1	93·8	350·7	286·5	5·0	4·5	29·6	33·4
2 P.M.	49·6	47·6	59·8	148·3	188·7	160·6	155·1	182·5	152·9	30·1	51·2	44·5
6	51·5	48·2	69·0	134·3	195·3	145·9	158·5	177·9	107·1	28·6	62·4	46·8
10	52·3	46·1	56·1	109·5	178·6	141·4	144·2	177·1	88·7	18·6	54·6	47·1

Ratio of the Wind's progressive motion in its mean direction to the total distance traveled. New Haven, Conn., 1844–1852.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
6 A.M.	0·463	0·461	0·440	0·346	0·200	0·214	0·210	0·197	0·369	0·475	0·468	0·546
10	0·469	0·421	0·307	0·034	0·147	0·140	0·061	0·133	0·328	0·340	0·421	0·494
2 P.M.	0·366	0·355	0·197	0·194	0·253	0·412	0·351	0·347	0·076	0·052	0·278	0·473
6	0·377	0·396	0·249	0·129	0·226	0·359	0·322	0·304	0·070	0·063	0·272	0·446
10	0·367	0·389	0·257	0·115	0·133	0·319	0·282	0·299	0·043	0·094	0·294	0·417

In order to present the results of the second series of observations palpably to the eye, the curves shown on Plate XI have been drawn upon the same principle as those given on Plate VIII to represent the observations at Wallingford, Conn. These curves were constructed in the following manner: The wind's mean direction for January at

6 A. M. was set off by means of a protractor (a vertical line upon the paper being taken to represent the meridian), and a line half an inch in length was drawn in this direction. From the extremity of this line the wind's direction for 10 A. M. was set off, and another line drawn of the same length as before. In like manner were drawn the directions for each of the hours of observation. We thus obtain a broken line, which may be regarded as representing the average progress of a particle of air for each hour of observation through the month of January, supposing the wind's velocity to be the same at all hours. In like manner the curves for each of the twelve months were constructed.

TABLE IV, Part 1.—*Differences between the mean directions of the Wind at New Haven, Conn., as determined by the two series of observations.*

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
6 A.M.	+10°·8	+16°·4	+ 6°·6	+ 2°·6	+28°·1	− 1°·4	+21°·5	+30°·8	+12°·5	+36°·9	+16°·7	+23°·7
2 P.M.	+ 9·3	+16·9	+17·0	− 9·1	−15·3	+ 3·2	+ 5·3	−12·7	−25·5	+64·2	+16·6	+18·8
6 P.M.	+ 9·2	+18·4	− 7·5	−52·3	−62·2	−12·8	−26·1	−42·4	−20·1	+59·2	+11·1	+16·3

TABLE IV, Part 2.—*Differences between the mean directions of the Wind at New Haven and Wallingford, Conn.*

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
6 A.M.	−12°·1	− 5°·6	+13°·7	+ 7°·4	+ 13°·0	−11°·7	+63°·1	+15·3	+18°·7	+17°·9	+10°·8	− 3°·3
10	−20·1	−10·6	+ 6·8	−32·3	+114·3	−31·3	+77·1	+91·8	+32·1	+25·1	+12·4	− 3·9
2 P.M.	−14·3	− 6·1	− 6·7	−93·0	− 33·1	−46·5	−10·5	−84·2	−88·3	+19·5	+ 7·3	− 6·5
6	−15·8	− 3·8	− 5·0	−41·3	− 31·1	− 7·2	− 7·9	−20·6	+12·8	+35·4	+ 7·6	− 4·8
10	−19·0	− 8·1	− 8·8	−32·5	+ 2·8	+29·3	+24·2	− 5·9	+58·1	+24·6	− 2·8	−12·5

If we compare the curves thus obtained for New Haven with those given for Wallingford on Plate VIII, we shall find the results tolerably satisfactory. A numerical comparison of the observations at the two stations is given in Table IV, Part 2. For the month of October the curves at the two stations show but little difference, except that the direction at Wallingford is on an average twenty-four degrees more westerly than at New Haven. For the month of November the two curves bear a strong resemblance, the direction at Wallingford being on an average seven degrees more westerly than at New Haven. For the month of December the two curves bear a still closer resemblance, but the direction at New Haven is on an average six degrees more westerly than at Wallingford. For January and February the resemblance of the two curves is equally strong, but the direction at New Haven is sixteen degrees more westerly than at Wallingford in January and seven degrees more westerly in February. In March the resemblance of the two curves is not quite so close, but the mean direction for the two stations is identically the same.

We thus see that for the six colder months of the year the curves at the two stations are quite similar, but there is a difference in the mean direction of the wind, which changes from month to month with such regularity that we cannot ascribe it to errors of observation. This will appear from the following table, in which column second shows the average difference in the direction of the wind at New Haven and Wallingford for each of these six months, and column third shows the differences between the numbers in column second.

	N. H. — W.	Difference.
October,	+ 24°·5	17°·4
November,	+ 7·1	13·3
December,	— 6·2	10·1
January,	—16·3	9·5
February,	— 6·8	6·8
March,	0·0	

The regularity in the change of direction at the two stations is so great, as to indicate the operation of some physical law. Can these differences be reconciled with the explanation of the winds at Wallingford, given on page 249? It is somewhat hazardous to express an opinion upon this subject until we have observations from a sufficient number of stations to enable us to eliminate the effects due to purely local causes. We might expect that since New Haven is nearer to the ocean than Wallingford, the deflecting influence due to the warmer temperature of the ocean would be stronger at New Haven than at Wallingford, whereas the observations seem to indicate that during the winter months the contrary is true. The following explanation of these seeming anomalies is suggested: 1st, the Gulf Stream exerts an influence upon the direction of the winds in the vicinity of New Haven, which is more powerful than that of the nearer but cooler ocean; 2nd, the difference in the distances of the Gulf Stream from New Haven and Wallingford is so small that this cause ought to operate with sensibly the same energy at both stations; but 3rd, New Haven is situated in a basin near the level of the sea, while Wallingford is elevated about 130 feet above the sea, and has a very free exposure. The winds at New Haven are therefore frequently mere surface winds of limited extent, while those at Wallingford correspond more nearly with the general drift of the atmosphere in this region.

These conclusions appear to be confirmed by a comparison of the directions of the wind at New Haven and Wallingford during the six warmer months of the year. In the months of April and September the diurnal change of direction is much greater at New Haven than at Wallingford, the wind being almost exactly North in the morning, and nearly South at the hottest part of the day. In May and August the wind at both stations is nearly North in the morning and South in the afternoon, but with this difference, that at Wallingford the Westerly motion exceeds the Easterly, while at New Haven the Easterly motion exceeds the Westerly. It seems probable that the latter effect is confined to places but little elevated above the level of the sea. In June the curves at the two stations are quite similar; while in July the diurnal change is much the greatest at New Haven. We conclude therefore that the New Haven observations are not inconsistent with the explanation heretofore given of the winds at Wallingford, and that the peculiarities of New Haven result from local causes, among which are to be enumerated its low position, and perhaps also the shallow water of Long Island Sound, with Long Island on the south of it. It is suspected that these local winds at New Haven are of the nature of counter currents, analogous to the counter currents observed along the banks of rapid rivers, especially where the banks are considerably indented.

Velocity of the Wind.

In the year 1860, a Robinson's anemometer, made by L. Casella of London, was procured by Prof. Elias Loomis for Yale College. The hemispheres are three inches in diameter, the distance between the centers of the opposite cups is 13·5 inches, and the distance traveled by the wind is recorded up to 500 miles. The anemometer was erected upon one of the towers of Graduates' Hall at an elevation of 65 feet from the ground, where the exposure was entirely unobstructed. In December, 1863, regular observations were commenced by Prof. Loomis, and have been continued to the present time. The observations were made at intervals of one, two or three days, according as was found convenient, the object being simply to determine the average velocity of the wind for each month of the year. It was soon found that the velocity indicated by the observations was smaller than had been expected, and it was suspected that the instrument was not entirely reliable. After the observations had been continued for two or three years, Prof. Loomis decided to procure a second instrument from a different maker. He accordingly requested

Table V.—*Velocity of the Wind, New Haven, Conn.*

Month.	Year.	Observations compared.	d.	h.		d.	h.	Interval. h.	Miles traveled. Casella.	Miles traveled. Negretti	Mean h'ly veloc. Casella.	Mean h'ly veloc. Negretti	Mean. C. & N.
January.	1864	Jan.	2	11	Feb.	1	3½	724·5	4060	----	5·60	---	
	1865	Jan.	1	4	Jan.	31	1½	717·5	4095	----	5·71	---	
	1866	Jan.	1	1½	Jan.	31	1½	720·0	4690	----	6·51	---	
	1867	Jan.	1	12	Jan.	31	3	723·0	4205	----	5·82	---	
	1868	Jan.	1	5	Feb.	1	3	742·0	4130	4260	5·57	5·74	
	1869	Jan.	2	4	Jan.	31	4	696·0	3750	3956	5·39	5·69	
	1870	Jan.	2	1	Jan.	31	3	698·0	4250	4212	6·09	6·04	
	1871	Jan.	2	11	Jan.	30	2	675·0	4215	3993	6·25	5·92	
	Mean										5·87	5·85	6·31
February.	1864	Feb.	1	3½	Feb.	23	8½	521·0	3553	----	6·82	---	
	1865	Jan.	31	1½	Feb.	27	1	647·5	4430	----	6·84	---	
	1866	Feb.	1	1½	Feb.	28	1½	648·0	4770	----	7·36	---	
	1867	Jan.	31	3	Feb.	28	4	673·0	4755	----	7·07	---	
	1868	Feb.	1	3	Mar.	1	8	689·0	4116	4179	5·98	6·07	
	1869	Jan.	31	4	Feb.	27	4	648·0	4365	4283	6·74	6·61	
	1870	Jan.	31	3	Feb.	28	4	673·0	5085	5300	7·59	7·87	
	1871	Jan.	30	2	Feb.	28	12	694·0	4528	4339	6·52	6·26	
	Mean										6·86	6·70	7·38
March.	1864	Mar.	5	10	Mar.	31	5	631·0	4630	----	7·34	---	
	1865	Feb.	27	1	Mar.	31	1½	768·5	5625	----	7·32	---	
	1866	Mar.	1	1½	Mar.	31	1½	720·0	4590	----	6·38	---	
	1867	Feb.	28	4	Mar.	31	6	746·0	4930	----	6·61	---	
	1868	Mar.	1	8	April	1	5	753·0	4444	4277	5·90	5·68	
	1869	Feb.	27	4	April	1	8	784·0	5260	5054	6·71	6·45	
	1870	Feb.	28	4	April	1	5	769·0	5526	5523	7·19	7·18	
	1871	Feb.	28	12	Mar.	31	12	746·0	4642	4401	6·22	5·90	
	Mean										6·71	6·30	7·16
April.	1864	April	2	4½	May	1	5¼	696¾	5642	----	8·09	---	
	1865	April	1	1	April	26	11½	598·5	4875	----	8·15	---	
	1866	Mar.	31	1½	April	30	5	723·5	4615	----	6·38	---	
	1867	Mar.	31	6	May	1	6	744·0	4720	4538	6·34	6·10	
	1868	April	1	5	May	1	3	718·0	4962	4017	6·91	6·99	
	1869	April Mar.	8 31	12 (N 11 (C	May	3	9	597·0 790·0	4520	3598	5·70	6·03	
	1870	Mar.	29	3	April	30	4	769·0	4723	4856	6·14	6·32	
	1871	Mar.	31	2	May	1	4	746·0	4094	3835	5·49	5·14	
	Mean										6·65	6·12	7·16
May.	1864	May	1	5¼	June	1	4	744¾	4279	----	5·74	---	
	1865	May	1	12½	June	1	4	675·5	3830	----	5·67	---	
	1866	April	30	5	June	1	1½	771·5	4645	----	6·02	---	
	1867	May	1	6	June	1	12	738·0	4351	4330	5·89	5·87	
	1868	April	30	10	May	31	4	750·0	4247	4346	5·66	5·79	
	1869	April	29	4½	June	1	9	784·5	4013	4195	5·12	5·61	
	1870	April	30	4	May	30	4	720·0	3749	3861	5·21	5·36	
	Mean										5·62	5·66	6·09
June.	1864	June	1	4	July	1	5½	721·5	3239	----	4·49	---	
	1865	June	1	4	June	30	7	699·0	2965	----	4·24	---	
	1866	June	1	1½	June	30	1½	696·0	3235	----	4·65	---	
	1867	June	1	12	June	30	4	670·0	3921	3818	5·85	5·70	
	1868	May	31	4	June	28	5	673·0	2804	2906	4·17	4·32	
	1869	June	1	9	July	1	4	727·0	2594	2590	3·57	3·56	
	1870	May	30	4	July	2	5	793·0	3074	2896	3·88	3·65	
	Mean										4·41	4·31	4·72

TABLE V—continued.

Month.	Year.	Observations compared.	d.	h.		d.	h.	Inter-val.	Miles traveled.		Mean h'ly veloc.		Mean.
								h.	Casella.	Negretti	Casella.	Negretti	C. & N.
July.	1864	July	1	5½	July	29	10	664·5	3024	----	4·70	---	
	1865	June	30	7	July	27	9	638·0	3285	----	5·15	---	
	1866	June	30	1½	July	31	5	747·5	3060	----	4·09	---	
	1867	June	30	4	Aug.	2	6	794·0	3313	3340	4·17	4·21	
	1868	June	28	5	Aug.	1	6	817·0	2956	2782	3·62	3·41	
	1869	July	1	4	Aug.	3	10	786·0	3160	2970	4·02	3·78	
	1870	June	28	5	July	29	7	746·0	3140	3217	4·21	4·31	
	Mean										4·28	3·93	4·57
August.	1864	Aug.	13	5	Aug.	29	6	385·0	1685	----	4·39	---	
	----	----	--	--	----	--	--	----	----	----	---	---	
	1866	July	31	5	Aug.	31	7	746·0	3190	----	4·28	---	
	1867	Aug.	2	6	Sept.	2	7½	733·5	2765	2843	3·77	3·88	
	1868	Aug.	1	6	Aug.	31	3	717·0	2720	2820	3·80	3·93	
	1869	July	29	10	Sept.	1	12	814·0	3153	2966	3·87	3·64	
	1870	July	29	7	Sept.	1	2	811·0	3015	3025	3·72	3·73	
	Mean										3·97	3·79	4·27
September.	1864	Sept.	11	5	Oct.	1	1½	476·5	3113	----	6·53	---	
	1865	Sept.	10	5	Sept.	30	2	477·0	3061	---	6·42	---	
	1866	Aug.	31	7	Sept.	30	5	718·0	2885	----	4·02	---	
	1867	Sept.	2	7½	Sept.	30	4	680·5	3091	3031	4·54	4·45	
	1868	Aug.	31	3	Oct.	1	5	746·0	3375	3630	4·52	4·87	
	1869	Sept.	1	12	Oct.	1	4	724·0	2857	2799	3·95	3·87	
	1870	Sept.	1	2	Oct.	1	8	714·0	3020	2856	4·23	4·00	
	Mean										4·89	4·30	5·25
October.	1864	Oct.	1	1½	Nov.	1	1	743·5	4121	----	5·54	---	
	1865	Sept.	30	2	Nov.	1	8	762·0	4170	----	5·45	---	
	1866	Oct.	1	3½	Nov.	1	5	745·5	4025	----	5·40	---	
	1867	Sept.	30	4	Nov.	1	12	764·0	3885	3956	5·09	5·18	
	1868	Oct.	1	5	Nov.	1	4	743·0	3610	3685	4·86	4·96	
	1869	Oct.	1	4	Oct.	30	3	695·0	3180	3245	4·58	4·68	
	1870	Oct.	1	8	Oct.	31	9	721·0	4710	4965	6·55	6·88	
	Mean										5·35	5·42	5·80
November.	1864	Oct.	31	1	Nov.	30	2	721·0	4250	----	5·90	---	
	1865	Nov.	1	8	Dec.	1	4	728·0	4915	----	6·75	---	
	1866	Nov.	1	5	Nov.	30	5	696·0	4295	----	6·18	---	
	1867	Nov.	1	12	Dec.	1	8	716·0	4339	4256	6·06	5·94	
	1868	Nov.	1	4	Nov.	30	4	696·0	4192	4209	6·02	6·05	
	1869	Nov.	2	10	Nov.	30	4	678·0	3979	4021	5·87	5·93	
	1870	Oct.	31	9	Nov.	30	12	723·0	5552	5517	7·68	7·63	
	Mean										6·35	6·39	6·82
December.	1863	Dec.	2	11	Dec.	22	3	484·0	3592	----	7·42	---	
	1864	Dec.	1	1	Jan.	1	4	747·0	5370	----	7·19	---	
	1865	Dec.	1	4	Dec.	31	4	720·0	4730	----	6·57	---	
	1866	Nov.	30	5	Jan.	1	12	763·0	4865	----	6·38	---	
	1867	Dec.	1	8	Jan.	1	5	753·0	5420	5232	7·20	6·95	
	1868	Nov.	30	4	Jan.	2	4	792·0	4783	4976	6·04	6·29	
	1869	Nov.	30	4	Jan.	2	1	789·0	4909	4894	6·22	6·20	
	1870	Nov.	30	12	Jan.	2	11	791·0	5423	5290	6·86	6·69	
	Mean										6·73	6·53	7·23

Mr. Glaisher, who has charge of the Meteorological Department of the Greenwich Observatory, to select an anemometer similar to one of those in use at Greenwich, to set it up in proper position and observe it carefully for a sufficient time to determine its error as compared with the Greenwich instruments. Mr. Glaisher promptly acceded to this request, and selected a Robinson anemometer made by Negretti & Zambra of London. The diameter of the cups was 3·8 inches, the distance between the centers of the opposite cups was 13·8 inches, and the instrument recorded the wind's progress up to one thousand miles. From a comparison continued for several weeks Mr. Glaisher concluded that the readings of this instrument needed to be increased in the ratio of 93 to 100, in order to make them accord with the Greenwich standards. This anemometer was received in New Haven in the winter of 1867, and was immediately set up on the same tower as the former instrument, and distant from it sixteen feet. Both instruments have been observed regularly to the present time, the observations having been made chiefly by Prof. E. Loomis. It is found that the results obtained from the two instruments differ but slightly. When the velocity of the wind is small, the Negretti anemometer gains somewhat upon Casella; and when the velocity is great, Casella gains somewhat upon Negretti; but in the results of an entire year, the difference between the two instruments is entirely inappreciable.

Table V contains a summary of the distances traveled by the wind for each month since the observations commenced, according to the indications of each anemometer. In column 3rd are given the dates of the observations corresponding most nearly to the beginning and end of each month; column 4th shows the included interval of time expressed in hours; column 5th shows the distance traveled by the wind during the preceding interval according to Casella's anemometer, and column 6th shows the distance for the same interval according to Negretti's anemometer; columns 7th and 8th show the mean hourly velocity deduced from the observations with the separate instruments. The following table affords a comparison of the indications of the two instruments, the velocities given for the Casella anemometer being the mean velocities determined for the years of observation when both instruments were employed.

Comparison of Casella's and Negretti's Anemometers.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Casella	5·82	6·71	6·50	6·12	5·47	4·37	4·00	3·79	4·31	5·26	6·41	6·58
Negretti	5·85	6·70	6·30	6·12	5·66	4·31	3·93	3·79	4·30	5·42	6·39	6·53

For the entire year, the average difference between the two instruments is less than one hundredth of a mile, and their indications may be regarded as identical. The last column in Table V shows the mean velocity of the wind for each month of the year as derived from the indications of both instruments combined, and increased in the ratio of 93 to 100, or a little over seven per cent.

TABLE VI.—*Examples of High Winds observed at New Haven, Conn.*

Beginning.				Ending.		Interval.	Wind's progress, in miles.	Average velocity, in miles.
		d.	h.	d.	h.	h.		
1863	Dec.	9	12	10	12½	24½	330	13·47
1863	Dec.	14	12¾	15	12½	23¾	350	14·74
1864	Jan.	19	5	20	4½	23½	345	14·68
1864	Feb.	16	5½	17	3	21½	362	16·84
1864	Apr.	6	12½	7	9¾	21¼	267	12·56
1864	Apr.	19	12½	20	5	28½	358	12·56
1864	Oct.	28	1	29	1	24	329	13·71
1865	Jan.	23	3	24	1	22	245	11·14
1865	Feb.	5	12½	6	1	24½	340	13·88
1865	Feb.	8	1½	9	1	23½	265	11·28
1865	Mar.	16	1	17	1	24	335	13·96
1865	Mar.	17	1	18	1	24	360	15·00
1865	Mar.	22	1	23	1	24	440	18·33
1865	Mar.	23	1	24	1½	24½	275	11·23
1865	Oct.	19	9	20	8	23	375	16·30
1865	Oct.	20	8	21	2	30	385	12·83
1865	Nov.	6	8	7	1	29	335	11·55
1866	Mar.	5	1½	6	1½	24	375	15·62
1866	Mar.	25	1	26	1½	24½	410	16·73
1867	Mar.	22	3	23	4	25	420	16·80
1867	June	8	10	9	5	31	505	16·29
1868	Feb.	9	4	10	3	23	392	17·04

A few examples of unusually high winds are exhibited in Table VI. This table does not show by any means the greatest velocity of the wind which sometimes prevails at New Haven for a few hours, but only the greatest average velocity for a period of 24 hours. As the observations were never made at intervals less than about 24 hours, and generally at intervals of two or three days, they do not afford the means of determining the maximum velocity prevailing for an hour or two, and in only a few cases do they indicate the greatest average velocity for a period of 24 hours. The examples quoted in the table are derived mainly from the record of the first two years, for the reason that the anemometer was then observed more frequently than in subsequent years.

The average velocity of the wind at New Haven is so small that it has been thought desirable to compare it with the results obtained from similar observations at other stations. For this purpose a collection of observations has been made, as complete as the materials accessible in New Haven have permitted. The results are shown in Table VII.

TABLE VII.—*Mean velocity of the Wind at various stations.*

Greenwich, England.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1843	---	---	---	---	---	---	---	---	10·4	13·7	14·5	11·7	---
1844	13·4	15·1	21·7	---	14·1	14·2	---	8·1	9·1	14·2	11·8	8·3	13·0
1845	14·1	11·1	14·5	14·1	12·0	10·4	9·8	11·9	11·9	11·9	13·1	17·7	12·8
1846	---	10·5	13·3	10·4	9·1	8·8	12·6	9·1	8·2	14·1	12·6	11·9	10·9
1847	10·1	13·0	10·5	10·9	---	13·2	9·3	10·2	13·0	10·9	11·9	15·1	11·7
1848	11·1	21·4	12·9	11·8	9·5	15·4	12·7	12·7	9·5	12·9	14·9	14·5	13·3
1849	18·1	11·9	---	7·1	9·1	7·6	10·9	8·4	7·3	9·5	9·1	10·9	10·0
1850	9·9	15·2	8·2	10·5	9·8	9·0	8·7	11·2	8·3	11·1	13·9	10·2	10·5
1851	11·6	8·8	10·9	8·3	8·1	12·1	10·3	10·1	7·8	10·1	7·6	7·5	9·5
1852	14·2	13·7	9·5	9·2	9·0	9·8	6·9	9·1	7·0	9 0	14·3	15·3	10·6
1853	10·8	8·3	7·3	10·9	9·5	9·7	10·9	7·3	9·0	7·8	7·0	6·5	8·7
1854	10·4	12·1	8·5	8·3	9·7	9·8	8·4	8·4	8·4	8·8	9·8	16·2	9·9
1855	6·6	7·3	7·3	9·5	11·1	8·8	7·6	10·2	8·0	10 2	7·2	10·7	8·7
1856	9·5	11·8	9·8	12·0	13·2	8·2	8·9	7·9	9·2	6·9	9·2	12·6	9·9
1857	9·9	7·3	8·9	8·9	7·3	11·1	9·8	6·2	7 0	8·3	6·4	10·4	8·5
1858	11·1	8·4	8·8	7·8	9·5	5·8	8·2	---	9·7	10·2	7·7	9·1	8·7
1859	10·1	13·3	13·2	12·1	8·1	7·0	7·1	8 7	9·5	6·9	8·7	6·3	9·3
1860	10·3	13·0	14·2	10·8	10·2	11 2	7·2	---	8·3	10·8	7·7	7·9	10·1
1861	7·4	10·3	14·4	7·9	8·4	8·2	11·5	11·2	10·6	7·5	13·3	9 2	10·0
1862	10·7	9 5	9·9	11·2	9·1	11·2	10·9	8·0	7·2	12·0	7·2	13·5	10·0
1863	15·4	10·2	9·9	10·7	10·0	6·3	6·2	10·3	10·8	9·4	10·7	13·8	10·3
1864	8·9	10·7	11·7	8·0	7·9	10·2	9·1	8·1	9·7	10·3	10·2	9·1	9·5
1865	11·3	11·5	11·2	7·0	8·8	7·5	8·8	8·7	6·5	9·5	11·0	9·2	9·3
1866	15·0	14·0	10·0	12·2	10·0	10·1	9·7	10·6	10·5	7·7	13·9	14·2	11·5
1867	14·4	14·3	13·7	16·9	9·7	9·7	10·4	8·3	11·1	10·7	10 0	12·4	11·8
1868	14·8	15·0	14·9	12·2	9·7	8·7	9·7	10·9	10·0	10·9	12·0	17·2	12·2
Mean	11·2	11·9	11·5	10·4	9·7	9·8	9·4	9·4	9·2	10·2	10·6	11·6	10·4*

Oxford, England.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1858	11·5	11 0	11·4	10·9	11·9	7·1	9·1	9·5	9·0	10·1	9·1	11·6	10·2
1859	12·9	14·2	15·9	13·0	11·8	8·9	7·8	9·1	11·8	8·8	9·6	---	11·3
1860	---	---	---	12·5	10·7	12·8	8·0	---	9·0	11·2	11·2	9·2	11·2
1861	---	14·8	14·7	8·1	8·7	9·0	11·5	11·9	11·0	8·5	13·7	10·7	11·3
1862	13·4	12·1	11·5	12·1	10·4	11·5	14·8	---	8·3	---	6·8	---	11·1
1863	17·0	11·5	11·5	12·0	12·1	10·6	7·6	11·0	12·5	11·1	11·9	15·8	12·0
1864	9·5	12·1	14·4	9·1	8·7	11·9	10·0	8·8	11·2	11·3	11 0	11·0	10·7
1865	14·6	12·3	12·2	8·7	9·5	8·2	9·1	10·0	6·8	9·6	11·4	9·9	10·2
1866	16 6	15·1	10·7	12·3	10·5	13·2	10·4	12·2	12·8	8·5	13·9	13·5	12·5
Mean	13·6	12·9	12·8	10·9	10·5	10·4	9·8	10·4	10·3	9·9	10·9	11·7	11·2*

Liverpool, England.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1852	19·2	18·6	9·0	9 3	12·6	13·5	10·5	10·6	11·2	11·6	12·6	17·6	13·0
1853	15·3	12·0	10·3	17·0	11·3	9·8	15·2	10·7	12·3	11·7	9·8	9·6	12·1
1854	16·0	19·2	13·9	12·8	10·6	12·6	10·4	11·4	12·8	13·2	13·7	23·9	14·6
1855	9·6	9·8	12·6	13·8	12·5	12·4	9·6	14·6	8·1	13·9	8·5	15·5	11·8
1857	13·1	12·1	14·4	11·3	10·1	11·1	13·2	9·8	9·1	11.2	8·9	13·7	11·5
Mean	14·6	14·3	12·0	12·8	11·4	11·9	11·8	11·4	10·7	12·3	10·7	16·1	12·5*

Kew, England.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1856	11·14	11·89	13·32	13·18	12·44	8·37	8·93	10·15	9·22	6·95	7·66	11·17	10·36
1857	12·01	8·75	12·15	10·18	10·35	11 00	9 68	8·37	7·18	8·14	8·14	9·59	9·63
Mean	11·57	10·32	12·73	11·68	11·39	9·68	9·30	9·26	8·20	7·54	7·90	10·38	9·99*

Plymouth, England.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1842	8·7	9·5	10·0	8·9	8·6	7·4	6·1	8·8	10·6	10·4	10·2	8·5	9·0*

* Miles per hour.

TABLE VII—continued.

Brussels, Belgium.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1867	0·83	0·95	0·44	1·07	0·22	0·19	0·48	0 12	0·36	0·36	0·28	0·47	0·48
1868	0·85	0·71	0·68	0·61	0·36	0·16	0·24	0·39	0·38	0·45	0·57	---	0·49
Mean	0·84	0·83	0·56	0·84	0·29	0·17	0·36	0·25	0·37	0·40	0·42	0·47	0·48*
Mean	1·85	1·83	1·23	1·85	0·64	0·37	0·79	0·55	0·81	0·88	0·92	1·03	1·06†
Mean	19·2	19·1	15·7	19·2	11·3	8·6	12·6	10·5	12·7	13·0	13·6	14·3	14·5 ‡

Madrid, Spain.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1866	---	---	25·3	16·8	18·8	16·4	17·9	17·2	16·2	10·9	9·9	10·0	---
1867	18·7	12·6	24·5	16 4	18·0	19·7	17·9	16·3	16·7	14·3	12·1	---	16·5
Mean	18·7	12·6	24·9	16·6	18·4	18·0	17·9	16·8	16·4	12·6	11·0	10·2	16·2‖
Mean	11·6	7.8	15·5	10·3	11·4	11·2	11·1	10·4	10·2	7·8	6·8	6·3	10·0‡

Mühlhausen, France.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1842	12·7	8·2	16·2	15·8	15·0	15·3	15·8	9·7	13·0	15·7	11·4	12·9	13·4§
	9·2	5·9	11·8	11·5	10·9	11·1	11·4	7·0	9·5	11·4	8·3	9·4	9·8‡

Madras, India.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1841	---	---	0·24	0·24	0·53	0·26	0·33	0·12	0·11	0·14	0·12	0·21	
1842	0·11	0·16	0·12	0·25	0·38	0·43	0·71	0·28	0·08	0·31	0·25	0·30	
1843	0·56	0·09	0·36	0·54	0·69	0·35	0·30	0·26	0·24	0·07	0·47	0·38	
1844	0·26	0·17	0·25	0·57	0·49	0·42	0·34	0·18	0·15	0·01	0·32	0·52	
1845	0·09	0·04	0·12	0·58	0·33	0·35	0·33	0·24	0·11	0·15	0·37	0·19	
Mean	0·25	0·11	0·22	0·44	0·48	0·36	0·40	0·22	0·14	0·14	0·31	0·32	0·28†
Mean	7·14	4·80	6·60	9·34	9·84	8·51	8·97	6·57	5·25	5·21	7·82	8·00	7·33‡

Cape of Good Hope.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1842	2·30	2·30	1·70	0·95	0·90	0 89	1·25	1·53	1·80	2·01	1·42	1·80	1·57
1843	2·16	1·10	2·07	1·00	1·10	1·24	1·10	1·20	1·43	1·49	1·30	2·43	1·47
1844	2·54	1·86	1·55	1·13	1·22	0·88	0·79	1·47	1·11	1·48	1·72	2·45	1·52
1845	2·71	2·08	1·43	0·98	0·91	0·70	0·93	1·33	1·33	1·90	1·44	1·65	1·45
1846	2·79	2·97	2·25	1·75	1·04	1·11	1·35	1·83	2·28	2·62	2·76	2·62	2·11
1847	2·17	2·61	2·27	1·19	0·71	1·02	0·45	1·02	1·57	2·28	1·59	1·10	1·50
1848	2·39	1·02	1·21	0·42	0·60	0·71	0·85	0·77	1·44	1·12	1·65	1·32	1·13
1849	1·39	1·54	0·74	0·82	0·52	0·85	0·83	0·62	0·74	1·43	1·38	1·45	1·03
1850	1·36	1·21	0·79	0·63	0·70	1·57	1·30	0·89	1·16	1·09	1·23	0·88	1·07
1851	1·27	1·87	1.05	0·40	0·78	0·50	0·81	0·74	1·06	1·20	0·62	0·88	0·94
1852	1·07	1·55	1·25	0 92	0·92	0·78	1·09	1·19	1·12	0·84	1·18	1·41	1·11
1853	1·20	1·06	1·05	0·93	0·61	0·75	0·77	0·87	1·14	0·90	1·61	1·05	1·00
1854	1·61	1·38	1·06	0·94	0·90	0·90	0·87	0·80	1·21	1·15	1·22	1·44	1·12
1855	1·24	1·47	1·13	0·83	0·56	0·93	0·71	1·08	1·34	1·38	1·45	2·11	1·19
Mean	1·87	1·72	1·40	0·92	0·82	0·92	0·94	1·10	1·34	1·49	1·47	1·61	1·30†
Mean	19·3	18·5	16·7	13·6	12·8	13·6	13·7	14·8	16·3	17·3	17·1	17·9	17·0 ‡

Philadelphia, Pa.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1841	---	---	---	---	---	---	0·15	0·28	0·51	0·60	0·48	0·61	
1841	0·14	---	---	---	---	---	0·21	0.03	0·09	0·20	0·58	0·75	
1842	0·53	1·70	0·69	0·79	0·41	0·26	0·15	0·24	0·17	0·28	0·43	0·55	
1843	0·56	0·84	1·33	0·44	0·23	0·20	0·16	0·26	0·78	0·74	0·78	0·68	
1844	1·10	0·68	1·06	0·54	0·59	0·46	0·46	0·37	0·86	0·91	0·80	1·14	
1845	1·23	1·16	1·80	1·70	1·46	1·02	---	---	---	---	---	---	
Mean	0·71	1·09	1·22	0·87	0·67	0·48	0·23	0·24	0·48	0·55	0·61	0·75	0.66†
Mean	11.9	14·7	15·6	13·2	11·6	9·8	6·8	6·9	9·8	10·5	11·0	12·2	11·5 ‡

* Kilogrammes. † Pounds per square foot. ‡ Miles per hour.
‖ Kilometers. § Paris feet per second.

TABLE VII—concluded.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
Wallingford, Conn.													
1857	---	---	---	---	---	---	---	---	3·40	5·14	5·98	5·87	
1858	5·35	7·74	7·37	5·38	4·75	3·34	2·88	3·62	4·46	6·00	7·06	4·55	
1859	3·47	5·07	8·83	8·50	3·36	4·14	2·99	---	---	---	---	---	
Mean	4·41	6·40	8·10	6·94	4·05	3·74	2·93	3·62	3·93	5·57	6·52	5·21	5·12*
Mean	6·35	9·22	11·66	9·99	5·83	5·39	4·22	5·21	5·66	8·02	9·39	7·50	7·37†
Mean	8·89	10·73	12·07	11·17	8·53	8·20	7·25	8·06	8·40	10·01	10·83	9·68	9·59‡
New York City.													
1869	6·97	8·00	7·88	8·67	7·48	5·56	6·33	5·81	6·68	7·81	9·26	8·84	7·44‡
Toronto, Canada.													
1854	6·91	6·91	8·03	6·81	5·38	4·15	4·03	4·60	4·04	4·57	7·54	8·56	5·96
1855	7·26	8·17	9·95	7·57	5·93	5·70	6·47	6·97	7·61	9·88	10·81	11·38	8·14
1856	10·69	10·71	11·39	6·05	9·81	5·30	5·84	7·03	6·53	6·07	8·75	11·56	8·31
1857	10·31	9·82	10·84	10·24	8·13	7·60	4·74	6·36	5·55	6·24	9·25	6·84	7·99
1858	7·40	9·12	8·56	9·57	9·30	5·53	5·76	6·50	5·69	5·96	8·87	9·36	7·64
1859	8·76	8·50	10·39	10·79	5·70	7·19	5·81	5·96	6·36	8·12	9·65	10·77	8·17
Mean	8·56	8·87	9·86	8·50	7·37	5·91	5·44	6·24	5·96	6·81	9·15	9·75	7·70‡

* Ounces per 100 square inches. † Ounces per 141 square inches. ‡ Miles per hour.

The results for Greenwich were derived from the "Greenwich Magnetic and Meteorological Observations." The instruments employed were Whewell's and Robinson's anemometers, the indications of the former having been reduced to those of the latter in the "Greenwich Observations for 1862. Introduction, p. 52." The results for Oxford were derived from the "Radcliffe Observations," and the instrument employed was Robinson's anemometer. The results for Liverpool were derived from the "Report of the British Association for the Advancement of Science for 1855," and the "Radcliffe Observations for 1857." The observations were made with Osler's anemometer. The results for Kew were derived from the "Radcliffe Observations for 1857." The results for Plymouth were derived from the "Quarterly Journal of Meteorological and Physical Science for 1842–3." The instrument employed was Whewell's anemometer. The results for Brussels were derived from Osler's anemometer, and are taken from the "Annales Meteorologiques de l'Observatoire royale de Bruxelles." The numbers denote pressure in kilogrammes, which have been reduced to pounds per square foot, and hence has been deduced the velocity in miles per hour in accordance with the Tables of the British Board of Trade (see Loomis' Meteorology, page 277). The results for Madrid were obtained from a Robinson's anemometer made by Casella, and are taken from the "Observaciones Meteorologicas Efectuadas en el Real Observatorio de Madrid." The results are given in kilometers, and have been reduced to miles per hour. The results for Mülhausen were derived from a Valz anemometer, and were taken from "Schmid's Meteorologie," p. 501. The results are expressed in Paris feet per second, which have been reduced to miles per hour. The results for Madras, India, were derived from Osler's anemometer, and were taken from the "Madras Meteorological Observations." The pressures expressed in pounds per square foot have been reduced to velocities in miles per hour by Loomis' Table. The results for the Cape of Good Hope were derived from Osler's anemometer, and were taken from the first number of the "Meteorological Papers of the Board of Trade, London, 1857." The results are given in pounds pressure per square foot, and have been reduced to velocities in miles per hour. The Philadelphia observations were made with Osler's anemometer, and are taken from the "Magnetic and Meteorological Observations at Girard College." The results, which are given in pounds per square foot, have been reduced to velocities in miles per hour. The results for Wallingford, Conn., were derived from Osler's anemometer, and are given in ounces of pressure on a surface of 100 square inches, which have been reduced to velocities in miles per hour. The observations for New York City were made with Robinson's anemometer, and are taken from the "Thirteenth Annual Report of the Board of Commissioners of the Central Park." The observations at Toronto, Canada, were made with Robinson's anemometer, and are derived from the "Abstracts of Meteorological Observations made at Toronto from 1854 to 1859."

TABLE VIII.—*Mean Monthly and Annual Velocities of the Wind, in miles per hour.*

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Cape of Good Hope	19·3	18·5	16·7	13·6	12·8	13·6	13·7	14·8	16·3	17·3	17·1	17·9	17·00
Brussels, Bel.,	19·2	19·1	15·7	19·2	11·3	8·6	12·6	10·5	12·7	13·0	13·6	14·3	14·50
Liverpool, Eng.	14·6	14·3	12·0	12·8	11·4	11·9	11·8	11·4	10·7	12·3	10·7	16·1	12·50
Philadelphia, Pa.	11·9	14·7	15·6	13·2	11·6	9 8	6·8	6·9	9·8	10·5	11·0	12·2	11·50
Oxford, Eng.	13 6	12·9	12·8	10·9	10·5	10·4	9·8	10·4	10·3	9·9	10·9	11·7	11·20
Greenwich, Eng.	11·2	11·9	11·5	10·4	9·7	9·8	9·4	9·4	9·2	10·2	10·6	11·6	10·40
Kew, Eng.,	11·6	10·3	12·7	11·7	11·4	9·7	9·3	9·3	8·2	7·5	7·9	10·4	10·00
Madrid, Spain,	11·6	7·8	15·5	10·3	11·4	11·2	11·1	10·4	10·2	7·8	6·8	6·3	10·00
Mülhausen, France	9·2	5·9	11·8	11·5	10·9	11·1	11·4	7 0	9·5	11·4	8·3	9·4	9·80
Wallingford, Conn.	8·9	10·7	12·1	11·2	8·5	8·2	7·2	8·1	8·4	10·0	10·8	9·7	9·59
Plymouth, Eng.	8·7	9·5	10·0	8·9	8·6	7·4	6·1	8·8	10·6	10·4	10·2	8·5	9 00
Toronto, Can.	8·6	8·9	9·9	8·5	7·4	5·9	5·4	6·2	6·0	6·8	9·1	9·7	7·70
New York City.	7·0	8·0	7·9	8·7	7·5	5·6	6·3	5·8	6·7	7·8	9·3	8·8	7·40
Madras, India,	7·1	4·8	6·6	9·3	9·8	8·5	9·0	6·6	5·2	5·2	7·8	8·0	7·34
New Haven, Conn.	6·3	7·4	7·2	7·2	6·1	4·7	4·6	4·3	5·2	5·8	6·8	7·2	6·06
Cairo, Egypt,	1·6	4·6	5·2	5·4	---	---	---	---	- -	---	---	---	----

Table VIII contains a summary of the mean monthly and annual velocities in miles per hour for each of the preceding stations. The stations are arranged in the order of the mean velocity of the wind. New Haven shows a less velocity than any other of the stations, except Cairo in Egypt. The observations for Cairo embrace only four months of the year 1865, and are derived from the "Appendix to the Edinburgh Astronomical Observations, Vol. XIII."

IX. Notes on the Geology of the Island of Yesso, Japan, from Observations made in 1862. By W. P. Blake.

Read February 21, 1872.

The salient features of the geology of the Island of Yesso, Japan, are volcanic. Symmetrical cones, snow-capped for a great part of the year, are the first landmarks that greet the eyes of the marine, as he approaches the coast, and are the last to disappear as he leaves it behind. The cone of Esan, in a solfataric condition, forms the eastern and southern headland of the island, not far distant from the port of Hakodadi and from Komangadaki Mountain, another solfataric cone which rises conspicuously upon the southern shore of Volcano Bay, at about the same distance from Hakodadi. This last mentioned mountain was in a state of violent eruption a few years ago, and threw out an enormous quantity of ashes, pumice, and hot water. Further north, beyond Volcano Bay, the beautiful cone of Shiribets is grouped with several others, but all of them are remarkable for their symmetry and grandeur. Most of these volcanic mountains may be regarded as extinct, though many yield quantities of sulphur and emit steam. At an early period their activity must have been prodigious, for almost everywhere throughout the island, or at least the southern portion of it, so far as explored, there is a vast deposit of fragments of trachyte, lava, scoriæ and volcanic débris. These materials are generally in the form of a stratified brecciated conglomerate, sometimes alternating with finer materials, such as beds of sandstone and of volcanic ashes.

A coarse conglomerate of this formation is found bordering the island from Esan nearly to Komangadaki, and extensively upon the western coast, as in the neighborhood of Iwanai. It is also found extensively developed in the interior.

Older and stratified formations appear to form the basis or foundation for the volcanic formations. At Ota, on the west coast, granitic and metamorphic rocks, in well defined outcrops, form a rugged coast. In the interior they form the principal watershed, and give rise to many rivers, in the beds of which gold is found in deposits which can be profitably worked. These metamorphic strata are uplifted, and generally trend northwest and southeast, and show flexure and bending exactly as in other and better known regions. Slates, sandstones, and limestones are found also at Esan, Shuokobi, and near Kakumi, and at the lead mines of Ishinowatari and Urup. The rocks at the two last-named places are not as much uplifted and metamorphosed as the granitic and auriferous rocks, but they are probably parts of the same series of formations. The only recognizable fossil found is apparently a fragment of a calamite, leading me to suspect that the beds are of Carboniferous age; but this is by no means certain, and although diligent search was made no other evidence of the age of these formations could be found. Near Iwanai there are beds of good coking coal in strata that have no lithological resemblance to the auriferous series, but they are uplifted at a high angle. Fossils apparently of Cretaceous or Jurassic age are found in the eastern part of the island.

The next stratified formation of interest is marine Tertiary or Post-tertiary, which rests unconformably upon the older stratified beds, and is highly charged in some places with well preserved fossils scarcely distinguishable from the mollusca now existing upon the coasts. In these deposits, and in later terrace-like formations, there is abundant evidence of the comparatively recent uplift of the whole island, and the same evidences are found upon the island of Nipon.

Dynamically, the formation of greatest interest is without doubt the volcanic conglomerate and the associated beds of finer volcanic materials. They record the most energetic volcanic action at an early period before the recent uplift, for it is almost certain that the mass of the conglomerate was deposited under water. It seems as if there had been a series of violent subaqueous eruptions, perhaps at the time the now-existing cones began to be formed. It is most probable that the island has been gradually formed by the rising of these separate cones above the sea, thus giving at first a group of islets, each a volcano, similar perhaps to those which can now be seen off the coast and at the entrance to the Bay of Yeddo. One is represented opposite the western coast on the Japanese maps.

X. Comparison of the Muscles of the Chelonian and Human Shoulder-girdles.* By Henry Shaler Williams.

Presented January, 1872.

The object of the following paper is to show the importance of the positions and relations to each other, and to the axes of the bones, of the *areas* of origin and insertion of muscles.

While comparing the muscles of the Chelonians with those of man, the writer observed that while the bones were found to differ much in shape and proportions, and the size, form and number of the muscular bundles, and their relations to each other, were often found to differ, the relations of the areas of origin to each other were found to be remarkably constant. Hence in dissecting out the muscles of the Chelonians from the body outward, or, in other words, tracing the muscles from the origin of motion to the part moved, it was observed that the areas of origin numbered 1, 2, 3, &c., on each bone, as they were exposed, belonged to muscles which were, in final action, very similar in all, however much they might differ in their size and strength and shape, and even insertion, in the different genera. Then came the assumption that the fundamental reason why muscles in different vertebrate animals should receive the same name is that they perform the same functions, or that their final action is the same; and in conclusion, we reach the rule that the areas of origin (or, in general, of the attachment) of muscles furnish the most exact means for determining the homologies existing in the muscular systems of different forms of animals.

To apply and illustrate this rule, we take the unique shoulder-girdle of the Chelonians and compare it with that of man.

The shoulder-girdle of man is composed, on each side, of a scapula (Pl. 12, figs. 1 and 2), which alone supports the fore limb, and a clavicle which articulates with a process of the scapula and connects it with the sternum. From, the scapula there arises a process from the median line of its posterior surface, called the spine (Pl. 12, fig. 1, s.), which extends outward into a process called the acromion process (Pl. 12, fig. 1, a.).

From the superior border, next the glenoid fossa, another process

* Abstract of a portion of a Thesis presented to the Sheffield Scientific School, when a candidate for the degree of Ph.D., July, 1871.

extends upward and forward, called the coracoid process (Pl. 12, fig. 1, c.). The axillary border of the scapula (Pl. 12, fig. 1, b.) is thickened, and is connected with the "spine" by a thin sheet of bone. The "acromion process" is articulated with the clavicle which passes from it to the sternum. The clavicle is also attached to the "coracoid process" by a ligament.

The shoulder-girdle of the Chelonian (Pl. 13, figs. 1 and 2) is composed of three shafts of bone, diverging from the glenoid cavity. One (Pl. 13, fig. 1, b′.) is attached proximally to the under side of the anterior part of the carapace by a ligament near to the first dorsal vertebra. The other two lie in a horizontal position, the one (Pl. 13, fig. 1, a′.) running from the articular end of the girdle to the anterior part of the upper side of the plastron, and attached to the latter by a strong ligament at its medial line; the third part runs obliquely toward the center of the plastron, its proximal or medial end being more or less free.

In homologizing the elements of these shoulder-girdles, the following results have been reached. The perpendicular shaft (Pl. 13, figs. 1, 2, b′.) of the Chelonian is regarded as the representative of the "external" or "axillary" border of the human scapula (Pl. 12, fig. 1, b.), and may be called the *scapula* proper.

The second anterior horizontal shaft of the girdle (Pl. 13, figs. 1, 5, 6, a′.) represents the "spine" and "acromion process" together, of the human scapula (Pl. 12, fig. 1, a. s.), and may be called the *acromion.*

The third, or posterior horizontal element (Pl. 13, fig. 1, c.), represents the "coracoid process," and may be called the *coracoid.*

From the "posterior" surface of the human scapula and its processes arise six or seven distinct muscles. Let us consider them separately, in their relations of origin and insertion.

The "teres major" arises from near the medial end of the axillary border of the scapula (Pl. 12, fig. 1, 1): part of the "latissimus dorsi" sometimes arises from the extreme end of this border (Pl. 12, fig. 1, 2): the direction of these two muscles, as well as their action and areas of insertion on the humerus, are closely related. The corresponding muscle in the Chelonians (Pl. 13, fig. 1, 1), called "teres major" by most all writers on the subject, arises from the anterior face of the *scapula*, the area of origin being a narrow line extending from the medial end to the acromio-scapular angle. It is inserted into the neck of the humerus together with the representative of the "latissimus" (Pl. 13, fig. 7, 1).

There is considerable difference in the positions of the areas of insertion of this muscle, here and in man, the discussion of which will not be introduced at this place.

The muscles "teres minor" and "infraspinatus" (Pl. 12, fig. 1, 3, 4) arise from the more distal or articular half of the "axillary" border, and from the thin lamina of bone connecting this border with the "spine." These two muscles are intimately associated in direction of action, as well as in their points of origin and of insertion, both being inserted on the more dorsal side of the greater (of anthropotomy), or radial tuberosity (Pl. 12, fig. 4, r., 4, 3). If these two muscles are represented in the Chelonians, I have little doubt but that the thin sheet of muscle arising from the angle formed by the scapula and acromion (Pl. 13, fig. 1, 3, 4), and inserted into the humerus on the dorsal side of the lateral tuberosity (Pl. 13, figs. 4 and 7, 3, 4), is the true one.

I have called this the *musculus scapulo-acromio-humeralis*, and am strongly inclined to consider it the true representative of the "teres minor" of anthropotomy. The "infraspinatus" may be considered as wanting, or as fused with the "teres minor"—to form this bundle. The assumption is that the lamina of bone connecting the "axillary border" with the "spine" in the mammalian form of scapula is not developed in the Chelonians, and that the element called *acromion* in the latter is the representative of the ridge called "spine" and the "acromion process" of the former, as will be further explained.

In the human scapula we observe again a strong muscle arising from the "spine" and acromion process (Pl. 12, fig. 1, 5), called the deltoid. The area of origin for this muscle is on the edge and surface of the spine and acromion, opposite the coracoid process, and reaching from the medial border of the scapula to the end of the acromion, where it articulates with the clavicle. It is inserted into the shaft of the humerus, near its middle, on a line with the greater or radial tuberosity (Pl. 12, fig. 3, 5).

The representative of this muscle in the Chelonians arises from the anterior side of the acromion; its area of origin extending from near the scapulo-acromial angle (where it is quite continuous with the *musculus scapulo-acromio-humeralis*, this fact quite agreeing with the idea that this latter muscle is the representative of the "infraspinatus and teres minor,") to near the medial extremity of the acromion (Pl. 13, fig. 1, 5).

Its insertion is into the radial tuberosity on its dorsal side (Pl. 13, figs. 4 and 7, 5). It will be observed that all the humeral motors in the Chelonians are inserted high up, close about the proximal head of the humerus, to the neck and tuberosities, so that we may not look for exact homologies in regard to their *insertional* areas.

The muscle next to be noticed is the "supraspinatus," which arises from the surface of the scapula beyond the spine, and between it and the coracoid (Pl. 12, fig. 1, 6).

If our homologizing of the Chelonian shoulder-girdle be correct, the representative of this muscle should arise from between the cora coid and acromion elements. Its insertion should be into the external or radial tuberosity. Now let us see how nearly these requirements are met. In the Chelonians there are two, more or less distinct bundles of muscle arising from the *acromion* and *coracoid*—from the edges facing each other and from the lower surfaces (Pl. 13, figs. 1, 5 and 6, 6, 6^a, 6^b,). In some genera these two bundles are quite distinct and separate throughout all their fleshy portion, and in others they are continuous, forming a broad but thin bundle, filling up the space between the *acromion* and *coracoid*, even to their medial extremities—the fibers forming the middle part of the bundle arising from the coraco-acromial ligament; but, in all cases observed, the two bundles have a common insertional tendon, which is inserted into the head of the radial (the "greater" in anthropotomy, the "lesser" of Chelonians) tuberosity of the humerus (Pl. 13, figs. 3 and 4, 6). These two muscles are the *M. acromio-humeralis secundus*, and the *M. coraco-humeralis secundus.* It will be observed that the insertion of their common tendon is near the insertion of *M. scapulo-acromio-humeralis*, the representative of the "infraspinatus" and "teres minor," the relation between them being almost precisely that which is observed in anthropotomy.

The only other humeral motor arising from this surface of the human scapula is the "coraco brachialis." In man this muscle arises from the extreme end of the coracoid process, together with one head of the triceps (Pl. 12, fig. 1, 7). In its course it lies outside of the "subscapularis," and is inserted into the shaft of the humerus near its middle, in a line with the lesser or ulnar tuberosity (Pl. 12, fig. 3, 7).

In the Chelonians we find a muscle arising from the upper surface of the coracoid (Pl. 13, fig. 2, 7), passing outside of the representative of the "*subscapularis*," and inserted into the humerus on the head and lower edge of the ulnar tuberosity (Pl. 13, figs. 3 and 4, 7), which is here greatly developed, so that it is larger than the radial one. This is the *M. coraco-humeralis primus*, and must be regarded as the representative of the "coraco-brachialis," if the assumptions already made be correct.

The "biceps" of anthropotomy arises by two heads; one area of origin covers the rim of the glenoid cavity at the base of the coracoid (Pl. 12, fig. 1, 9); the other area, in connection with that for the "coraco-brachialis," covers the end of the coracoid process (*9a*). The two heads run together on the under side of the arm, to be inserted by a single strong terete tendon into the ulna, near its proximal end.

In most Chelonians this muscle (Pl. 13, figs. 2, 6, 9) is represented by two distinct muscles, the *M. coraco-ulnaris* and *M. coraco radialis;* the former arising from the more distal part of the posterior edge of the coracoid, being inserted into the ulna near the proximal end; the other arising from the medial half of the same edge of the coracoid, being inserted into the radius and outer side of the wrist, and sometimes running as far as to the thumb. In one genus (*Chelonia*) the second part of the muscle is represented by only a tendonous ribbon continued on from the outside of the lower end of the first, and inserted in the region of the wrist.

There are two muscles remaining which have a scapular origin in man, the "subscapularis," and the long head of the "triceps." The area of origin for the "subscapularis" (Pl. 12, fig. 2, s), covers the anterior surface of the human scapula, its fibers converging toward the head of the humerus. Its insertion is into the lesser or ulnar tuberosity (Pl. 12, fig. 3, s).

In the Chelonians this is represented by two more or less distinct bundles (*M. M. scapulo-humeralis secundus* and *tertius*), arising from the scapula and inserted into the internal (ulnar) tuberosity (Pl. 13, figs. 1 and 2, s*a*, s*b*). The area of their origin covers the greater part of the shaft of the scapula from the origin of the "teres major" (Pl. 13, fig. 1, 1), extending around in front and on the posterior side quite to the inner side of the shaft. On account of the small size of the shaft, the origin, ends, and body of these muscles are pretty well fused together, but toward their distal ends two bundles may, in some cases, be made out, and in *Ptychemys*, of which the most careful dissections were made, two distinct insertions were made out, one on the outer, the other on the inner side of the ulnar—that is the greater, or internal, tuberosity (Pl. 13, figs. 3 and 4, s*a*, s*b*). The lower part of the insertion of the *M. coraco-humeralis primus*,—the representative of the "coraco-brachialis" (figs. 3 and 4, 7), separates these areas.

From the rim of the glenoid cavity on the outer side, at the base of the *scapula* (Pl. 13, fig. 1, 11*a*), arises, by a tendon, a muscle which is joined by a stronger bundle, having a humeral origin, and which it overlies for its whole length. It is inserted into the proximal head of the ulna, on its dorsal side, and acts as an extensor of the forearm. I presume there will be no hesitancy in regarding this as the representative of the long head of the "triceps" of anthropotomy.

This closes the list of muscles arising from the scapula and its processes in man, and acting upon the arm.

There is some reason for believing the episternal plates to be the representatives of the "clavicles" of anthropotomy. A portion of the representatives of the deltoid arises from the above mentioned elements. The *acromion* is attached to it ligamentously. The representative of the "sterno-cleido-mastoid" does not arise from it in any cases I have observed, but generally only from the medial edges of the "hyosternal plates," when they meet, or from the middle of the cartilaginous part of the sternum, when these plates do not meet at the medial line.

If we are to presume that the Chelonians have a representative of the mammalian clavicle, I think the episternal plate presents more characters homological with those of the clavicle than does any other element of the skeleton.

The anterior horizontal element of the shoulder-girdle, it will be remembered, is, in this paper, considered to be the representative of the spine and acromion process of the mammalian scapula, and not the clavicle, as Rüdinger and some others regard it.

Parker, in his work on the Shoulder-girdle and Sternum, regards the episternal element of the plastron as the representative of the clavicle. (See Parker's Mongr. on Shoulder-girdle and Sternum, 1868, pp. 133, &c.)

In the Chelonians there are no muscles, now remaining to be considered, which arise from the shoulder-girdle proper and act upon the parts of the fore-limb. In the genus *Chelonia* a few special bundles were observed arising from the base of the scapula and acting upon the humerus; but they must be regarded as "special muscles," as they were observed in no other specimens dissected.

In the Chelonians a long muscle arises from the anterior edge of the coracoid (Pl. 13, figs. 1, 5, 10), and runs forward under the neck to the hyoid apparatus.

It arises in man from the "superior" (coracoidal) border, at the base of the coracoid process (Pl. 12, fig. 1, 10), and is inserted into the hyoid apparatus. The relations which the areas of origin for this muscle, the "supraspinatus" and the "coraco-brachialis," bear to each other, is too closely followed in the Chelonians to be passed over as of no importance.

The areas of attachment of the muscles thus help in the determination of the bones, while they furnish the means, probably the most accurate, for determining the muscles themselves in the study of comparative anatomy.

I think it will be granted, after the comparisons already made, that the area of origin for the "omohyoid" in the Chelonian shoulder-girdle would find its true position on the *coracoid* or *acromion*, rather than on the *scapula*, and considering the origin of the representative of the "supraspinatus"—from both the acromion and the coracoid,—we are not so much puzzled to find where the representative of the former should arise, as we are surprised at the accuracy with which our rule is carried out.

The muscles which are inserted into the shoulder-girdle cannot be homologized so easily, nor should we expect them to agree so closely in different types of structure, since the attachment of the shoulder-girdle to the body is not by close joints, but by loose muscular and ligamentous attachments. Nevertheless a muscle arising from the edge of the carapace and inserted into the ends of the scapula (Pl. 13, fig. 2, 12), and attached by a thin sheet to the side of the same as far as to its base, then continued on to the end of the coracoid (Pl. 13, figs. 2 and 5, 12*b*), may certainly be considered as a representative of the "serratus anticus major" and "pectoralis minor," and though presenting slight variations, these are not more than the great modification of the whole arrangement of the shoulder-girdle of the Chelonians would demand.

The above considerations have suggested a theoretical explanation for the unique relation that the shoulder-girdle bears to the general frame-work of the skeleton in the Chelonians, which will, however, be deferred to some future time.

I have avoided making mention of the interpretations that other authors have given to the muscles under consideration, reserving this matter till the close. In the first place, I had access to only one original work on the subject (Rüdinger's Muskelen, &c.), and his interpretation of homologies did not satisfy me, and I also had difficulty in making out with certainty how much of the descriptions and determinations was original and how much had been taken from other writers. I left them all, therefore, and with scalpel and pencil undertook to work out the problem for myself.

Explanation of the Plates.

Plate 12.

Fig. 1. Outer surface of the left Human scapula.
" 2. Inner " " " " "
" 3. Anterior view of the left Human humerus.
" 4. Posterior " " " " "

Plate 13.

Fig. 1. Anterior view of the left shoulder-girdle of a Chelonian (*Ptychemys rugosa*). The upper end of the scapula points downward in the figure.
Fig. 2. Posterior view of the same.
Fig. 3. Left humerus; showing the ulnar side of the upper half of the bone.
Fig. 4. Left humerus; showing the radial side of the upper half of the bone.
Fig. 5. Superior view of the left shoulder-girdle of the same.
Fig. 6. Inferior view of the same.
Fig. 7. Dorsal view of the left humerus of the same.

Explanation of the Figures.

The dotted lines mark out the areas of attachment of the several muscles to the bones. The round dots, thus . . . . . ., are used to define the areas of origin, and the elongated ones, thus – – – –, are used to define the areas of insertion.

In the following list the names in the first row are those in common use in anthropotomy; those in the second row are names applied by various authors to corresponding parts in Chelonians.

The same numbers are used in both plates to designate parts, or areas, considered to be homologous.

1.	*Musculus teres major,*	*M. teres major.*
2.	" *latissimus dorsi,*	*M. latissimus dorsi.*
3. 4. 5.	" *teres minor,* " *infraspinatus,* " *deltoideus,*	*M. deltoideus.*
6.	" *supraspinatus,*	6*b*, *M. claviculo-brachialis* Rüd. 6*a*. *M. coraco-brachialis proprius anticus* Rüd.
7.	" *coraco-brachialis,*	*M. coraco-brachialis* Rüd.
8.	" *subscapularis,*	8*a*, *M. subscapularis* Rüd. *M. claviculo-brachialis* Boj. *M. supraspinatus*, anon. *M. subscapularis* Oken. 8*b*, *M. infraspinatus* Rüd.
9.	" *biceps,*	*M. biceps brachii* Rüd.
10.	" *omohyoideus,*	*M. coraco-hyoideus* Rüd., *omohyoideus* Boj.
11.	" *triceps,*	11*a*, 11*b*, *M. triceps brachii.*
12. 12*b*.	*M. serratus magnus.* *M. pectoralis minor.*	12*a*. *pars M. serratus anticus major* Rüd. *S. M. costo-scapularis* Rüd. 12*b*. *pars M. serratus anticus major* Rüd. *S. M. costo-coracoideus* Rüd. *S. M. pectoralis minor* Rüd. 12*c*. *pars M. serratus anticus major* Rüd. *S. M. subclaveus* Rüd. *S. M. costo-clavicularis* Rüd.
13.	*musculus pectoralis major.*	
14.	" *trapezius.*	

a,	Acromion process of scapula.	a′, *acromion.*
b,	Axillary border " "	b′, *scapula.*
c,	Coracoid process " "	c, *coracoid.*
s,	Spine " "	
g,	Glenoid cavity " "	
l,	Coraco-acromial ligament.	
r,	"Radial," or "greater" tuberosity.	"Radial," "lesser," or "outer" tuberosity of the humerus.
u,	"Ulnar," or "lesser" tuberosity.	"Ulnar," "greater," or "inner" tuberosity.
h,	Head of humerus.	

XI. Graphical Methods in the Thermodynamics of Fluids.

By J. Willard Gibbs.

Although geometrical representations of propositions in the thermodynamics of fluids are in general use, and have done good service in disseminating clear notions in this science, yet they have by no means received the extension in respect to variety and generality of which they are capable. So far as regards a general graphical method, which can exhibit at once all the thermodynamic properties of a fluid concerned in reversible processes, and serve alike for the demonstration of general theorems and the numerical solution of particular problems, it is the general if not the universal practice to use diagrams in which the rectilinear co-ordinates represent volume and pressure. The object of this article is to call attention to certain diagrams of different construction, which afford graphical methods coextensive in their applications with that in ordinary use, and preferable to it in many cases in respect of distinctness or of convenience.

QUANTITIES AND RELATIONS WHICH ARE TO BE REPRESENTED BY THE DIAGRAM.

We have to consider the following quantities:—

v, the volume,
p, the pressure,
t, the (absolute) temperature,
ϵ, the energy,
η, the entropy,
} of a given body in any state,

also W, the work done,
and H, the heat received,*
} by the body in passing from one state to another.

These are subject to the relations expressed by the following differential equations:—

* Work spent upon the body is as usual to be considered as a negative quantity of work done by the body, and heat given out by the body as a negative quantity of heat received by it.

It is taken for granted that the body has a uniform temperature throughout, and that the pressure (or expansive force) has a uniform value both for all points in the body and for all directions. This, it will be observed, will exclude irreversible processes, but will not entirely exclude solids, although the condition of equal pressure in all directions renders the case very limited, in which they come within the scope of the discussion.

$$dW = \alpha p dv, \tag{a}$$
$$d\varepsilon = \beta dH - dW, \tag{b}$$
$$d\eta = \frac{dH^*}{t}, \tag{c}$$

where α and β are constants depending upon the units by which v, p, W and H are measured. We may suppose our units so chosen that $\alpha=1$ and $\beta=1$,† and write our equations in the simpler form,

$$d\varepsilon = dH - dW, \tag{1}$$
$$dW = pdv, \tag{2}$$
$$dH = td\eta. \tag{3}$$

Eliminating dW and dH, we have

$$d\varepsilon = td\eta - pdv. \tag{4}$$

The quantities v, p, t, ε and η are determined when the state of the body is given, and it may be permitted to call them *functions of the state of the body.* The state of a body, in the sense in which the term is used in the thermodynamics of fluids, is capable of two independent variations, so that between the five quantities v, p, t, ε and η there exist relations expressible by three finite equations, different in general for different substances, but always such as to be in harmony with the differential equation (4). This equation evidently signifies that if ε be expressed as function of v and η, the partial differential co-efficients of this function taken with respect to v and to η will be equal to $-p$ and to t respectively.‡

* Equation (a) may be derived from simple mechanical considerations. Equations (b) and (c) may be considered as defining the energy and entropy of any state of the body, or more strictly as defining the differentials $d\varepsilon$ and $d\eta$. That functions of the state of the body exist, the differentials of which satisfy these equations, may easily be deduced from the first and second laws of thermodynamics. The term *entropy*, it will be observed, is here used in accordance with the original suggestion of Clausius, and not in the sense in which it has been employed by Professor Tait and others after his suggestion. The same quantity has been called by Professor Rankine the *Thermodynamic function.* See Clausius, Mechanische Wärmetheorie, Abhnd. ix, § 14; or Pogg. Ann., Bd. cxxv (1865), p. 390; and Rankine, Phil. Trans., vol. 144, p. 126.

† For example, we may choose as the unit of volume, the cube of the unit of length,—as the unit of pressure the unit of force acting upon the square of the unit of length,—as the unit of work the unit of force acting through the unit of length,—and as the unit of heat the thermal equivalent of the unit of work. The units of length and of force would still be arbitrary as well as the unit of temperature.

‡ An equation giving ε in terms of η and v, or more generally any finite equation between ε, η and v for a definite quantity of any fluid, may be considered as the fundamental thermodynamic equation of that fluid, as from it by aid of equations (2), (3) and (4) may be derived all the thermodynamic properties of the fluid (so far as reversible

On the other hand W and H are not functions of the state of the body (or functions of any of the quantities v, p, t, ε and η), but are determined by the whole series of states through which the body is supposed to pass.

FUNDAMENTAL IDEA AND GENERAL PROPERTIES OF THE DIAGRAM.

Now if we associate a particular point in a plane with every separate state, of which the body is capable, in any continuous manner, so that states differing infinitely little are associated with points which are infinitely near to each other,* the points associated with states of equal volume will form lines, which may be called *lines of equal volume*, the different lines being distinguished by the numerical value of the volume, (as lines of volume 10, 20, 30, etc.) In the same way we may conceive of *lines of equal pressure*, *of equal temperature*, *of equal energy*, *and of equal entropy*. These lines we may also call *isometric*, *isopiestic*, *isothermal*, *isodynamic*, *isentropic*,† and if necessary use these words as substantives.

Suppose the body to change its state, the points associated with the states through which the body passes will form a line, which we may call the *path* of the body. The conception of a path must include the idea of direction, to express the order in which the body passes through the series of states. With every such change of state there is connected in general a certain amount of work done, W, and of heat received, H, which we may call the *work* and the *heat* of the *path*.‡

processes are concerned,) viz: the fundamental equation with equation (4) gives the three relations existing between v, p, t, ε and η, and these relations being known, equations (2) and (3) give the work W and heat H for any change of state of the fluid.

* The method usually employed in treatises on thermodynamics, in which the rectangular co-ordinates of the point are made proportional to the volume and pressure of the body, is a single example of such an association.

† These lines are usually known by the name given them by Rankine, *adiabatic*. If, however, we follow the suggestion of Clausius and call that quantity *entropy*, which Rankine called the *thermodynamic function*, it seems natural to go one step farther, and call the lines in which this quantity has a constant value *isentropic*.

‡ For the sake of brevity, it will be convenient to use language which attributes to the diagram properties which belong to the associated states of the body. Thus it can give rise to no ambiguity, if we speak of the volume or the temperature of a point in the diagram, or of the work or heat of a line, instead of the volume or temperature of the body in the state associated with the point, or the work done or the heat received by the body in passing through the states associated with the points of the line. In like manner also we may speak of the body moving along a line in the diagram, instead of passing through the series of states represented by the line.

The value of these quantities may be calculated from equations (2) and (3),

$$dW = pdv$$
$$dH = td\eta,$$

i. e.,

$$W = \int pdv \qquad (5)$$
$$H = \int td\eta, \qquad (6)$$

the integration being carried on from the beginning to the end of the path. If the direction of the path is reversed, W and H change their signs, remaining the same in absolute value.

If the changes of state of the body form a cycle, i. e., if the final state is the same as the initial, the path becomes a *circuit*, and the work done and heat received are equal, as may be seen from equation (1), which when integrated for this case becomes $0 = H - W$.

The circuit will enclose a certain area, which we may consider as positive or negative according to the direction of the circuit which circumscribes it. The direction in which areas must be circumscribed in order that their value may be positive, is of course arbitrary. In other words, if x and y are the rectangular co-ordinates, we may define an area either as $\int ydx$, or as $\int xdy$.

If an area be divided into any number of parts, the work done in the circuit bounding the whole area is equal to the sum of the work done in all the circuits bounding the partial areas. This is evident from the consideration, that the work done in each of the lines which separate the partial areas appears twice and with contrary signs in the sum of the work done in the circuits bounding the partial areas. Also the heat received in the circuit bounding the whole area is equal to the sum of the heat received in all the circuits bounding the partial areas.*

If all the dimensions of a circuit are infinitely small, the ratio of the included area to the work or heat of the circuit is independent of the shape of the circuit and the direction in which it is described, and varies only with its position in the diagram. That this ratio is independent of the direction in which the circuit is described, is evident from the consideration that a reversal of this direction simply changes the sign of both terms of the ratio. To prove that the ratio

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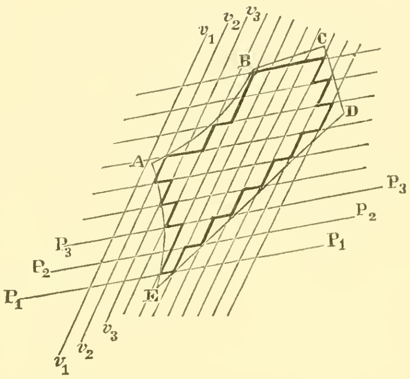
* The conception of areas as positive or negative renders it unnecessary in propositions of this kind to state explicitly the direction in which the circuits are to be described. For the directions of the circuits are determined by the signs of the areas, and the signs of the partial areas must be the same as that of the area out of which they were formed.

is independent of the shape of the circuit, let us suppose the area ABCDE (fig. 1) divided up by an infinite number of isometrics v_1v_1, v_2v_2, etc., with equal differences of volume dv, and an infinite number of isopiestics p_1p_1, p_2p_2, etc., with equal differences of pressure dp.* Now from the principle of continuity, as the whole figure is infinitely small, the ratio of the area of one of the small quadrilaterals into which the figure is divided to the work done in passing around it is approximately the same for all the different quadrilaterals. Therefore the area of the figure composed of all the complete quadrilaterals which fall within the given circuit has to the work done in circumscribing this figure the same ratio, which we will call γ. But the area of this figure is approximately the same as that of the given circuit, and the work done in describing this figure is approximately the same as that done in describing the given circuit, (eq. 5). Therefore the area of the given circuit has to the work done or heat received in that circuit this ratio γ, which is independent of the shape of the circuit.

Fig. 1.



Now if we imagine the systems of equidifferent isometrics and isopiestics, which have just been spoken of, extended over the whole diagram, the work done in circumscribing one of the small quadrilaterals, so that the increase of pressure directly precedes the increase of volume, will have in every part of the diagram a constant value, viz., the product of the differences of volume and pressure $(dv \times dp)$, as may easily be proved by applying equation (2) successively to its four sides. But the area of one of these quadrilaterals, which we could consider as constant within the limits of the infinitely small circuit, may vary for different parts of the diagram, and will indicate proportionally the value of γ, which is equal to the area divided by $dv \times dp$.

In like manner, if we imagine systems of isentropics and isothermals drawn throughout the diagram for equal differences $d\eta$ and dt, the heat received in passing around one of the small quadrilaterals, so that the increase of t shall directly preceed that of η, will be the constant product $d\eta \times dt$, as may be proved by equation (3), and the value of γ, which is equal to the area divided by the heat, will be indicated proportionally by the areas.*

This quantity γ, which is the ratio of the area of an infinitely small circuit to the work done or heat received in that circuit, and which we may call the scale on which work and heat are represented by areas, or more briefly, the *scale of work and heat*, may have a constant value throughout the diagram or it may have a varying value. The diagram in ordinary use affords an example of the first case, as the area of a circuit is everywhere proportional to the work or heat. There are other diagrams which have the same property, and we may call all such *diagrams of constant scale.*

In any case we may consider the scale of work and heat as known for every point of the diagram, so far as we are able to draw the isometrics and isopiestics or the isentropics and isothermals. If we

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* The indication of the value of γ by systems of equidifferent isometrics and isopiestics, or isentropics and isothermals, is explained above, because it seems in accordance with the spirit of the graphical method, and because it avoids the extraneous consideration of the co-ordinates. If, however, it is desired to have analytical expressions for the value of γ based upon the relations between the co-ordinates of the point and the state of the body, it is easy to deduce such expressions as the following, in which x and y are the rectangular co-ordinates, and it is supposed that the sign of an area is determined in accordance with the equation $A=\int ydx$:—

$$\frac{1}{\gamma}=\frac{dv}{dx}\cdot\frac{dp}{dy}-\frac{dp}{dx}\cdot\frac{dv}{dy}=\frac{d\eta}{dx}\cdot\frac{dt}{dy}-\frac{dt}{dx}\cdot\frac{d\eta}{dy},$$

where x and y are regarded as the independent variables;—or

$$\gamma=\frac{dx}{dv}\cdot\frac{dy}{dp}-\frac{dy}{dv}\cdot\frac{dx}{dp},$$

where v and p are the independent variables;—or

$$\gamma=\frac{dx}{d\eta}\cdot\frac{dy}{dt}-\frac{dy}{d\eta}\cdot\frac{dx}{dt},$$

where η and t are the independent variables;—or

$$\frac{1}{\gamma}=\frac{-\dfrac{d^2\varepsilon}{dv\,d\eta}}{\dfrac{dx}{dv}\cdot\dfrac{dy}{d\eta}-\dfrac{dy}{dv}\cdot\dfrac{dx}{d\eta}},$$

where v and η are the independent variables.

These and similar expressions for $\frac{1}{\gamma}$ may be found by dividing the value of the work or heat for an infinitely small circuit by the area included. This operation can be most conveniently performed upon a circuit consisting of four lines, in each of which one of the independent variables is constant. E. g., the last formula can be most easily found from an infinitely small circuit formed of two isometrics and two isentropics.

write δW and δH for the work and heat of an infinitessimal circuit, and δA for the area included, the relations of these quantities are thus expressed:—*

$$\delta W = \delta H = \frac{1}{\gamma}\,\delta A. \tag{7}$$

We may find the value of W and H for a circuit of finite dimensions by supposing the included area A divided into areas δA infinitely small in all directions, for which therefore the above equation will hold, and taking the sum of the values of δH or δW for the various areas δA. Writing W^C and H^C for the work and heat of the circuit C, and Σ^C for a summation or integration performed within the limits of this circuit, we have

$$W^C = H^C = \Sigma^C \frac{1}{\gamma}\,\delta A. \tag{8}$$

We have thus an expression for the value of the work and heat of a circuit involving an integration extending over an area instead of one extending over a line, as in equations (5) and (6).

Similar expressions may be found for the work and the heat of a path which is not a circuit. For this case may be reduced to the preceding by the consideration that $W=0$ for a path on an isometric or on the line of no pressure (eq. 2), and $H=0$ for a path on an isentropic or on the line of absolute cold. Hence the work of any path S is equal to that of the circuit formed of S, the isometric of the final state, the line of no pressure and the isometric of the initial state, which circuit may be represented by the notation $[S, v'', p^0, v']$. And the heat of the same path is the same as that of the circuit $[S, \eta'', t^0, \eta']$. Therefore using W^S and H^S to denote the work and heat of any path S, we have

$$W^S = \Sigma^{[S, v'', p^0, v']} \frac{1}{\gamma}\,\delta A, \tag{9}$$

$$H^S = \Sigma^{[S, \eta'', t^0, \eta']} \frac{1}{\gamma}\,\delta A, \tag{10}$$

where as before the limits of the integration are denoted by the ex-

* To avoid confusion, as dW and dH are generally used and are used elsewhere in this article to denote the work and heat of an infinite short path, a slightly different notation, δW and δH. is here used to denote the work and heat of an infinitely small circuit. So δA is used to denote an element of area which is infinitely small in all directions, as the letter d would only imply that the element was infinitely small in one direction. So also below, the integration or summation which extends to all the elements written with δ is denoted by the character Σ, as the character $\int$ naturally refers to elements written with d.

pression occupying the place of an index to the sign Σ.* These equations evidently include equation (8) as a particular case.

It is easy to form a material conception of these relations. If we imagine, for example, mass inherent in the plane of the diagram with a varying (superficial) density represented by $\frac{1}{\gamma}$, then $\Sigma \frac{1}{\gamma} \delta A$ will evidently denote the mass of the part of the plane included within the limits of integration, this mass being taken positively or negatively according to the direction of the circuit.

Thus far we have made no supposition in regard to the nature of the law, by which we associate the points of a plane with the states of the body, except a certain condition of continuity. Whatever law we may adopt, we obtain a method of representation of the thermodynamic properties of the body, in which the relations existing between the functions of the state of the body are indicated by a net-work of lines, while the work done and the heat received by the body when it changes its state are represented by integrals extending over the elements of a line, and also by an integral extending over the elements of certain areas in the diagram, or, if we choose to introduce such a consideration, by the mass belonging to these areas.

The different diagrams which we obtain by different laws of association are all such as may be obtained from one another by a process of *deformation*, and this consideration is sufficient to demonstrate

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* A word should be said in regard to the sense in which the above propositions should be understood. If beyond the limits, within which the relations of v, p, t, ε and η are known and which we may call the limits of the known field, we continue the isometrics, isopiestics, &c., in any way we please, only subject to the condition that the relations of v, p, t, ε and η shall be consistent with the equation $d\varepsilon = td\eta - pdv$, then in calculating the values of quantities W and H determined by the equations $dW = pdv$ and $dH = td\eta$ for paths or circuits in any part of the diagram thus extended, we may use any of the propositions or processes given above, as these three equations have formed the only basis of the reasoning. We will thus obtain values of W and H, which will be identical with those which would be obtained by the immediate application of the equations $dW = pdv$ and $dH = td\eta$ to the path in question, and which in the case of any path which is entirely contained in the known field will be the true values of the work and heat for the change of state of the body which the path represents. We may thus use lines outside of the known field without attributing to them any physical signification whatever, without considering the points in the lines as representing any states of the body. If however, to fix our ideas, we choose to conceive of this part of the diagram as having the same physical interpretation as the known field, and to enunciate our propositions in language based upon such a conception, the unreality or even the impossibility of the states represented by the lines outside of the known field cannot lead to any incorrect results in regard to paths in the known field.

their properties from the well-known properties of the diagram in which the volume and pressure are represented by rectangular co-ordinates. For the relations indicated by the net-work of isometrics, isopiestics etc., are evidently not altered by deformation of the surface upon which they are drawn, and if we conceive of mass as belonging to the surface, the mass included within given lines will also not be effected by the process of deformation. If, then, the surface upon which the ordinary diagram is drawn has the uniform superficial density 1, so that the work and heat of a circuit, which are represented in this diagram by the included area, shall also be represented by the mass included, this latter relation will hold for any diagram formed from this by deformation of the surface on which it is drawn.

The choice of the method of representation is of course to be determined by considerations of simplicity and convenience, especially in regard to the drawing of the lines of equal volume, pressure, temperature, energy and entropy, and the estimation of work and heat. There is an obvious advantage in the use of diagrams of constant scale, in which the work and heat are represented simply by areas. Such diagrams may of course be produced by an infinity of different methods, as there is no limit to the ways of deforming a plane figure without altering the magnitude of its elements. Among these methods, two are especially important,—the ordinary method in which the volume and pressure are represented by rectilinear co-ordinates, and that in which the entropy and temperature are so represented. A diagram formed by the former method may be called, for the sake of distinction, a *volume-pressure* diagram,—one formed by the latter, an *entropy-temperature* diagram. That the latter as well as the former satisfies the condition that $\gamma=1$ throughout the whole diagram, may be seen by reference to page 313.

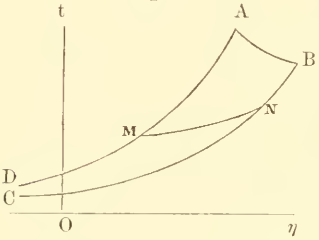
THE ENTROPY-TEMPERATURE DIAGRAM COMPARED WITH THAT IN ORDINARY USE.

Considerations independent of the nature of the body in question.

As the general equations (1), (2), (3) are not altered by interchanging v, $-p$ and $-W$ with η, t and H respectively, it is evident that, so far as these equations are concerned, there is nothing to choose between a volume-pressure and an entropy-temperature diagram. In the former, the work is represented by an area bounded by the path which represents the change of state of the body, two ordinates and the axis of abscissas. The same is true of the heat received in the latter diagram. Again, in the former diagram the heat received is represented by an area bounded by the path and certain lines, the character of which depends upon the nature of the body under consideration. Except in the case of an ideal body, the properties of which are determined by assumption, these lines are more or less unknown in a part of their course, and in any case the area will generally extend to an infinite distance. Very much the same inconveniences attach themselves to the areas representing work in the entropy-temperature diagram.* There is, however, a consideration of a general character, which shows an important advantage on the side of the entropy-temperature diagram. In thermodynamic problems, heat received at one temperature is by no means the equivalent of the same amount of heat received at another temperature. For example, a supply of a million calories at 150^c is a very different thing from a supply of a million calories at 50^c. But no such distinction exists in regard to work. This is a result of the general law, that heat can only pass from a hotter to a colder body, while work can be transferred by mechanical means from one fluid to any other, whatever may be

* In neither diagram do these circumstances create any serious difficulty in the estimation of areas representing work or heat. It is always possible to divide these areas into two parts, of which one is of finite dimensions, and the other can be calculated in the simplest manner. Thus, in the entropy-temperature diagram, the work done in a path AB (fig. 2) is represented by the area included by the path AB, the isometric BC, the line of no pressure and the isometric DA. The line of no pressure and the adjacent parts of the isometrics in the case of an actual gas or vapor are more or less undetermined in the present state of our knowledge, and are likely to remain so; for an ideal gas the line of no pressure coincides with the axis of abscissas, and is an asymptote to the isometrics. But, be this as it may, it is not necessary to examine the form of the remoter parts of the diagram. If we draw an isopiestic MN, cutting AD and BC, the area MNCD, which represents the work done in MN, will be equal to $p(v''-v')$, where p denotes the presure in MN, and v'' and v' denote the volumes at B and A respectively (eq. 5). Hence the work done in AB will be represented by ABNM$+p(v''-v')$. In the volume-pressure diagram, the areas representing heat may be divided by an isothermal, and treated in a manner entirely analogous.

Fig. 2.

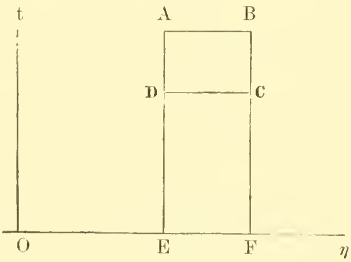


Or, we may make use of the principle, that, for a path which begins and ends on the same isodynamic, the work and heat are equal, as appears by integration of equation (1). Hence, in the entropy-temperature diagram, to find the work of any path, we may extend it by an isometric (which will not alter its work), so that it shall begin and end on the same isodynamic, and then take the heat (instead of the work) of the path thus extended. This method was suggested by that employed by Cazin (Théorie élémentaire des Machines à Air Chaud, p. 11) and Zeuner (Mechanische Wärmetheorie, p. 80) in the reverse case, viz: to find the heat of a path in the volume-pressure diagram.

the pressures. Hence, in thermodynamic problems, it is generally necessary to distinguish between the quantities of heat received or given out by the body at different temperatures, while as far as work is concerned, it is generally sufficient to ascertain the total amount performed. If, then, several heat-areas and one work-area enter into the problem, it is evidently more important that the former should be simple in form, than that the latter should be so. Moreover, in the very common case of a circuit, the work-area is bounded entirely by the path, and the form of the isometrics and the line of no pressure are of no especial consequence.

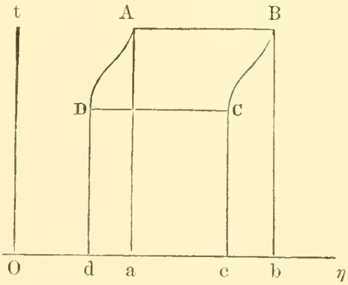
It is worthy of notice that the simplest form of a perfect thermodynamic engine, so often described in treatises on thermodynamics, is represented in the entropy-temperature diagram by a figure of extreme simplicity, viz: a rectangle of which the sides are parallel to the co-ordinate axes. Thus in figure 3, the circuit ABCD may represent the series of states through which the fluid is made to pass in such an engine, the included area representing the work done, while the area ABFE represents the heat received from the heater at the highest temperature AE, and the area CDEF represents the heat transmitted to the cooler at the lowest temperature DE.

Fig. 3.



There is another form of the perfect thermodynamic engine, viz: one with a perfect regenerator as defined by Rankine (Phil. Trans. vol. 144, p. 140), the representation of which becomes peculiarly simple in the entropy-temperature diagram. The circuit consists of two equal straight lines AB and CD (fig. 4) parallel to the axis of abscissas, and two precisely similar curves of any form BC and AD. The included area ABCD represents the work done, and the areas ABba and CDdc represent respectively the heat received from the heater and that transmitted to the cooler. The heat imparted by the fluid to the regenerator in passing from B to C, and afterward restored to the fluid in its passage from D to A, is represented by the areas BCcb and DAad.

Fig. 4.



It is often a matter of the first importance in the study of any thermodynamic engine, to compare it with a perfect engine. Such a comparison will obviously be much facilitated by the use of a method in which the perfect engine is represented by such simple forms.

The method in which the co-ordinates represent volume and pressure has a certain advantage in the simple and elementary character of the notions upon which it is based, and its analogy with Watt's indicator has doubtless contributed to render it popular. On the other hand, a method involving the notion of *entropy*, the very existence of which depends upon the second law of thermodynamics, will doubtless seem to many far-fetched, and may repel beginners as obscure and difficult of comprehension. This inconvenience is perhaps more than counterbalanced by the advantages of a method which makes the second law of thermodynamics so prominent, and gives it so clear and elementary an expression. The fact, that the different states of a fluid can be represented by the positions of a point in a plane, so that the ordinates shall represent the temperatures, and the heat received or given out by the fluid shall be represented by the area bounded by the line representing the states through which the body passes, the ordinates drawn through the extreme points of this line, and the axis of abscissas,—this fact, clumsy as its expression in words may be, is one which presents a clear image to the eye, and which the mind can readily grasp and retain. It is, however, nothing more nor less than a geometrical expression of the second law of thermodynamics in its application to fluids, in a form exceedingly convenient for use, and from which the analytical expression of the same law can, if desired, be at once obtained. If, then, it is more important for purposes of instruction and the like to familiarize the learner with the second law, than to defer its statement as long as possible, the use of the entropy-temperature diagram may serve a useful purpose in the popularizing of this science.

The foregoing considerations are in the main of a general character, and independent of the nature of the substance to which the graphical method is applied. On this, however, depend the forms of the isometrics, isopiestics and isodynamics in the entropy-temperature diagram, and of the isentropics, isothermals and isodynamics in the volume-pressure diagram. As the convenience of a method depends largely upon the ease with which these lines can be drawn, and upon the peculiarities of the fluid which has its properties represented in the diagram, it is desirable to compare the methods under consideration in some of their most important applications. We will commence with the case of a perfect gas.

Case of a perfect gas.

A perfect or ideal gas may be defined as such a gas, that for any constant quantity of it the product of the volume and the pressure varies as the temperature, and the energy varies as the temperature, i. e.,

$$pv = at, \qquad \text{(A)*}$$

$$\varepsilon = ct. \qquad \text{(B)}$$

The significance of the constant a is sufficiently indicated by equation (A). The significance of c may be rendered more evident by differentiating equation (B) and comparing the result

$$d\varepsilon = c\,dt$$

with the general equations (1) and (2), viz:

$$d\varepsilon = dH - dW, \quad dW = p\,dv.$$

If $dv = 0$, $dW = 0$, and $dH = c\,dt$, i. e.,

$$\left(\frac{dH}{dt}\right)_v = c,\dagger \qquad \text{(C)}$$

i. e., c is the quantity of heat necessary to raise the temperature of the body one degree under the condition of constant volume. It will be observed, that when different quantities of the same gas are considered, a and c both vary as the quantity, and $c \div a$ is constant; also, that the value of $c \div a$ for different gases varies as their specific heat determined for equal volumes and for constant volume.

With the aid of equations (A) and (B) we may eliminate p and t from the general equation (4), viz:

$$d\varepsilon = t\,d\eta - p\,dv,$$

which is then reduced to

$$\frac{d\varepsilon}{\varepsilon} = \frac{1}{c}\,d\eta - \frac{a}{c}\frac{dv}{v},$$

and by integration to

$$\log \varepsilon = \frac{\eta}{c} - \frac{a}{c}\log v.\ddagger \qquad \text{(D)}$$

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* In this article, all equations which are designated by arabic numerals subsist for any body whatever (subject to the condition of uniform pressure and temperature), and those which designated by small capitals subsist for any quantity of a perfect gas as defined above (subject of course to the same conditions).

† A subscript letter after a differential co-efficient is used in this article to indicate the quantity which is made constant in the differentiation.

‡ If we use the letter e to denote the base of the Naperian system of logarithms, equation (D) may also be written in the form

$$\varepsilon = e^{\frac{\eta}{c}}\, v^{-\frac{a}{c}}$$

This may be regarded as the fundamental thermodynamic equation of an ideal gas. See

The constant of integration becomes 0, if we call the entropy 0 for the state of which the volume and energy are both unity.

Any other equations which subsist between v, p, t, ε and η may be derived from the three independent equations (A), (B) and (D). If we eliminate ε from (B) and (D), we have

$$\eta = a \log v + c \log t + c \log c. \tag{E}$$

Eliminating v from (A) and (E), we have

$$\eta = (a+c) \log t - a \log p + c \log c + a \log a. \tag{F}$$

Eliminating t from (A) and (E), we have

$$\eta = (a+c) \log v + c \log p + c \log \frac{c}{a}. \tag{G}$$

If v is constant, equation (E) becomes

$$\eta = c \log t + \text{Const.},$$

i. e., the isometrics in the entropy-temperature diagram are logarithmic curves identical with one another in form,—a change in the value of v having only the effect of moving the curve parallel to the axis of η. If p is constant, equation (F) becomes

$$\eta = (a+c) \log t + \text{Const.},$$

so that the isopiestics in this diagram have similar properties. This identity in form diminishes greatly the labor of drawing any considerable number of these curves. For if a card or thin board be cut in the form of one of them, it may be used as a pattern or ruler to draw all of the same system.

The isodynamics are straight in this diagram (eq. B).

To find the form of the isothermals and isentropics in the volume-pressure diagram, we may make t and η constant in equations (A) and (G) respectively, which will then reduce to the well-known equations of these curves:—

$$pv = \text{Const.},$$

and

$$p^c \, v^{a+c} = \text{Const.}$$

The equation of the isodynamics is of course the same as that of the isothermals. None of these systems of lines have that property of identity of form, which makes the systems of isometrics and isopiestics so easy to draw in the entropy-temperature diagram.

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the last note on page 310. It will be observed, that there would be no real loss of generality if we should choose, as the body to which the letters refer, such a quantity of the gas that one of the constants a and c should be equal to unity.

Case of condensable vapors.

The case of bodies which pass from the liquid to the gaseous condition is next to be considered. It is usual to assume of such a body, that when sufficiently superheated it approaches the condition of a perfect gas. If, then, in the entropy-temperature diagram of such a body we draw systems of isometrics, isopiestics and isodynamics, as if for a perfect gas, for proper values of the constants a and c, these will be asymptotes to the true isometrics, etc., of the vapor, and in many cases will not vary from them greatly in the part of the diagram which represents vapor unmixed with liquid, except in the vicinity of the line of saturation. In the volume-pressure diagram of the same body, the isothermals, isentropics and isodynamics, drawn for a perfect gas for the same values of a and c, will have the same relations to the true isothermals, etc.

In that part of any diagram which represents a mixture of vapor and liquid, the isopiestics and isothermals will be identical, as the pressure is determined by the temperature alone. In both the diagrams which we are now comparing, they will be straight and parallel to the axis of abscissas. The form of the isometrics and isodynamics in the entropy-temperature diagram, or that of the isentropics and isodynamics in the volume-pressure diagram, will depend upon the nature of the fluid, and probably cannot be expressed by any simple equations. The following property, however, renders it easy to construct equidifferent systems of these lines, viz: any such system will divide any isothermal (isopiestic) into equal segments.

It remains to consider that part of the diagram which represents the body when entirely in the condition of liquid. The fundamental characteristic of this condition of matter is that the volume is very nearly constant, so that variations of volume are generally entirely inappreciable when represented graphically on the same scale on which the volume of the body in the state of vapor is represented, and both the variations of volume and the connected variations of the connected quantities may be, and generally are, neglected by the side of the variations of the same quantities which occur when the body passes to the state of vapor.

Let us make, then, the usual assumption that v is constant, and see how the general equations (1), (2), (3) and (4) are thereby affected. We have first,

$$dv = 0,$$

then $$dW = 0,$$

and $$d\varepsilon = t\,d\eta.$$

If we add $$dH = t\,d\eta,$$

these four equations will evidently be equivalent to the three independent equations (1), (2) and (3), combined with the assumption which we have just made. For a liquid, then, ε, instead of being a function of two quantities v and η, is a function of η alone,—t is also a function of η alone, being equal to the differential co-efficient of the function ε; that is, the value of one of the three quantities t, ε and η, is sufficient to determine the other two. The value of v, moreover, is fixed without reference to the values of t, ε and η (so long as these do not pass the limits of values possible for liquidity); while p does not enter into the equations, i. e., p may have any value (within certain limits) without affecting the values of t, ε, η or v. If the body change its state, continuing always liquid, the value of W for such a change is 0, and that of H is determined by the values of any one of the three quantities t, ε and η. It is, therefore, the relations between t, ε, η and H, for which a graphical expression is to be sought; a method, therefore, in which the co-ordinates of the diagram are made equal to the volume and pressure, is totally inapplicable to this particular case; v and p are indeed the only two of the five functions of the state of the body, v, p, t, ε and η, which have no relations either to each other, or to the other three, or to the quantities W and H, to be expressed.* The values of v and p do not really determine the state of an incompressible fluid,—the values of t, ε and η are still left undetermined, so that through every point in the volume-pressure diagram which represents the liquid there must pass (in general) an infinite number of isothermals, isodynamics and isentropics. The character of this part of the diagram is as follows:—the states of liquidity are represented by the points of a line parallel to the axis of pressures, and the isothermals, isodynamics and isentropics, which cross the field of partial vaporization and meet this line, turn upward and follow its course.†

In the entropy-temperature diagram the relations of t, ε and η are distinctly visible. The line of liquidity is a curve AB (fig. 5) determined by the relation between t and η. This curve is also an iso-

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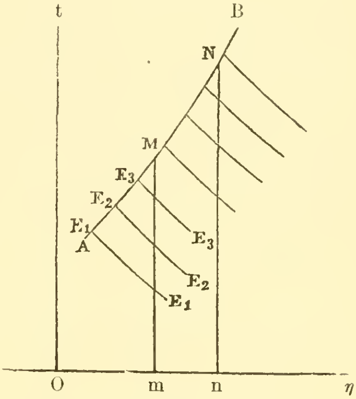
* That is, v and p have no such relations to the other quantities, as are expressible by equations; p, however, cannot be *less* than a certain function of t.

† All these difficulties are of course removed when the differences of volume of the liquid at different temperatures are rendered appreciable on the volume-pressure diagram. This can be done in various ways,—among others, by choosing as the body to which v, etc., refer, a sufficiently large quantity of the fluid. But, however we do it, we must evidently give up the possibility of representing the body in the state of vapor in the same diagram without making its dimensions enormous.

metric. Every point of it has a definite volume, temperature, entropy and energy. The latter is indicated by the isodynamics E_1E_1, E_2E_2, etc., which cross the region of partial vaporization and terminate in the line of liquidity. (They do not in this diagram turn and follow the line.) If the body pass from one state to another, remaining liquid, as from M to N in the figure, the heat received is represented as usual by the area MNnm. That the work done is nothing, is indicated by the fact that the line AB is an isometric. Only the isopiestics in this diagram are superposed in the line of fluidity, turning downward where they meet this line and following its course, so that for any point in this line the pressure is undetermined. This is, however, no inconvenience in the diagram, as it simply expresses the fact of the case, that when all the quantities v, t, ε and η are fixed, the pressure is still undetermined.

Fig. 5.



DIAGRAMS IN WHICH THE ISOMETRICS, ISOPIESTICS, ISOTHERMALS, ISODYNAMICS AND ISENTROPICS OF A PERFECT GAS ARE ALL STRAIGHT LINES.

There are many cases in which it is of more importance that it should be easy to draw the lines of equal volume, pressure, temperature, energy and entropy, than that work and heat should be represented in the simplest manner. In such cases it may be expedient to give up the condition that the scale (γ) of work and heat shall be constant, when by that means it is possible to gain greater simplicity in the form of the lines just mentioned.

In the case of a perfect gas, the three relations between the quantities v, p, t, ε and η are given on page 321, equations (A), (B) and (D). These equations may be easily be transformed into the three

$$\log p + \log v - \log t = \log a, \qquad \text{(H)}$$

$$\log \varepsilon - \log t = \log c, \qquad \text{(I)}$$

$$\eta - c \log \varepsilon - a \log v = 0; \qquad \text{(J)}$$

so that the three relations between the quantities $\log v$, $\log p$, $\log t$, $\log \varepsilon$, and η are expressed by linear equations, and it will be possible to make the five systems of lines all rectilinear in the same diagram, the distances of the isometrics being proportional to the differences of the logarithms of the volumes, the distances of the isopiestics being proportional to the differences of the logarithms of the pressures, and so with the isothermals and the isodynamics,—the distances of the isentropics, however, being proportional to the differences of entropy simply.

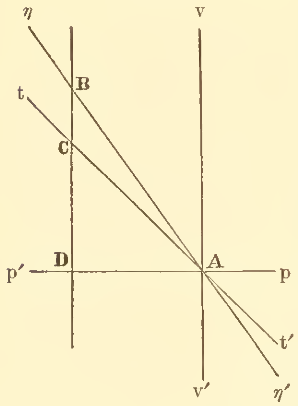
The scale of work and heat in such a diagram will vary inversely as the temperature. For if we imagine systems of isentropics and isothermals drawn throughout the diagram for equal small differences of entropy and temperature, the isentropics will be equidistant, but the distances of the isothermals will vary inversely as the temperature, and the small quadrilaterals into which the diagram is divided will vary in the same ratio: $\therefore \gamma \backsim 1 \div t$. (See page 313.)

So far, however, the form of the diagram has not been completely defined. This may be done in various ways: e. g., if x and y be the rectangular co-ordinates, we may make

$$\begin{cases} x = \log v, \\ y = \log p; \end{cases} \quad \text{or} \quad \begin{cases} x = \eta, \\ y = \log t; \end{cases} \quad \text{or} \quad \begin{cases} x = \log v, \\ y = \eta; \end{cases} \text{etc.}$$

Or we may set the condition that the logarithms of volume, of pressure and of temperature, shall be represented in the diagram on the same scale. (The logarithms of energy are necessarily represented on the same scale as those of temperature.) This will require that the isometrics, isopiestics and isothermals cut one another at angles of 60°.

Fig. 6.



The general character of all these diagrams, which may be derived from one another by projection by parallel lines, may be illustrated by the case in which $x = \log v$, and $y = \log p$.

Through any point A (fig. 6) of such a diagram let there be drawn the isometric vv′, the isopiestic pp″, the isothermal tt′ and the isentropic $\eta\eta'$. The lines pp′ and vv′ are of course parallel to the axes. Also by equation (II)

$$\tan tAp = \left(\frac{dy}{dx}\right)_t = \left(\frac{d \log p}{d \log v}\right)_t = -1,$$

and by (G)

$$\tan \eta Ap = \left(\frac{dy}{dx}\right)_\eta = \left(\frac{d \log p}{d \log v}\right)_\eta = -\frac{c+a}{c}.$$

Therefore, if we draw another isometric, cutting $\eta\eta'$, tt′, and pp′ in B, C and D,

$$\frac{\text{BD}}{\text{CD}}=\frac{c+a}{c},\quad \frac{\text{BC}}{\text{CD}}=\frac{a}{c},\quad \frac{\text{CD}}{\text{BC}}=\frac{c}{a}.$$

Hence, in the diagrams of different gases, CD ÷ BC will be proportional to the specific heat determined for equal volumes and for constant volume.

As the specific heat, thus determined, has probably the same value for most simple gases, the isentropics will have the same inclination in diagrams of this kind for most simple gases. This inclination may easily be found by a method which is independent of any units of measurement, for

$$\text{BD} : \text{CD} :: \left(\frac{d \log p}{d \log v}\right)_\eta : \left(\frac{d \log p}{d \log v}\right)_t :: \left(\frac{dp}{dv}\right)_\eta : \left(\frac{dp}{dv}\right)_t,$$

i. e., BD ÷ CD is equal to the quotient of the co-efficient of elasticity under the condition of no transmission of heat, divided by the co-efficient of elasticity at constant temperature. This quotient for a simple gas is generally given as 1.408 or 1.421. As CA ÷ CD = $\sqrt{2}=1.414$, BD is very nearly equal to CA (for simple gases), which relation it may be convenient to use in the construction of the diagram.

In regard to compound gases the rule seems to be, that the specific heat (determined for equal volumes and for constant volume) is to the specific heat of a simple gas inversely as the volume of the compound is to the volume of its constituents (in the condition of gas); that is, the value of BC ÷ CD for a compound gas is to the value of BC÷CD for a simple gas, as the volume of the compound is to the volume of its constituents. Therefore, if we compare the diagrams (formed by this method) for a simple and a compound gas, the distance DA and therefore CD being the same in each, BC in the diagram of the compound gas will be to BC in the diagram of the simple gas, as the volume of the compound is to the volume of its constituents.

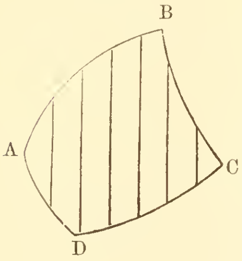
Although the inclination of the isentropics is independent of the quantity of gas under consideration, the rate of increase of η will vary with this quantity. In regard to the rate of increase of t, it is evident that if the whole diagram be divided into squares by isopiestics and isometrics drawn at equal distances, and isothermals be drawn as diagonals to these squares, the volumes of the isometrics, the pressures of the isopiestics and the temperatures of the isothermals will each form a geometrical series, and in all these series the ratio of two contiguous terms will be the same.

The properties of the diagrams obtained by the other methods mentioned on page 326 do not differ essentially from those just described. For example, in any such diagram, if through any point we draw an isentropic, an isothermal and an isopiestic, which cut any isometric not passing through the same point, the ratio of the segments of the isometric will have the value which has been found for BC : CD.

In treating the case of vapors also, it may be convenient to use diagrams in which $x = \log v$ and $y = \log p$, or in which $x = \eta$ and $y = \log t$; but the diagrams formed by these methods will evidently be radically different from one another. It is to be observed that each of these methods is what may be called a *method of definite scale* for work and heat; that is, the value of γ in any part of the diagram is independent of the properties of the fluid considered. In the first method $\gamma = \frac{1}{e^{x+y}}$, in the second $\gamma = \frac{1}{e^{y}}$. In this respect these methods have an advantage over many others. For example, if we should make $x = \log v$, $y = \eta$, the value of γ in any part of the diagram would depend upon the properties of the fluid, and would probably not vary in any case, except that of a perfect gas, according to any simple law.

The conveniences of the entropy-temperature method will be found to belong in nearly the same degree to the method in which the coordinates are equal to the entropy and the logarithm of the temperature. No serious difficulty attaches to the estimation of heat and work in a diagram formed on the latter method on account of the variation of the scale on which they are represented, as this variation follows so simple a law. It may often be of use to remember that such a diagram may be reduced to an entropy-temperature diagram by a vertical compression or extension, such that the distances of the isothermals shall be made proportional to their differences of temperature. Thus if we wish to estimate the work or heat of the circuit ABCD (fig. 7), we may draw a number of equidistant ordinates (isentropics) as if to estimate the included area, and for each of the ordinates take the differences of temperature of the points where it cuts the circuit; these differences of temperature will be equal to the lengths of the segments made by the corresponding circuit in the entropy-temperature diagram upon a corresponding system of equidistant ordinates, and may be used to calculate the

Fig. 7.



area of the circuit in the entropy-temperature diagram, i.e., to find the work or heat required. We may find the work of any path by applying the same process to the circuit formed by the path, the isometric of the final state, the line of no pressure (or any isopiestic; see note on page 318), and the isometric of the initial state. And we may find the heat of any path by applying the same process to a circuit formed by the path, the ordinates of the extreme points and the line of absolute cold. That this line is at an infinite distance occasions no difficulty. The lengths of the ordinates in the entropy-temperature diagram which we desire are given by the temperature of points in the path determined (in either diagram) by equidistant ordinates.

The properties of the part of the entropy-temperature diagram representing a mixture of vapor and liquid, which are given on page 323, will evidently not be altered if the ordinates are made proportional to the logarithms of the temperatures instead of the temperatures simply.

The representation of specific heat in the diagram under discussion is peculiarly simple. The specific heat of any substance at constant volume or under constant pressure may be defined as the value of

$$\left(\frac{dH}{dt}\right)_v \text{ or } \left(\frac{dH}{dt}\right)_p, \text{ i. e., } \left(\frac{d\eta}{d\log t}\right)_v \text{ or } \left(\frac{d\eta}{d\log t}\right)_p,$$

for a certain quantity of the substance. Therefore, if we draw a diagram, in which $x = \eta$ and $y = \log t$, for that quantity of the substance which is used for the determination of the specific heat, the tangents of the angles made by the isometrics and the isopiestics with the ordinates in the diagram will be equal to the specific heat of the substance determined for constant volume and for constant pressure respectively. Sometimes, instead of the condition of constant volume or constant pressure, some other condition is used in the determination of specific heat. In all cases, the condition will be represented by a line in the diagram, and the tangent of the angle made by this line with an ordinate will be equal to the specific heat as thus defined. If the diagram be drawn for any other quantity of the substance, the specific heat for constant volume or constant pressure, or for any other condition, will be equal to the tangent of the proper angle in the diagram, multiplied by the ratio of the quantity of the substance for which the specific heat is determined to the quantity for which the diagram is drawn.*

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* From this general property of the diagram, its character in the case of a perfect gas might be immediately deduced.

THE VOLUME-ENTROPY DIAGRAM.

The method of representation, in which the co-ordinates of the point in the diagram are made equal to the volume and entropy of the body, presents certain characteristics which entitle it to a somewhat detailed consideration, and for some purposes give it substantial advantages over any other method. We might anticipate some of these advantages from the simple and symmetical form of the general equations of thermodynamics, when volume and entropy are chosen as independent variables, viz:—*

$$p = -\frac{d\varepsilon}{dv}, \tag{11}$$

$$t = \frac{d\varepsilon}{d\eta}, \tag{12}$$

$$dW = p\,dv,$$

$$dH = t\,d\eta.$$

Eliminating p and t we have also

$$dW = -\frac{d\varepsilon}{dv}\,dv, \tag{13}$$

$$dH = \frac{d\varepsilon}{d\eta}\,d\eta. \tag{14}$$

The geometrical relations corresponding to these equations are in the volume-entropy diagram extremely simple. To fix our ideas, let the axes of volume and entropy be horizontal and vertical respectively, volume increasing toward the right and entropy upward. Then the pressure taken negatively will equal the ratio of the difference of energy to the difference of volume of two adjacent points in the same horizontal line, and the temperature will equal the ratio of the difference of energy to the difference of entropy of two adjacent points in the same vertical line. Or, if a series of isodynamics be drawn for equal infinitessimal differences of energy, any series of horizontal lines will be divided into segments inversely proportional to the pressure, and any series of vertical lines into segments inversely proportional to the temperature. We see by equations (13) and (14), that for a motion parallel to the axis of volume, the heat received is 0, and the work done is equal to the decrease of the energy, while for

* See page 310, equations (2), (3) and (4).

In general, in this article, where differential co-efficients are used, the quantity which is constant in the differentiation is indicated by a subscript letter. In this discussion of the volume-entropy diagram, however, v and η are uniformly regarded as the independent variables, and the subscript letter is omitted.

a motion parallel to the axis of entropy, the work done is 0, and the heat received is equal to the increase of the energy. These two propositions are true either for elementary paths or for those of finite length. In general, the work for any element of a path is equal to the product of the pressure in that part of the diagram into the horizontal projection of the element of the path, and the heat received is equal to the product of the temperature into the vertical projection of the element of the path.

If we wish to estimate the value of the integrals $\int p dv$ and $\int t d\eta$, which represent the work and heat of any path, by means of measurements upon the diagram, or if we wish to appreciate readily by the eye the approximate value of these expressions, or if we merely wish to illustrate their meaning by means of the diagram; for any of these purposes the diagram which we are now considering will have the advantage that it represents the differentials dv and $d\eta$ more simply and clearly than any other.

But we may also estimate the work and heat of any path by means of an integration extending over the elements of an area, viz: by the formulæ of page 315,

$$W^C = H^C = \Sigma^C \frac{1}{\gamma}\,\delta A,$$

$$W^S = \Sigma^{[S, v'', p^0, v']}\frac{1}{\gamma}\,\delta A,$$

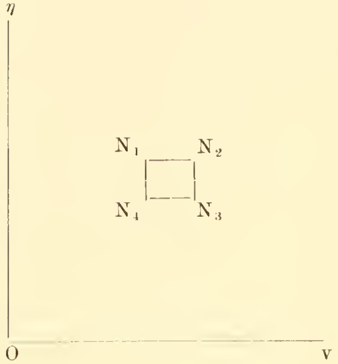
$$H^S = \Sigma^{[S, \eta'', t^0, \eta']}\frac{1}{\gamma}\,\delta A.$$

In regard to the limits of integration in these formulæ, we see that for the work of any path which is not a circuit, the bounding line is composed of the path, the line of no pressure and two vertical lines, and for the heat of the path, the bounding line is composed of the path, the line of absolute cold and two horizontal lines.

As the sign of γ, as well as that of δA, will be indeterminate until we decide in which direction an area must be circumscribed in order to be considered positive, we will call an area positive which is circumscribed in the direction in which the hands of a watch move. This choice, with the positions of the axes of volume and entropy which we have supposed, will make the value of γ in most cases positive, as we shall see hereafter.

The value of γ, in a diagram drawn according to this method, will depend upon the properties of the body for which the diagram is drawn. In this respect, this method differs from all the others which have been discussed in detail in this article. It is easy to find an expression for γ depending simply upon the variations of the energy, by comparing the area and the work or heat of an infinitely small circuit in the form of a rectangle having its sides parallel to the two axes.

Fig. 8.



Let $N_1N_2N_3N_4$ (fig. 8) be such a circuit, and let it be described in the order of the numerals, so that the area is positive. Also let ε_1, ε_2, ε_3, ε_4 represent the energy at the four corners. The work done in the four sides in order commencing at N_1, will be $\varepsilon_1-\varepsilon_2$, 0, $\varepsilon_3-\varepsilon_4$, 0. The total work, therefore, for the rectangular circuit is

$$\varepsilon_1-\varepsilon_2+\varepsilon_3-\varepsilon_4.$$

Now as the rectangle is infinitely small, if we call its sides dv and $d\eta$, the above expression will be equivalent to

$$-\frac{d^2\varepsilon}{dv\,d\eta}\,dv\,d\eta.$$

Dividing by the area $dv\,d\eta$, and writing $\gamma_{v,\,\eta}$ for the scale of work and heat in a diagram of this kind, we have

$$\frac{1}{\gamma_{v,\,\eta}}=-\frac{d^2\varepsilon}{dv\,d\eta}=\frac{dp}{d\eta}=-\frac{dt}{dv}. \qquad (15)$$

The two last expressions for the value of $1\div\gamma_{v,\,\eta}$ indicate that the value of $\gamma_{v,\,\eta}$ in different parts of the diagram will be indicated proportionally by the segments into which vertical lines are divided by a system of equidifferent isopiestics, and also by the segments into which horizontal lines are divided by a system of equidifferent isothermals. These results might also be derived directly from the propositions on page 313.

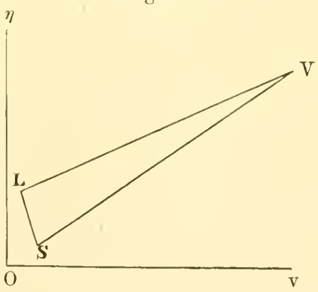
As, in almost all cases, the pressure of a body is increased when it receives heat without change of volume, $\frac{dp}{d\eta}$ is in general positive, and the same will be true of $\gamma_{v,\,\eta}$ under the assumptions which we have made in regard to the directions of the axes (page 330) and the definition of a positive area (page 331).

In the estimation of work and heat it may often be of use to consider the deformation necessary to reduce the diagram to one of constant scale for work and heat. Now if the diagram be so deformed, that each point remains in the same vertical line, but moves in this line so that all isopiestics become straight and horizontal lines, at distances proportional to their differences of pressure, it will evidently become a volume-pressure diagram. Again, if the diagram be so deformed that each point remains in the same horizontal line, but moves in it so that isothermals becomes straight and vertical lines at distances proportional to their differences of temperature, it will become a entropy-temperature diagram. These considerations will enable us to compute numerically the work or heat of any path which is given in a volume-entropy diagram, when the pressure and temperature are known for all points of the path, in a manner analogous to that explained on page 328.

The ratio of any element of area in the volume-pressure or the entropy-temperature diagram, or in any other in which the scale of work and heat is unity, to the corresponding element in the volume-entropy diagram is represented by $\frac{1}{\gamma_{v,\eta}}$ or $-\frac{d^2\varepsilon}{dv\,d\eta}$. The cases in which this ratio is 0, or changes its sign, demand especial attention, as in such cases the diagrams of constant scale fail to give a satisfactory representation of the properties of the body, while no difficulty or inconvenience arises in the use of the volume-entropy diagram.

As $-\frac{d^2\varepsilon}{dv\,d\eta}=\frac{dp}{d\eta}$, its value is evidently zero in that part of the diagram which represents the body when in part solid, in part liquid, and in part vapor. The properties of such a mixture are very simply and clearly exhibited in the volume-entropy diagram.

Fig. 9.



Let the temperature and the pressure of the mixture, which are independent of the proportions of vapor, solid and liquid, be denoted by t' and p'. Also let V, L and S (fig. 9) be points of the diagram which indicate the volume and entropy of the body in three perfectly defined states, viz: that of a vapor of temperature t' and pressure p', that of a liquid of the same temperature and pressure, and that of a solid of the same temperature and pressure. And let v_V, η_V, v_L, η_L, v_S, η_S denote the volume and entropy of these states. The position of the point which represents the body, when part is vapor, part liquid, and part solid, these parts being as μ, ν, and $1-\mu-\nu$, is determined by the equations

$$v = \mu\, v_V + \nu\, v_L + (1 - \mu - \nu)\, v_S,$$
$$\eta = \mu\, \eta_V + \nu\, \eta_L + (1 - \mu - \nu)\, \eta_S,$$

where v and η are the volume and entropy of the mixture. The truth of the first equation is evident. The second may be written

$$\eta - \eta_S = \mu\,(\eta_V - \eta_S) + \nu\,(\eta_L - \eta_S),$$

or multiplying by t',

$$t'\,(\eta - \eta_S) = \mu\, t'\,(\eta_V - \eta_S) + \nu\, t'\,(\eta_L - \eta_S).$$

The first member of this equation denotes the heat necessary to bring the body from the state S to the state of the mixture in question under the constant temperature t', while the terms of the second member denote separately the heat necessary to vaporize the part μ, and to liquefy the part ν of the body.

The values of v and η are such as would give the center of gravity of masses μ, ν and $1-\mu-\nu$ placed at the points V, L and S.* Hence the part of the diagram which represents a mixture of vapor, liquid and solid, is the triangle VLS. The pressure and temperature are constant for this triangle, i. e., an isopiestic and also an isothermal here expand to cover a space. The isodynamics are straight and equidistant for equal differences of energy. For $\frac{d\varepsilon}{dv} = -p'$, and $\frac{d\varepsilon}{d\eta} = t'$, both of which are constant throughout the triangle.

This case can be but very imperfectly represented in the volume-pressure, or in the entropy-temperature diagram. For all points in the same vertical line in the triangle VLS will, in the volume-pressure diagram, be represented by a single point, as having the same volume and pressure. And all the points in the same horizontal line will be represented in the entropy-temperature diagram by a single point, as having the same entropy and temperature. In either diagram, the whole triangle reduces to a straight line. It must reduce to a line in any diagram whatever of constant scale, as its area must become 0 in such a diagram. This must be regarded as a defect in these diagrams, as essentially different states are represented by the same point. In consequence, any circuit within the triangle

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* These points will not be in the same straight line unless

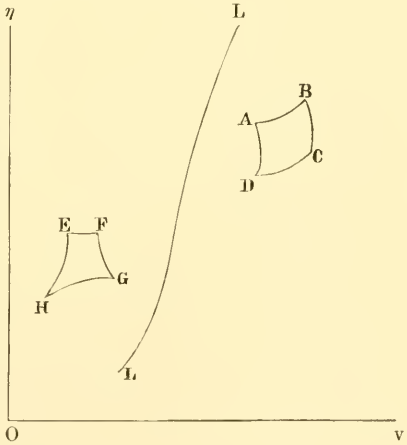
$$t'\,(\eta_V - \eta_S) : t'\,(\eta_L - \eta_S) :: v_V - v_S : v_L - v_S,$$

a condition very unlikely to be fulfilled by any substance. The first and second terms of this proportion denote the heat of vaporization (from the solid state) and that of liquefaction.

VLS will be represented in any diagram of constant scale by two paths of opposite directions superposed, the appearance being as if a body should change its state and then return to its original state by inverse processes, so as to repass through the same series of states. It is true that the circuit in question is like this combination of processes in one important particular, viz: that $W = H = 0$, i. e., there is no transformation of heat into work. But this very fact, that a circuit without transformation of heat into work is possible, is worthy of distinct representation.

A body may have such properties that in one part of the volume-entropy diagram $\frac{1}{\gamma_{v,\eta}}$, i. e., $\frac{dp}{d\eta}$ is positive and in another negative. These parts of the diagram may be separated by a line, in which $\frac{dp}{d\eta} = 0$, or by one in which $\frac{dp}{d\eta}$ changes abruptly from a positive to a negative value.* (In part, also, they may be separated by an area in which $\frac{dp}{d\eta} = 0$.) In the representation of such cases in any diagram of constant scale, we meet with a difficulty of the following nature.

Fig. 10.



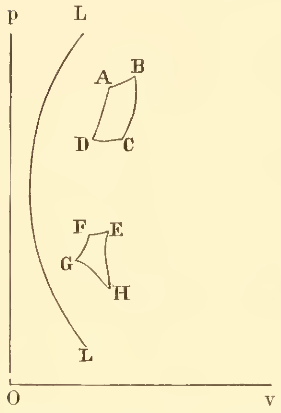
Let us suppose that on the right of the line LL (fig. 10) in a volume-entropy diagram, $\frac{dp}{d\eta}$ is positive, and on the left negative. Then, if we draw any circuit ABCD on the right side of LL, the direction being that of the hands of a watch, the work and heat of the circuit will be positive. But if we draw any circuit EFGH in the same direction on the other side of the line LL, the work and heat will be negative. For

$$W = H = \Sigma \frac{1}{\gamma_{v,\eta}} \delta A = \Sigma \frac{dp}{d\eta} \delta A,$$

* The line which represents the various states of water at its maximum density for various constant pressures is an example of the first case. A substance which as a liquid has no proper maximum density for constant pressure, but which expands in solidifying, affords an example of the second case.

and the direction of the circuits makes the areas positive in both cases. Now if we should change this diagram into any diagram of constant scale, the areas of the circuits, as representing proportionally the work done in each case, must necessarily have opposite signs, i. e., the direction of the circuits must be opposite. We will suppose that the work done is positive in the diagram of constant scale, when the direction of the circuit is that of the hands of a watch. Then, in that diagram, the circuit ABCD would have that direction, and the circuit EFGH the contrary direction, as in figure 11. Now if we imagine an indefinite number of circuits on each side of LL in the volume-entropy diagram, it will be evident that to transform such a diagram into one of constant scale, so as to change the direction of all the circuits on one side of LL, and of none on the other, the diagram must be *folded over* along that line; so that the points on one side of LL in a diagram of constant scale do not represent any states of the body, while on the other side of this line, each point, for a certain distance at least, represents two different states of the body, which in the volume-entropy diagram are represented by points on opposite sides of the line LL. We have thus in a part of the field two diagrams superposed, which must be carefully distinguished. If this be done, as by the help of different colors, or of continuous and dotted lines, or otherwise, and it is remembered that there is no continuity between these superposed diagrams, except along the bounding line LL, all the general theorems which have been developed in this article can be readily applied to the diagram. But to the eye or to the imagination, the figure will necessarily be much more confusing than a volume-entropy diagram.

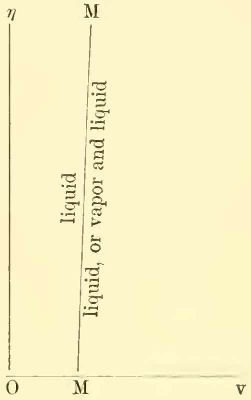
Fig. 11.



If $\frac{dp}{d\eta} = 0$ for the line LL, there will be another inconvenience in the use of any diagram of constant scale, viz: in the vicinity of the line LL, $\frac{dp}{d\eta}$, i. e., $1 \div \gamma_{v,\,\eta}$ will have a very small value, so that areas will be very greatly reduced in the diagram of constant scale, as compared with the corresponding areas in the volume-entropy diagram. Therefore, in the former diagram, either the isometrics, or the isentropics, or both, will be crowded together in the vicinity of the line LL, so that this part of the diagram will be necessarily indistinct.

It may occur, however, in the volume-entropy diagram, that the same point must represent two different states of the body. This occurs in the case of liquids which can be vaporized. Let MM (fig. 12) be the line representing the states of the liquid bordering upon vaporization. This line will be near to the axis of entropy, and nearly parallel to it. If the body is in a state represented by a point of the line MM, and is compressed without addition or subtraction of heat, it will remain of course liquid. Hence, the points of the space immediately on the left of MM represent simple liquid. On the other hand, the body being in the original state, if its volume should be increased without addition or subtraction of heat, and if the conditions necessary for vaporization are present (conditions relative to the body enclosing the liquid in question, etc.), the liquid will become partially vaporized, but if these conditions are not present, it will continue liquid. Hence, every point on the right of MM and sufficiently near to it represents two different states of the body, in one of which it is partially vaporized, and in the other it is entirely liquid. If we take the points as representing the mixture of vapor and liquid, they form one diagram, and if we take them as representing simple liquid, they form a totally different diagram superposed on the first. There is evidently no continuity between these diagrams except at the line MM; we may regard them as upon separate sheets united only along MM. For the body cannot pass from the state of partial vaporization to the state of liquid except at this line. The reverse process is indeed possible; the body can pass from the state of superheated liquid to that of partial vaporization, if the conditions of vaporization alluded to above are supplied, or if the increase of volume is carried beyond a certain limit, but not by gradual changes or reversible processes. After such a change, the point representing the state of the body will be found in a different position from that which it occupied before, but the change of state cannot be properly represented by any path, as during the change the body does not satisfy that condition of uniform temperature and pressure which has been assumed throughout this article, and which is necessary for the graphical methods under discussion. (See note on page 309.)

Fig. 12.



Of the two superposed diagrams, that which represents simple liquid is a continuation of the diagram on the left of MM. The isopiestics, isothermals and isodynamics pass from one to the other without abrupt change of direction or curvature. But that which represents a mixture of vapor and liquid will be different in its character, and its isopiestics and isothermals will make angles in general with the corresponding lines in the diagram of simple liquid. The isodynamics of the diagram of the mixture, and those of the diagram of simple liquid, will differ in general in curvature at the line MM, but not in direction, for $\frac{d\varepsilon}{dv} = -p$ and $\frac{d\varepsilon}{d\eta} = t$.

The case is essentially the same with some substances, as water, for example, about the line which separates the simple liquid from a mixture of liquid and solid.

In these cases the inconvenience of having one diagram superposed upon another cannot be obviated by any change of the principle on which the diagram is based. For no distortion can bring the three sheets, which are united along the line MM (one on the left and two on the right), into a single plane surface without superposition. Such cases, therefore, are radically distinguished from those in which the superposition is caused by an unsuitable method of representation.

To find the character of a volume-entropy diagram of a perfect gas, we may make ε constant in equation (D) on page 321, which will give for the equation of an isodynamic and isothermal

$$\eta = a \log v + \text{Const.},$$

and we may make p constant in equation (G), which will give for the equation of an isopiestic

$$\eta = (a + c) \log v + \text{Const.}$$

It will be observed that all the isodynamics and isothermals can be drawn by a single pattern and so also with the isopiestics.

The case will be nearly the same with vapors in a part of the diagram. In that part of the diagram which represents a mixture of liquid and vapor, the isothermals, which of course are identical with the isopiestics, are straight lines. For when a body is vaporized under constant pressure and temperature, the quantities of heat received are proportional to the increments of volume; therefore, the increments of entropy are proportional to the increments of volume. As $\frac{d\varepsilon}{dv} = -p$ and $\frac{d\varepsilon}{d\eta} = t$, any isothermal is cut at the same angle by all the isodynamics, and is divided into equal segments by equidifferent isodynamics. The latter property is useful in drawing systems of equidifferent isodynamics.

ARRANGEMENT OF THE ISOMETRIC, ISOPIESTIC, ISOTHERMAL AND ISENTROPIC ABOUT A POINT.

The arrangement of the isometric, the isopiestic, the isothermal and the isentropic drawn through any same point, in respect to the order in which they succeed one another around that point, and in respect to the sides of these lines toward which the volume, pressure, temperature and entropy increase, is not altered by any deformation of the surface on which the diagram is drawn, and is therefore independent of the method by which the diagram is formed.* This arrangement is determined by certain of the most characteristic thermodynamic properties of the body in the state in question, and serves in turn to indicate these properties. It is determined, namely, by the value of $\left(\frac{dp}{d\eta}\right)_v$ as positive, negative, or zero, i. e., by the effect of heat as increasing or diminishing the pressure when the volume is maintained constant, and by the nature of the internal thermodynamic equilibrium of the body as stable or neutral,—an unstable equilibrium, except as a matter of speculation, is of course out of the question.

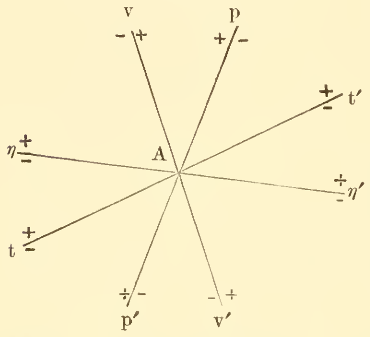
Let us first examine the case in which $\left(\frac{dp}{d\eta}\right)_v$ is positive and the equilibrium is stable. As $\left(\frac{dp}{d\eta}\right)_v$ does not vanish at the point in question, there is a definite isopiestic passing through that point, on one side of which the pressures are greater, and on the other less, than on the line itself. As $\left(\frac{dt}{dv}\right)_\eta = -\left(\frac{dp}{d\eta}\right)_v$, the case is the same with the isothermal. It will be convenient to distinguish the sides of the isometric, isopiestic, etc., on which the volume, pressure, etc., increase, as the *positive* sides of these lines. The condition of stability requires that, when the pressure is constant, the temperature shall increase with the heat received,—therefore with the entropy. This may be written $[dt:d\eta]_p > 0$.† It also requires that, when there is no

* It is here assumed that, in the vicinity of the point in question, each point in the diagram represents only one state of the body. The propositions developed in the following pages cannot be applied to points of the line where two superposed diagrams are united (see pages 335–338) without certain modifications.

† As the notation $\frac{dt}{d\eta}$ is used to denote the limit of the ratio of dt to $d\eta$, it would not be quite accurate to say that the condition of stability requires that $\left(\frac{dt}{d\eta}\right)_p > 0$. This

transmission of heat, the pressure should increase as the volume diminishes, i. e., that $[dp:dv]_\eta < 0$. Through the point in question, A (fig. 13), let there be drawn the isometric vv′ and the isentropic $\eta\eta'$, and let the positive sides of these lines be indicated as in the figure. The conditions $\left(\frac{dp}{d\eta}\right)_v > 0$ and $[dp:dv]_\eta < 0$ require that the pressure at v and at η shall be greater than at A, and hence, that the isopiestic shall fall as pp′ in the figure, and have its positive side turned as indicated. Again, the conditions

Fig. 13.



$$\left(\frac{dt}{dv}\right)_\eta < 0 \text{ and } [dt:d\eta]_p > 0$$

require that the temperature at η and at p shall be greater than at A, and hence, that the isothermal shall fall as tt′ and have its positive side turned as indicated. As it is not necessary that $\left(\frac{dt}{d\eta}\right)_p > 0$, the lines pp′ and tt′ may be tangent to one another at A, provided that they cross one another, so as to have the same order about the point A as is represented in the figure; i. e., they may have a contact of the second (or any even) order.* But the condition that $\left(\frac{dp}{d\eta}\right)_v > 0$, and hence $\left(\frac{dt}{dv}\right)_\eta < 0$, does not allow pp′ to be tangent to vv′, nor tt′ to $\eta\eta'$.

If $\left(\frac{dp}{d\eta}\right)_v$ be still positive, but the equilibrium be neutral, it will be possible for the body to change its state without change either of temperature or of pressure; i. e., the isothermal and isopiestic will be

condition requires that the ratio of the differences of temperature and entropy between the point in question and any other infinitely near to it and upon the same isopiestic should be positive. It is not necessary that the limit of this ratio should be positive.

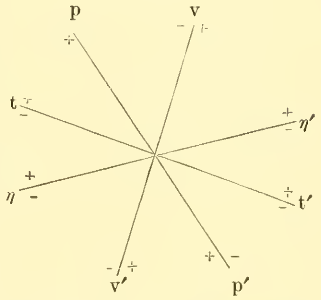
* An example of this is doubtless to be found at the critical point of a fluid. See Dr. Andrews "On the continuity of the gaseous and liquid states of matter." Phil. Trans., vol. 159, p. 575.

If the isothermal and isopiestic have a simple tangency at A, on one side of that point they will have such directions as will express an unstable equilibrium. A line drawn through all such points in the diagram will form a boundary to the *possible* part of the diagram. It may be that the part of the diagram of a fluid, which represents the superheated liquid state, is bounded on one side by such a line.

identical. The lines will fall as in figure 13, except that the isothermal and isopiestic will be superposed.

In like manner, if $\left(\frac{dp}{d\eta}\right)_v < 0$, it may be proved that the lines will fall as in figure 14 for stable equilibrium, and in the same way for neutral equilibrium, except that pp′ and tt′ will be superposed.*

Fig. 14.



The case that $\left(\frac{dp}{d\eta}\right)_v = 0$ includes a considerable number of conceivable cases, which would require to be distinguished. It will be sufficient to mention those most likely to occur.

In a field of stable equilibrium it may occur that $\left(\frac{dp}{d\eta}\right)_v = 0$ along a line, on one side of which $\left(\frac{dp}{d\eta}\right)_v > 0$, and on the other side $\left(\frac{dp}{d\eta}\right)_v < 0$. At any point in such a line the isopiestics will be tangent to the isometrics and the isothermals to the isentropics. (See, however, note on page 339.)

In a field of neutral equilibrium representing a mixture of two different states of the substance, where the isothermals and isopiestics are identical, a line may occur which has the threefold character of an isometric, an isothermal and an isopiestic. For such a line $\left(\frac{dp}{d\eta}\right)_v = 0$. If $\left(\frac{dp}{d\eta}\right)_v$ has opposite signs on opposite sides of this line, it will be an isothermal of maximum or minimum temperature.†

The case in which the body is partly solid, partly liquid and partly vapor has already been sufficiently discussed. (See page 333).

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* When it is said that the arrangement of the lines in the diagram must be like that in figure 13 or in figure 14, it is not meant to exclude the case in which the figure (13 or 14) must be turned over, in order to correspond with the diagram. In the case, however, of diagrams formed by any of the methods mentioned in this article, if the directions of the axes be such as we have assumed, the agreement with figure 13 will be *without inversion*, and the agreement with figure 14 will also be *without inversion* for volume-entropy diagrams, but *with inversion* for volume-pressure or entropy-temperature diagrams, or those in which $x = \log v$ and $y = \log p$, or $x = \eta$ and $y = \log t$.

† As some liquids expand and others contract in solidifying, it is possible that there are some which will solidify either with expansion, or without change of volume, or with contraction, according to the pressure. If any such there are, they afford examples of the case mentioned above.

The arrangement of the isometric, isopiestic, etc., as given in figure 13, will indicate directly the sign of any differential co-efficient of the form $\left(\frac{du}{dw}\right)_z$, where u, w and z may be any of the quantities v, p, t, η (and ε, if the isodynamic be added in the figure). The value of such a differential co-efficient will be indicated, when the rates of increase of v, p, etc., are indicated, as by isometrics, etc., drawn both for the values of v, etc., at the point A, and for values differing from these by a small quantity. For example, the value of $\left(\frac{dp}{dv}\right)_\eta$ will be indicated by the ratio of the segments intercepted upon an isentropic by a pair of isometrics and a pair of isopiestics, of which the differences of volume and pressure have the same numerical value. The case in which W or H appears in the numerator or denominator instead of a function of the state of the body, can be reduced to the preceding by the substitution of pdv for dW, or that of $td\eta$ for dH.

In the foregoing discussion, the equations which express the fundamental principles of thermodynamics in an analytical form have been assumed, and the aim has only been to show how the same relations may be expressed geometrically. It would, however, be easy, starting from the first and second laws of thermodynamics as usually enunciated, to arrive at the same results without the aid of analytical formulæ,—to arrive, for example, at the conception of energy, of entropy, of absolute temperature, in the construction of the diagram without the analytical definitions of these quantities, and to obtain the various properties of the diagram without the analytical expression of the thermodynamic properties which they involve. Such a course would have been better fitted to show the independence and sufficiency of a graphical method, but perhaps less suitable for an examination of the comparative advantages or disadvantages of different graphical methods.

The possibility of treating the thermodynamics of fluids by such graphical methods as have been described evidently arises from the fact that the state of the body considered, like the position of a point in a plane, is capable of two and only two independent variations. It is, perhaps, worthy of notice, that when the diagram is only used to demonstrate or illustrate general theorems, it is not necessary, although it may be convenient, to assume any particular method of forming the diagram; it is enough to suppose the different states of the body to be represented continuously by points upon a sheet.

XII. List of Marine Algæ collected near Eastport, Maine, in August and September, 1873, in connection with the work of the U. S. Fish Commission under Prof. S. F. Baird.* By Daniel C. Eaton.

1. **Fucus vesiculosus**, L.

2. **Fucus nodosus**, L

Both these species were very abundant on the rocks and wharves everywhere, between tide-marks. No *Fucus serratus* was found, though diligently sought for. It was found many years ago at Newburyport, Mass., by Capt. Pike (see Harvey's Nereis Bor. Am., III, p. 122), and has recently been sent from Pictou harbor, Nova Scotia, by *Rev. J. S. Fowler*.

3. **Desmarestia viridis**, Lamouroux.

Abundant on the wharves at Eastport, just below low-water-mark, and seen also at Dog Island.

4. **Desmarestia aculeata**, Lamour.

Even more common than the last, principally the aculeate form. The pencilled form, however, was found by *Mr. Prudden.*

5. **Alaria esculenta**, Grev.

Very abundant on rocks just below low-water-mark at Dog Island, and probably equally common in most similar places.—The shape of the pinnæ is varible, even on the same plant. One large specimen has obovate pinnæ five inches long and three broad, as those of *A. Pylaii* should be, but the base of the frond, so far from being cuneate and decurrent, is broad and rounded.

6. **Laminaria dermatodea**, De La Pylaie.

Dog Island, uncovered at extreme low-water. One specimen was brought up by the dredge off Campobello Island in twenty-five

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* I was at Eastport Aug. 12–17, collecting most of the time. Mr. T. M. Prudden and Mr. John B. Isham collected many specimens, both before and after my visit. Professor and Mrs. Verrill made large collections after I was at Eastport, and Dr. Edward Palmer collected a few species on Grand Menan. All these collections were placed in my hands for study. D. C. E.

fathoms of water. As the stem was freshly cut, and the frond not water-worn, the plant must have grown at this great depth.

7. **Laminaria longicruris,** De La Pylaie.

Common, but none were seen at Eastport of very great size. Grand Menan, 20 feet long, *Prof. Verrill.* A small but well characterized specimen was found by me in November, 1872, at Old Lyme, Connecticut: I believe it had not before been observed south of Cape Cod.

8. **Laminaria saccharina,** Lamouroux.

Common with the last, at and below low-water-mark. Among the specimens is one with a third lamina, or half-frond, somewhat narrower than the others, but running the whole length of the frond. Near the edge of one of the broadest wings are slight indications of a fourth wing. This explains the little known *L. trilaminata* of Mr. Olney, and shows it to be only a case of accidental deduplication or transverse chorisis. The specimen is about two feet long and six inches wide at the base, the stem slender and scarcely two inches long.

9. **Agarum Turneri,** Postells and Ruprecht.

Abundant, growing with the common Laminarias, also dredged at 20–25 fathoms by *Prof. Verrill.*

10. **Chorda Filum,** Stackhouse.

Common in Eastport harbor, from one to many feet below low-water-mark.

11. **Chorda lomentaria,** Lyngbye.

Abundant about the piers and wharves of the town, and at Dog Island, etc., mostly uncovered at low water. Some of the fronds are two or three feet long, half an inch in diameter, and often very much spirally twisted.

12. **Chordaria flagelliformis,** Agardh.

Very common in tide-pools and between tide-marks, assuming a great variety of forms. Var. *minor*, Agardh, is plentiful, especially in a great tide-pool at Dog Island. It is a profusely branched plant, with very slender branches, and might very easily be mistaken for *Dictyosiphon fœniculaceus.* Only very careful microscopic study will avail to distinguish them.

13. **Elachista fucicola,** Fries.

Common on Fucus, *Prof. Verrill.*

14. **Ectocarpus brachiatus,** Harvey.

15. **Ectocarpus littoralis,** Lyngbye.

16. **Ectocarpus siliculosus,** Lyngbye.

17. **Ectocarpus tomentosus,** Lyngbye.

All these species of Ectocarpus, and possibly one or two others, were collected on piles and rocks between tides, by *Prof. Verrill* and *Mr. Isham*. Authors do not seem to be at all united as to the limits of species in this genus, and with uncertain characters, and too often with specimens not in fruit, the identification of species is most doubtful.

18. **Polysiphonia urceolata,** Greville.

Common on rocks a few feet below low-water-mark. This is a very variable plant, passing from coarse and somewhat rigid forms, by many gradations, to the delicate var. *roseola* of J. G. Agardh (P. formosa, Harvey, Ner. Bor. Am.).

19. **Polysiphonia violacea,** Greville.

Collected early in August at Treat's Island by *Mr. Prudden*.

20. **Polysiphonia fastigiata,** Greville.

Very abundant on *Fucus nodosus* at Dog Island, etc. Grand Menan, *Dr. Palmer* (with 24–26 tubes!).

21. **Corallina officinalis,** Linn.

Rock-pools on outer coast of Campobello Island. Grand Menan, abundant, *Prof. Verrill*. This plant, which Dr. Harvey (Nereis Bor. Am., II, p. 83) said had not been sent him by any of his American correspondents, is abundant at Cape Ann, at Wood's Hole, and in various parts of Long Island Sound.

22. **Lithothamnion polymorphum,** Areschoug, in J. G. Agardh's Sp. Alg., II, p. 524.

Dredged in 18–20 fathoms, and encrusting rocks and shells up to low-water-mark; also seen in tide-pools. This is the common "Nullipore" of the coast of Maine, and occurs in a great many forms, from a minute dot up to branching knobby masses several inches in diameter.

23. **Delesseria sinuosa,** Lamouroux.

Cast ashore on Campobello Island and Grand Menan, also dredged abundantly in many places at ten to forty fathoms, and off Campobello Island in very deep water, (seventy-five fathoms, *Prof. Verrill*.)

24. **Delesseria alata**, Lamouroux.

Growing on *Ptilota serrata* at Dog Island, below low-water-mark, *Mr. Prudden.* Grand Menan, *Dr. Palmer.* Some of the specimens have the margins of the segments entire as described by Dr. Harvey, and as seen in fine Irish specimens sent me by Dr. Dickie, but others are much denticulated and laciniated, so as to suggest *D. denticulata* of Montague; but as transitions occur, and even the common Cape Ann plant has the margins by no means entire, I prefer to refer all the Eastport specimens to *D. alata.*

25. **Calliblepharis ciliata**, Kützing.

Campobello Island, *Mr. Prudden.* Grand Menan, *Dr. Palmer.*

26. **Polyides rotundus**, Greville.

Tide-pools, common.

27. **Hildenbrandtia**, ——?

Forming a very smooth, thickish, dark red crust on rocks, and sometimes on shells, always covered at low tide, and in rock-pools on Campobello Island. The only specimen brought home is not in fruit, and therefore I cannot identify it with certainty. The cells are about twice the diameter of those of the common *Hildenbrandtia* of southern New England, which I take to be *H. Crouani*, J. G. Agardh.

28. **Euthora cristata**, J. G. Agardh.

Rock-pools, on Campobello Island. Grand Menan, *Dr. Palmer*, with conceptacular fruit.

29. **Rhodymenia palmata**, Greville.

Very abundant, mostly between tides. A condition with numerous frondlets developed from the surface of the main frond is not uncommon.

30. **Ahnfeltia plicata**, Fries.

Grand Menan, *Dr. Palmer.*

31. **Cystoclonium purpurascens**, Kützing.

Tide-pools, on Campobello Island. Grand Menan, *Dr. Palmer.*

32. **Gigartina mamillosa**, J. G. Agardh.

Very abundant on rocks, mostly just above low-water-mark, also in tide-pools.

33. **Chondrus crispus**, Lyngbye.

A single specimen was given to Mr. Isham by a gentleman who found it at Grand Manan. The plant is dwarfish, and with narrow entangled divisions, but the section shows the proper cellular structure of this species.

34. **Halosaccion ramentaceum**, J. G. Agardh.

Plentiful on the rocks from half-tide down to the lowest tide-mark, and assuming very different forms. Some specimens are like the figure in Nereis Bor. Am., but most of the examples collected show a tendency to produce sword-shaped, flattened fronds, either simple or proliferously branched. The largest fronds are over a foot long, and an inch wide in the middle, from which they taper to a very slender base, and to a somewhat acute apex. When they remain simple, and all the largest are simple, they gradually become much curved, and the convex edge especially becomes much inflated and irregularly crested. For this form I propose the name of Var. *gladiatum*. Since I find no difference in the cellular structure, and since all kinds of intermediate forms occur, I dare not regard this form as a distinct species, though it is very unlike the forms hitherto known.

35. **Ceramium rubrum**, Agardh.

Found in a rock-pool on Campobello Island. Grand Manan, *Prof. Verrill* and *Dr. Palmer*.

36. **Ceramium Hooperi**, Harvey.

Found by *Prof. Verrill* on the piles of a wharf in Eastport, and at Grand Manan. Herring Cove, *Mr. Prudden*. In these specimens the creeping surculi are not preserved, but the cells, of nearly equal diameter and length, are filled with a beautiful rosy-purple endochrome, the nodes are coated with a definite band of rather large cellules, and some of the specimens show a few of the root-like filaments which Dr. Harvey saw on Mr. Hooper's original specimens from Penobscot Bay.

37. **Ptilota serrata**, Kützing.

Cast up on the shores, and dredged abundantly, even found at 75 fathoms. Growing below low-water-mark at Dog Island, *Mr. Prudden*. This alga varies considerably in the coarseness or delicacy of its parts, and one large but very delicate specimen from 50 fathoms depth off Grand Manan has some of the opposite branches or ramuli equally developed, so as to imitate *P. plumosa* not a little. I have seen no specimens from this region of undoubted *P. plumosa*, though as I write a true specimen of it is sent to me from Portland, collected by *Mrs. Roy*.

38. **Ptilota elegans**, Bonnemaison.

Tide-pools on Campobello Island, at Herring Cove. Little Green Island near Grand Manan, *Mr. Isham.*

39. **Callithamnion Americanum**, Harvey.

40. **Callithamnion Pylaisæi**, Montagne.

41. **Callithamnion floccosum**, Agardh.

These three species of *Callithamnion* were found parasitic on *Ptilota serrata* at Dog Island by *Mr. Prudden*, and Nos. 40 and 41 were found growing on muscle-shells among the wharves by *Prof. Verrill.*

42. **Callithamnion Rothii**, Lyngbye.

Growing in the piles of the wharves near low-water-mark, and on the rocks at Dog Island and Grand Manan, exposed at low-water, *Prof. Verrill* and *Mr. Prudden.*

43. **Porphyra vulgaris**, Agardh.

Very common between tide-marks, growing chiefly on other algæ, particularly on *Polysiphonia fastigiata.*

44. **Euteromorpha intestinalis**, Link.

Not so common as the next; found in a tide-pool near high-water-mark, on Campobello Island.

45. **Enteromorpha compressa**, Greville.

Very common about the docks, etc., growing as high up as the tide ever reaches.

46. **Enteromorpha** ——?

Floating in a large entangled mass in Cobscook Bay.—Fronds very pale-green, unbranched, filiform, tubular, varying in width, when compressed, from .001 inch to .03 inch; cells sub-quadrate or oblong, .0003 to .0005 inch in diameter, about eight rows in the slenderest fronds. I cannot identify this with any published species, but in the present state of my knowledge of the genus I am unwilling to give it a new name. The cells are much more regularly four-sided than in *E. compressa.*

47. **Ulva latissima**, L.

Very common.

48. **Cladophora arcta**, Dillwyn.

Abundant on rocks and piles of wharves near low-water-mark. Older plants, with the filaments much matted together (*C. centralis*, Kützing,) were found on the S. E. side of Campobello Island, in a rock-pool so high that ordinary tides would fail to reach it.

49. Cladophora ——?

On *Polyides rotundus* and *Gigartina*, at Dog Island, etc.—Plant forming deep-green tufts one-half to one inch in diameter, filament .0012 in. in diameter irregularly dichotomous, subcorymbose at the ends; cells mostly about twice as long as their diameter, rarely $2\frac{1}{2}$ times, often less than twice; rootlets none.—This has much the habit of *C. lanosa*, but lacks the rootlet-like branches, and has even the terminal cells very short.

50. Cladophora flexuosa, Griffiths.

Collected by *Prof. Verrill* and *Mr. Isham.*

51. Chætomorpha Melagonium, Weber and Mohr.

Tide-pools at very low levels, not rare.

52. Chætomorpha tortuosa, Dillwyn.

Grows in long entangled masses on *Fucus* and other large algæ, also on the piles of the wharves, quite common.

53. Hormotrichum boreale, Harvey?

Attached and free, in brackish pools just above high-water-mark on Little Green Island, *Prof. Verrill.*

Filaments light yellowish green, very long, entangled, average diameter, .0008 inch, cells from once to twice as long as their diameter, slightly constricted at the end; endochrome dispersed in roundish granules of very unequal size.

54. Hormotrichum speciosum, Carmichael?

Found on *Chordaria flagelliformis*, covering it with a dense dark-green pile. Filaments one-half to one inch long, their diameter .0015 to .0016 inch, very uniform; cells distinct, only one-fourth to one-third as long as their breadth, the filament slightly indented at each articulation; endochrome dense, a thin disk of it in each cell. I am very doubtful if this be the plant figured at plate 186 B of Phycologia Brittanica.

55. Hormotrichum Carmichaelii, Harvey.

On lobster-cages floating in the docks at Eastport, *Prof. Verrill.* Filaments much entangled, dark green, the diameter varying from .0008 inch to .0016 or even more, cell-wall very thick, the dissepiments not evident; endochrome dense, at first in barrel-shaped masses rather longer than thick, at last separating into somewhat lens-shaped disks.

56. Oscillatoria, ——?

Forms a dark blue or purple slimy coating on piles and logs, only in shaded places, *Prof. Verrill.* Filaments bluish-green, .0001 to .00013 inch in diameter. Probably a common European species, but I have no means of comparing it with authentic specimens.

The above list is as complete as the collections made will permit. It will be remembered that Algæ were sought for only a few weeks in August and September:—if this coast could be thoroughly explored at different seasons the list would doubtless be much extended.

New Haven, March 19th, 1873.

XIII.—The Early Stages of the American Lobster (*Homarus Americanus* Edwards). By Sidney I. Smith.*

A great part of the published observations on the early history of the higher crustacea has been confined to the changes which take place in the embryo within the egg or immediately after leaving it. Of the later stages, which connect the newly hatched young with the adult, very little is known, even in species of which the embryology proper has been considerably studied. This results naturally from the great difficulty of rearing the young of these animals in confinement. In fact, it is usually easier to obtain the young in the different stages directly from their native haunts, as has been so successfully done for some of the radiates and worms by Alexander Agassiz, than to attempt to rear them in ordinary vessels or small aquaria. In the case of many of the higher crustacea, a part of the early history might often be traced back from the adult more easily than it can be from the egg up.

The following account of the development of the American lobster during its free-swimming stages is one of the results of the facilities for collecting and studying the marine animals of Vineyard Sound, Buzzard's Bay and the adjacent region, afforded me during the summer of 1871, by Professor Spencer F. Baird, United States Commissioner of Fish and Fisheries.

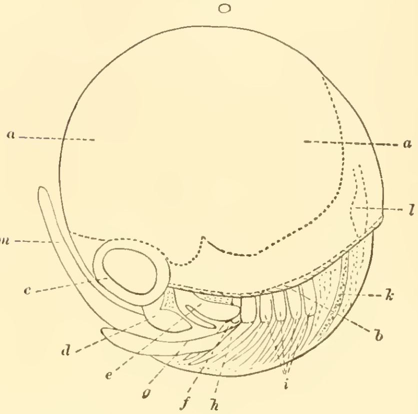
Numerous specimens of the free-swimming young of the lobster, in different stages of growth, were obtained in Vineyard Sound, but my time while there was so fully occupied in collecting that little was left for studying the animals while alive. The figures and descriptions which follow—except a few notes on color—have consequently all been made from specimens preserved in alcohol, so that this article is confined almost wholly to the development of the tegumentary appendages and does not include a study of the anatomy of the soft internal organs.

As no opportunities were offered in 1871 for observations upon the young within the egg, this deficiency has been partially supplied by

* A brief abstract of a part of this paper, with the figures on plate XIV, appeared in the American Journal of Science, 3d series, vol. iii, p. 1, June, 1872. A short notice of it is also inserted in an article on "The Metamorphoses of the Lobster and other Crustacea," in the Report of the U. S. Commissioner of Fish and Fisheries on the Condition of the Sea Fisheries of the Southern Coast of New England in 1871 and 1872, p. 522, 1873.

a few observations at New Haven in May, 1872.* Eggs taken May 2, from lobsters captured at New London, Connecticut, had embryos well advanced, as represented in figure 1. In this stage the eggs are slightly elongated spheroids, about 2.1^{mm} in the longer diameter and 1.9 in the shorter. One side is rendered very opaque dark green by the unabsorbed yolk mass, while the other shows the eyes as two large black spots, and the red pigment spots on the edge of the carapax, bases of the legs, etc., as irregular lines of pink markings.

Fig. 1.†



In a side view of the embryo, the lower edge of the carapax (*b*, figure 1) is clearly defined and extends in a gentle curve from the middle of the eye to the posterior border of the embryo. This margin of the carapax is marked with dendritic spots of red pigment. The whole dorsal portion, fully one-half the embryo, is still occupied by the unabsorbed portion of the yolk (*a*, *a*, figure 1), of which the lower margin, represented in the figure by a dotted line, extends from close above the eye in a curve nearly parallel with the lower margin of the carapax, but with a sharp indentation a little way behind the eye. The eyes (*c*, figure 1) are large, nearly round, not entirely separated from the surrounding tissues, and with a central portion of black pigment.

The antennulæ (*d*, figure 1) are simple, sack-like appendages, arising from just beneath the eyes, with the terminal portion turned back-

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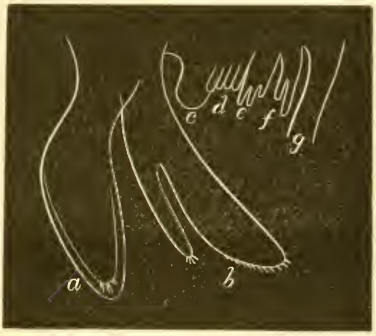
* The season at which the female lobsters carry eggs varies very much on different parts of the coast. Lobsters from New London and Stonington, Connecticut, are with eggs in April and May, while at Halifax, Nova Scotia, I found them with eggs, in which the embryos were just beginning to develop, early in September. A corresponding variation is noticed in the lobster of the European coast.

† Embryo, some time before hatching, removed from the external envelope and shown in a side view enlarged 20 diameters; *a*, *a*, dark-green yolk mass still unabsorbed; *b*, lateral margin of the carapax marked with many dendritic spots of red pigment; *c*, eye; *d*, antennula; *e*, antenna; *f*, external maxilliped; *g*, great cheliped which forms the big claw of the adult; *h*, outer swimming branch or exopodus of the same; *i*, the four ambulatory legs with their exopodal branches; *k*, intestine; *l*, heart; *m*, bilobed tail seen edgewise.

ward and marked with several large dendritic spots of red pigment. In specimens a little further advanced (figure 2) the future antennula is slightly separated from the external membrane of the sack and is seen forming within it, and at its tip there appear to be several rudimentary setæ.

Fig. 2.*



The antennæ (*e*, figure 1) are but little larger than the antennulæ and are sack-like and without articulations, but the scale and flagellum are separated and bent backward, the scale being represented by the large and somewhat expanded lobe, and the flagellum by a shorter and slender lobe which arises from near the base of the scale. In specimens a little further advanced (figure 2), the extremity of the scale shows a few very short and rudimentary setæ, and the flagellum is tipped with three of the same character.

The mandibles, both pairs of maxillæ, and the first and second maxillipeds are not sufficiently developed to be seen without removing the edge of the carapax and the adjacent parts. By dividing the embryo in two, however, removing the carapax, and viewing the parts under compression, a number of lobes corresponding to the mouth organs can be seen (figure 2). The anterior of these (*c*, figure 2), apparently representing the mandible, is broad, simple and clearly defined. Next are several small and indistinct lobes (*d*, figure 2) representing, probably, the maxillæ. Then, a larger lobe, indistinctly divided into three parts at the extremity (*e*, figure 2), represents the first maxilliped, and a slender lobe, with the terminal portion divided into two processes (*f*, figure 2), represents the second maxilliped. The external maxillipeds (*f*, figure 1, and *g*, figure 2) are well developed and almost exactly like the posterior cephalothoracic legs. Both the branches are simple and sack-like, the main branch, or endognathus,†

* Cephalic appendages of the left side of an embryo a little further advanced than figure 1, as seen under compression, enlarged 40 diameters; *a*, antennula; *b*, antenna; *c*, mandible; *d*, maxillæ; *e*, first maxilliped; *f*, second maxilliped; *g*, base of external maxilliped.

† To prevent confusion, the terms here used are the Latin forms of those proposed by Milne Edwards to designate the different branches of the cephalothoracic appendages: *endopodus*, for the main branch of a leg; *exopodus*, for the accessory branch; *epipodus*, for the flabelliform appendage; and *endognathus*, *exognathus*, and *epignathus*, for the corresponding branches of the mouth organs.

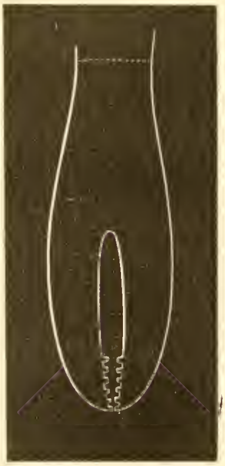
much larger and slightly longer than the outer branch, or exognathus, which is quite slender.

The five pairs of cephalothoracic legs (*g*, *h*, *i*, figure 1, and *a*, *b*, figure 3) are all similar and of about the same size, except the main branch of the first pair, (*g*, figure 1, and *a*, figure 3,) which is much larger than that of the others, but is still sack-like and entirely without articulations. The outer or exopodal branches of all the legs are slender, wholly unarticulated, sack-like processes, while the inner or main (endopodal) branches of the four posterior pairs are similar, but much stouter and slightly longer processes arising from the same bases. The bases of all the legs are marked with dendritic spots of red pigment like those upon the lower margin of the carapax.

Fig. 3.*

The abdomen (*m*, figure 1) is curved round beneath the cephalothorax, the extremity extending between and considerably in front of the eyes. The segments are scarcely distinguishable. The telson (figure 4) is fully a third of the entire length of the abdomen, and, as seen from beneath the embryo, is slightly expanded into a somewhat oval form, and very deeply divided by a narrow sinus, rounded at the extremity. The lobes into which the tail is thus divided are narrow, and somewhat approach each other toward the extremities, where they are each armed along the inner edge with six small obtuse teeth.

Fig. 4.†



The heart (*l*, figure 1) is readily seen, while the embryo is alive, by its regular pulsations. It appears as a slight enlargement in the dorsal vessel, just under the posterior portion of the carapax. The intestine (*k*, figure 1) is distinctly visible in the anterior portion of the abdomen as a well defined, transparent tube, in which float little granular masses. This material within the intestine is constantly oscillating back and forth as long as the embryo is alive.

* First and second cephalothoracic legs, as seen detached from the body and under compression, enlarged 40 diameters; *a*, leg of the anterior pair; *b*, leg of the second pair.

† Extremity of the abdomen, seen from above and slightly compressed, enlarged 30 diameters.

The subsequent development of the embryo within the egg was not observed.

The following observations on the young larvæ, after they have left the eggs, have been made upon specimens obtained in Vineyard Sound, or the adjacent waters, during July. These specimens were mostly taken at the surface in the day-time, either with the towing or hand net, and represent three quite different stages in the true larval condition, besides a later stage approaching closely the adult: (1) a free-swimming schizopodal form with the full number of cephalothoracic appendages, the abdomen without appendages, and the six posterior pairs of cephalothoracic appendages pediform and their exopodal branches developed into powerful swimming organs; (2) a similar form in which the rudimentary appendages have appeared upon the second to the fifth segments of the abdomen; and (3) a form in which the exopodal branches of the six posterior pairs of cephalothoracic appendages have decreased much in size, proportionally with the rest of the animal, and in which well formed appendages have appeared upon the penultimate segment of the abdomen in addition to those upon the second to the fifth segments. For convenience, I have designated these forms as the first, second, and third larval stages. In the next form observed the animal has lost all its schizopodal characters and assumed the more important features of the adult, although still retaining the free-swimming habit of the true larval forms. This stage I have indicated as the earliest stage of the adult form. The exact age of the larvæ in the first stage was not ascertained, but was probably only a few days, and they had most likely molted only once after leaving the eggs.

First larval stage.

In this stage the young are free-swimming schizopods about a third of an inch (7·8 to 8·0^{mm}·) in length (plate XIV, figs. *A*, *B*). The carapax is short and broad, somewhat gibbous posteriorly as seen from above, and projects in front into an unarmed, long, very slender and acute rostrum, which is horizontal, flattened vertically, and only a little less than half as long as the entire carapax including the rostrum. The inferior angle of the anterior margin projects, beneath the eye, into an acute, spiniform and prominent tooth. The cervical suture is faintly indicated, but no other areolation is perceptible. The posterior portions of the branchial regions are expanded laterally and the posterior margin incloses a space considerably larger than the base of the abdomen.

The ocular peduncles are very short and thick, directed straight outward, and apparently admit of only a small amount of motion. The cornea projects very slightly beyond the margin of the carapax and is very large, its diameter being about a third as great as the breadth of the carapax.

The antennulæ (plate XV, fig. 6, enlarged 30 diameters) are short, simple, sack-like appendages, about half as long as the rostrum, slightly contracted proximally, and entirely without division into segments. At tip they are each furnished with three simple setæ, one stout and about half as long as the antennula itself, the others very small and placed at the base of the larger. No sign of auditory apparatus could be discovered. In one specimen, which was approaching the time of molting, the antennulæ of the next stage was plainly visible through the integument (plate XV, fig. 7, enlarged 30 diameters), and show distinctly two separated segments representing the peduncle, the partial separation of the secondary, or inner, flagellum, and the hairs toward the tip of the outer flagellum.

The antennæ (plate XV, fig. 11, enlarged 30 diameters) are slightly longer than the antennulæ and much further developed. There is a sharp tooth at the base of the scale. The scale itself is highly developed and resembles considerably that of many of the Mysidea. It is broad, considerably longer than the flagellum, armed with a sharp tooth at the extremity of the outer margin, and the inner edge is furnished with very long plumose hairs, which are jointed through most of their length, and taper to very slender tips. The flagellum is shorter than the scale, separated from its peduncle by an articulation, but is itself not divided into segments, and is naked except at the tip, which is furnished with three equal, slender, plumose hairs like those upon the scale, only somewhat shorter.

The mandibles (plate XV, fig. 13, enlarged 25, and fig. 14, enlarged 40 diameters) are delicate and the crowns alone indurated. The palpi are very small, short and cylindrical, the three subequal segments faintly indicated, and the tip of each furnished with two short hairs. They are directed straight forward and apparently have no power of acting within the edges of the mandibles as in the adult. The coronal edges of the mandibles are asymmetrical. In both there is a very small molar-like area (fig. 14, *b*) at the posterior angle covered with fine teeth or bristles, and, in front of this, the margin, nearly to the anterior angle, is armed with acute spiriform teeth which are hooked slightly backward. At the anterior angle this margin is turned abruptly backward for a short distance below (in the natural position of the animal) the other edge, as a stout lamelliform process. This process is quite different in the two mandibles. In the left (fig. 14, *a*) its posterior margin is separated from the body of the mandible for quite a distance, and its inner, or terminal, edge divided into three irregular obtuse teeth, of which the posterior is most prominent; while on the right side this process is separated only for a short distance, the teeth are quite different in form, and the posterior one is the least prominent.

In the first pair of maxillæ (plate XVI, fig. 1, enlarged 40 diameters) the endognathus is composed, as in the adult, of two lobes (fig. 1, *a*, *b*), the proximal lobe (*a*) rounded at tip and margined with scattered setiform spinules, the distal lobe (*b*) truncated at the extremity, which is armed, somewhat as in the adult, with closely set acute spinules. The exognathus (fig. 1, *c*) is much shorter than the endognathus, is composed of a single article, and is armed at and near the distal extremity with four setæ (fig. 1*a*, enlarged 100 diameters), of which two are at the tip, the inner one about as long as the exognathus itself, the outer a little shorter; another, about as long as this last, arises from an emargination on the inside a little way from the tip; while the fourth arises near the base of the inner one and is very small.

In the second pair of maxillæ (plate XVI, fig. 4, enlarged 40 diameters) the four lobes of the endognathus (*a*) are proportionally much shorter than in the adult, the tips are broadly and evenly rounded and sparcely armed with stout and simple setæ. The exognathus (fig. 4, *b*) is short, scarcely reaching to the tip of the outer lobe of the endognathus. It is naked nearly to the tip, which is armed with six simple setæ. Three of these setæ are at the very tip (fig. 4*a*, enlarged 100 diameters), the inner and longest one equalling in length the body of the exognathus itself, the middle one somewhat shorter, and the outer very small; two others, as long as the middle one of the tip, arise together from an emargination upon the inner side near the extremity; while another starts from just below the bases of these, but is only half as long as they. The anterior portion of the epignathus (fig. 4, *c*) is about as long and slightly broader than the outer lobe of the endognathus, while the posterior portion is quite small, but little larger than the anterior. The edge of the epignathus is furnished all round with rather stout, jointed, and densely plumose hairs.

The first, or inner, maxillipeds (plate XVI, fig. 6, enlarged 40 diameters) differ from those of the adult chiefly in being more rudimentary. The endognathus (fig. 6, *a*) is only sparsely armed with stout setæ along and near the inner margin. The two segments of the mesognathus (fig. 6, *b*) are about equal in length, the basal one with two long simple setæ on the inner side at the distal extremity, and the terminal one with four at and near the tip. Of these terminal setæ (fig. 6*a*, enlarged 100 diameters) the longest about equals in length the terminal segment of the mesognathus itself and arises from an emargination on the inner side close to the tip, two, successively shorter, arise from the tip itself, while below the base of these is one still shorter. The exognathus (fig. 6, *c*) is not longer than the mesognathus, shows no segmentation, the outer edge is furnished with twelve to fifteen jointed, plumose setæ (fig. 6 *b*, enlarged 200 diameters), and at tip with two very short setæ, while the inner edge is naked. The epignathus (fig. 6, *d*) is small and naked, the posterior portion, though much longer than the anterior, is proportionally very much smaller than in the adult, and the extremity is rounded and produced at the inner angle.

The second maxillipeds (plate XVI, fig. 9, enlarged 40 diameters) are not flattened and appressed to the inner mouth organs as in the adult. The endognathus is stout and cylindrical, the last three segments are bent inward at nearly a right angle, and all the segments have about the same proportional lengths as in the adult. The inner sides of all the segments below the meral are armed with a few nearly straight setiform spines, while the carpal segment upon the outer side, and the succeeding ones all round, are sparcely armed with rather stout spines, some of which are minutely serrate; the terminal spine is much stouter than the others and curved toward the tip. The exognathus (fig. 9, *a*) is slender, rudimentary, composed of a single article, does not reach beyond the meral segment of the endognathus, and is furnished at the extremity with a very few short and rudimentary setæ, two of which are at the tip and two or three more arise from slight emarginations in each side, thus showing a very slight approach to the flagelliform character which this appendage has in the adult, although there is as yet no indication of segmentation, even at the tip. The epignathus (fig. 9, *b*) is rudimentary and sack-like, scarcely longer than the diameter of the segment from which it arises, and is apparently without a branchial appendage.

The external maxillipeds (plate XVI, fig. 13, enlarged 25 diameters) are elongated and pediform, the endognathus being as long as and much like the endopodi of the posterior legs, while the exognathus is like the exopodal branches of all the legs. The segments of the endognathus are all nearly cylindrical, and the five distal are armed with slender spines along the inner sides. The meral and propodal segments are equal in length, the ischial and carpal also equal in length, but a little shorter than the meral and propodal, while the terminal segment is scarcely longer than the diameter of the propodus, tapers rapidly to the tip, which is armed with three slender spines, the shortest of which is considerably longer than the segment itself and the longest nearly three times as long. The spines upon the distal end of the propodus are about as long as the segment itself, while those upon the inner sides of the other segments are much shorter. Most of the spines are armed for a large part of the length with two rows of acute and closely set teeth; although the two longest of the terminal ones and some of the others appear to be wholly unarmed. The exognathus (fig. 13, *a*) is about half as long as the endognathus, the distal, flagelliform portion being longer than the basal and composed of eight or nine segments, each of which is furnished at the distal end with two very long jointed and ciliated hairs, the distal ones fully as long as the flagelliform portion, but the ones toward the base somewhat shorter. The epignathus (fig. 13, *b*) and the three branchial appendages (fig. 13, *c*) are very rudimentary, being represented by small sack-like lobes, the one representing the epignathus larger than the others and distinguished from them by its better defined outline and less cellular structure.*

The anterior cephalothoracic legs (plate XIV, fig. *D*, enlarged 20, and plate XVII, fig. 9, enlarged 40 diameters), corresponding to the great chelate legs of the adult, are exactly alike, scarcely longer than the external maxillipeds, and only imperfectly subcheliform, with no power of prehension. The endopodus is stouter than in the second and third legs, but scarcely, if any, longer. The segments are all nearly cylindrical, and all except the coxal are armed along the inner

* The number of branchiæ, or branchial pyramids, in the American lobster is twenty on each side: a single small one upon the second maxilliped, three well-developed ones upon the external maxilliped, three upon the first cephalothoracic leg, four each upon the second, third, and fourth, and one upon the fifth. The number is probably the same in the European species, although the statements of different authors in regard to it are confused and contradictory. De Haan (Fauna Japonica, Crustacea, p. 146) states the number, for the genus *Homarus*, as nineteen on each side, giving only two for the external maxilliped, while Owen (Lectures on the Anatomy of the Invertebrate Animals, 2d ed., p. 322) and Edwards (Histoire naturelle des Crustacés, tome i, p. 86) gives the whole number on each side as twenty-two, although Edwards in another place in the same work, under *Homarus* (tome iii, p. 333), gives twenty as the number.

side, and the distal three all round, with slender spines. The propodus (plate XVII, fig. 9) is the longest and slightly the stoutest of the segments, the basal portion as long as the merus, the digital portion much shorter than the dactylus and tapering rapidly to a short spine-like tip, the inferior side armed with several pairs of slender spines, some of which are armed with two rows of acute teeth, and the distal end, on each side at the base of the digital portion, with a long slender spine armed, like those just mentioned, with two rows of acute teeth. The dactylus itself is much shorter than the basal portion of the propodus, tapers rapidly to the tip, which is terminated by a spine nearly as long as the dactylus itself, and is armed on both margins with several small and slender spines. The exopodus (plate XIV, fig. *D*, *a*) is just like the exognathus of the external maxillipeds, except that the flagelliform portion is a little longer and composed of ten segments. The epignathus (fig. *D*, *b*) and the three branchial appendages (fig. *D*, *c*) are almost exactly like those of the external maxillipeds. In the specimen figured all the branchial appendages were farther developed than in most of the specimens examined.

The second pair of legs (plate XVII, figs. 1 and 1*a*, enlarged 20 diameters) are nearly or quite as long as and very much like the first pair, but the endopodi are considerably more slender, the propodus is scarcely stouter than the carpus, is armed with fewer spines beneath, and the digital portion is much less developed, while the dactylus is more slender and is terminated by a longer spine. The exopodus, epipodus, and the four branchial appendages are just like the corresponding parts of the anterior legs, the flagelliform portion of the exopodus being composed of ten segments, as in all the other legs.

The third pair of legs are in all respects like the second pair, and appear to be quite indistinguishable from them.

The fourth and fifth pairs of legs are styliform, a little more slender than the second and third pairs, and the endopodi and exopodi in both pairs are quite similar in structure. The endopodi of the fourth pair are armed with slender spines like those upon the second and third pairs; their propodal segments are slender, longer than the other segments, and are armed on the inside, near the base of the dactylus, with several long spines themselves armed with two rows of acute teeth; and the dactyli are slender, rapidly tapering, half as long as the propodi, and are each terminated by a slender, slightly curved, spiniform stylet fully twice as long as the segment itself, and armed upon the outer side with rows of acute teeth like those upon the long spines of the propodus. The exopodi, epipodi, and the branchial appendages are exactly like the corresponding parts of the second and third pairs of legs.

In the posterior pair of legs (plate XVII, fig. 6, terminal portion of one, enlarged 40 diameters) the endopodus is slightly more slender than in the fourth pair, the propodus is proportionally a little longer, and the slender stylet at the tip of the dactylus is considerably more than twice as long as the dactylus itself. The exopodus is like that of the other legs, and the single rudimentary, branchial appendage is of the same size as those of the other legs.

The abdomen is slightly longer than the entire length of the carapax, quite slender, tapers gradually toward the extremity, and all the segments except the expanded telson are nearly cylindrical. The first segment does not extend beyond the posterior margin of the sides of the carapax and is entirely unarmed. The second, third, fourth and fifth segments are subequal in length, and each is armed with a stout dorsal spine arising from the posterior margin and curved backward, and has the posterior margin produced each side below into a smaller, straight, tooth-like spine. The lateral spines increase slightly in size from the second to the fifth segment. The dorsal spine upon the second segment is shorter than the segment itself, that upon the third is longer than the segment, and those upon the third and fourth are still longer and nearly equal. (Plate XVIII, fig. 8, lateral view of the fourth segment, enlarged 20 diameters, and fig. 9, diagram of a section of the same segment seen from behind, enlarged 30 diameters.) The penultimate segment is a little longer than the preceding, and is armed above with two short spines like the one upon the second segment, except that they are more curved toward the extremities.

The telson (plate XVIII, fig. 1, enlarged 20 diameters, and 1*a*, portion of one of the angles, enlarged 40 diameters) is closely articulated to the penultimate segment, so as apparently to admit of no motion between them, and is developed into a very large lamellar swimming appendage somewhat triangular in outline, with the posterior margin deeply concave. This caudal lamella is fully as long as the four preceding segments together and nearly the same in breadth across the posterior angles, being fully as broad as the widest part of the carapax. The posterior margin is deeply and regularly concave in outline, is armed with a stout median spine and the lateral angles project in long spiniform processes, while each side between the lateral angles and the median spine there are fourteen or fifteen stout plumose setæ articulated to the margin (plate XVIII, fig. 1*a*), the seta next the lateral angle being very much smaller than the others.

In life the eyes are bright blue; the anterior portion and the lower margin of the carapax and the bases of the legs are speckled with orange; the lower margin, the whole of the penultimate, and the basal portion of the ultimate segment of the abdomen, are brilliant reddish orange.

In this stage the larvæ were first taken July 1, when they were seen swimming rapidly about at the surface of the water among great numbers of zoëæ, megalops, and copeopods. Their motions and habits recall at once the species of *Mysis* and *Thysanopoda*, but their motions are not quite as rapid and are more irregular. They were frequently taken at the surface in different parts of Vineyard Sound from July 1 to 7, and several were taken off Newport, Rhode Island, as late as July 15, and they would very likely be found also in June, judging from the stage of development to which the embryos had advanced early in May in Long Island Sound. Besides the specimens taken in the open water of the Sound, a great number was obtained, July 6, from the well of a lobster-smack, where they were swimming in great abundance near the surface of the water, having undoubtedly been recently hatched from the eggs carried by the female lobsters confined in the well. Some of these specimens lived in vessels of fresh sea-water for two days, but all efforts to keep them alive long enough to observe their molting failed. They appeared, while thus in confinement, to feed principally upon very minute animals of different kinds, but were several times seen to devour small zoëæ, and occasionally when much crowded, so that some of them became exhausted, they fed upon each other, the stronger ones eating the weaker.

Second larval stage.

In this stage the larvæ have increased somewhat in size, and rudimentary appendages have appeared upon the second to the fifth segments of the abdomen.

The carapax is proportionally a little narrower than in the first stage and the cervical suture is a little more distinctly indicated. The rostrum (plate XV, fig. 2, enlarged 10 diameters) is much broader at base, more triangular in outline, and is armed on each side toward the base with three or four teeth, the terminal portion being slender, acute and unarmed. The number of teeth upon the sides of the rostrum vary somewhat in different specimens and often on the different sides of the same specimen. In all, however, there is a stout tooth each side over the eye and either two or three smaller ones in front of it.

The ocular peduncles are slightly longer and less stout in proportion than in the first stage, and the cornea is not quite as broad.

The antennulæ (plate XV, fig. 8, enlarged 20 diameters) are proportionately no larger than in the last stage, but the three segments of the peduncle are distinctly defined and the flagella are separated down to the peduncle. The primary, or outer, flagellum is as short as the peduncle, indistinctly divided into about six segments, and the inner side furnished, especially toward the distal extremity, with many cylindrical, and apparently tubular, hairs, which are half as long as the flagellum itself and truncated at tip. The secondary, or inner, flagellum is slender, about a third the diameter of the primary, and considerably shorter, shows no division into segments, and is furnished with one long and one very short cilium at tip. The distal segment of the peduncle bears, near the base of the secondary flagellum, a single, long, sparsely cillated hair, perhaps auditory in its function, but no other indication of auditory apparatus connected with the peduncle was discovered.

The antennæ are as in the first stage, except that the flagella are almost as long as the scales, and in all the specimens examined are without the long hairs at the tips.

The mandibles are as in the first stage, except that they are perhaps slightly more indurated and the segments of the palpi more distinctly indicated.

In the first maxillæ, the spines and setæ upon the lobes of the endognathus have increased slightly in number and size. The exognathus is proportionally somewhat longer and has an additional seta at the tip, so that there are three terminal ones increasing in length from the outside; while the large one upon the inside arises somewhat further from the tip.

In the second maxillæ, the lobes of the endognathus and the exognathus are as in the first stage, except a slight increase in the number and size of the spines upon the lobes of the endognathus. The posterior portion of the epignathus has increased considerably in length and is much broader than the anterior portion.

The first, or inner, maxillipeds differ only very slightly from those in the first stage. The mesognathus is relatively of the same size and is furnished with the same number of setæ. The exognathus is slightly longer in proportion and the posterior portion of the epignathus is proportionally larger than the anterior portion.

In the second maxillipeds the endognathus has changed very little from the first stage, the proportions of the segments and the number and arrangement of the spines being almost exactly the same, while the articulations between the segments seem to be more distinctly marked. The exognathus has increased very slightly in length, and the extremity shows a slight approach to the flagelliform character in the increased length of the rudimentary setæ, though there is still no segmentation even at the tip. The epignathus (plate XVI, fig. 10, enlarged 40 diameters) has increased very little in size, but shows a very slight rudiment of a branchial appendage as a minute lobe on the inside near the base (fig. 10, *c*).

The endognathi and exognathi of the external maxillipeds are as in the first stage, except that the endognathus is a little more slender and the terminal segment proportionally a little longer. The epignathus and the three branchial appendages have increased very much in size, the latter being elongated and the edges distinctly crenulated, but the epignathus still somewhat sack-like and entirely without hairs. These appendages are in exactly the same stage of development as those upon the legs, and as represented in the figure of one of the legs of the second pair (plate XVII, fig. 2, *b*, *c*, enlarged 20 diameters).

The anterior cephalothoracic legs (plate XVII, fig. 10, distal portion of one, enlarged 20 diameters) are proportionally much larger than in the first stage, and have become truly cheliform. The propodus is proportionally much longer than in the first stage, is armed only with very short spines, and the digital portion is nearly as long as the basal, and its tip is incurved and terminates in a short and slender nail. The dactylus is very slightly longer than the digital portion of the propodus, is shaped very much like it, and has apparently some power of prehension with it. The exopodus is larger, having increased in proportion with the other legs. The epignathus and the three branchial appendages are like those of the external maxillipeds.

The second and third pairs of legs (plate XVII, fig. 2, one of the second pair, enlarged 20 diameters) are alike and have increased considerably in length. The spines upon the propodus are shorter and the digital portion is more elongated, slightly incurved, and terminated by a short nail. The dactylus is more slender, much longer than the digital portion of the propodus, and terminates in a spiniform stylet nearly as long as the dactylus itself, but considerably shorter than in the first stage. The exopodus, epipodus, and the branchial appendages are like those of the anterior legs.

The fourth pair of legs have increased in length proportionally with the second and third pairs, the spines upon the distal extremity of the propodus are relatively shorter, the body of the dactylus has increased in length so that it is more than half as long as the propodus, but the styliform tip is much shorter, scarcely if at all longer than the dactylus itself, but still retains its armature of sharp teeth along one side. The exopodus, epipodus, and the four branchial appendages are the same as in the second and third pairs.

The posterior legs (plate XVII, fig. 5, enlarged 20 diameters, and fig. 5*a*, terminal portion enlarged 40 diameters) are proportionally as long as the fourth pair, but are more slender. The propodus and dactylus are relatively longer and more slender than in the first stage, and the terminal stylet of the dactylus, though longer than in the fourth pair, is but little longer than the dactylus itself. The exopodus is like that of the other legs and the single branchial appendage is like the others.

The abdomen is slightly stouter relatively than in the first stage, and the appendages of the second, third, fourth and fifth segments have appeared. The dorsal spines upon the second to the sixth segment are of the same form but slightly shorter than in the first stage, and the spiniform lateral angles of the same segments are a little shorter and stouter.

The telson (plate XVIII, fig. 2, enlarged 20 diameters) is relatively smaller and broader at base, being more quadrilateral in outline, and the stout plumose setæ of the posterior margin are much smaller. The articulation between the telson and the penultimate segment is more distinct than in the first stage, but apparently still admits of very little if any motion.

The natatory legs of the second, third, fourth and fifth segments (plate XVIII, fig. 5, one of the legs of the third segment, enlarged 30 diameters) differ somewhat in size in different specimens, but are nearly as long as the segments themselves. The terminal lamellæ of these appendages are simple, oblong and sack-like, without sign of segmentation or clothing of hairs or setæ.

Specimens in this stage were taken only twice, July 1 and 15. They have the same habits and general appearance as in the first stage. In color they are almost exactly the same, only the orange-colored markings are perhaps a little less intense.

Third larval stage.

In this stage (plate XIV, fig. *E*, enlarged 8 diameters) the larvæ are about half an inch (12 to 13^{mm}) in length, the integument is of a firmer consistency than in the earlier stages, and the entire animal has begun to lose its schizopodal characters and to assume some of the features of the adult.

The carapax has nearly the same general form as in the earlier stages, but the cervical suture is much more distinct, and the inferior angle of the anterior margin is prolonged into a much less prominent tooth. The rostrum (plate XV, fig. 3, enlarged 10 diameters) is somewhat depressed from the base to near the tip, is proportionally shorter and broader than in either of the earlier stages, and its margins are armed with the same variable number of teeth as in the second stage.

The ocular peduncles are slightly more slender, the eyes themselves are proportionally a little smaller than in the second stage, and the peduncles apparently admit of considerable motion.

The antennulæ (plate XV, fig. 9, enlarged 20 diameters) are longer and more slender than in the second stage, but are still considerably shorter than the rostrum. The outer flagellum is distinctly divided into about ten equal segments, and the distal half of the inner margin is furnished with numerous hairs similar to those in the second stage, only smaller and not more than half as long. The inner flagellum is three-fourths as long as the outer, slender, rather indistinctly divided into eight to ten segments, and entirely naked.

The antennæ retain the essential features of the earlier stages. The scale is proportionally as large, and is furnished with the same form of plumose hairs along the inner margin as in the first and second stages. The flagellum is about a half longer than the scale, indistinctly multiarticulate and apparently without terminal setæ or lateral hairs.

The mandibles (plate XV, fig. 15, enlarged 25 diameters, and figs. 16, 17, 18) have nearly the same form as in the first and second stages, but the crowns are more indurated and thickened, the teeth not quite as acute, and the anterior portion of the margin not quite as abruptly recurved, while the palpi have increased considerably in size, the last segment being much longer than either of the others, and tipped with five, instead of two, short hairs or setæ.

In the first maxillæ, the spines and setæ upon the lobes of the endognathus are more numerous and considerably stouter than in the second stage. The exognathus is proportionally no longer than in the first and second stages, and has the same number of setæ at the extremity as in the second stage; these setæ (plate XVI, fig. 2, enlarged 100 diameters) are, however, proportionally a little shorter and stouter, the inner, and longer, of the three terminal ones is a little below the tip, and the two upon the inner side are still further from the tip than in the second stage.

The second maxillæ have not changed from the last stage, except in a slight increase in the number of setæ upon the lobes of the endognathus, and a similar increase in the stout plumose hairs upon the margins of the epignathus, of which the posterior lobe is a little broader than in the second stage.

In the first maxillipeds (plate XVI, fig. 7, enlarged 40 diameters), the anterior portion of the endognathus is proportionally larger and the spines upon its inner margin are more numerous than in the first and second stages. The mesognathus has the same number of terminal setæ (fig. 7*a*, enlarged 100 diameters) as in the earlier stages, but there are several short hairs along the outer margin, and three setæ upon the inner side of the distal end of the basal segment. The exognathus has increased considerably in length, and its extremity has begun to show slightly the flagelliform character, although there are as yet no distinct articulations, and only three or four short hairs on the inner margin near the tip.

In the second maxillipeds, the endognathus has become slightly compressed and the meral segment is longer in proportion, but otherwise is nearly as in the first stage. The exognathus has increased somewhat in length, and the terminal portion shows two or three distinct segments and several quite long plumose and jointed hairs, thus clearly indicating its flagelliform character. The epignathus (plate XVI, fig. 11, enlarged 40 diameters) has increased slightly in size, and the branchial appendage at its base appears as a well defined lobe (fig. 11, *c*) longer than the breadth of the epignathus itself.

The external maxillipeds show a slight change toward the adult form. They have not increased in size so rapidly as the legs, and the form and proportions of the segments of the endognathus are quite different, the segments being slightly flattened and angulated on the inner margin, the ischial, meral and propodal segments about equal in length and longer than the others, the articulation between the ischium and merus oblique, and the distal portion carried bent inward by a marked geniculation between the merus and carpus and a slight one between the propodus and dactylus. The terminal segment also is longer and more slender than in the earlier stages, and the spines at the tip and on the whole inner margin of the endognathus are proportionally smaller, although of about the same number as in the adult. There are no indications of teeth or crenulations upon the inner margin of the ischium. The exognathus is relatively shorter than in the earlier stages, having increased scarcely at all in size. The flagelliform portion is composed of the same number of segments as in the earlier stages, but the plumose hairs are somewhat shorter. The epignathus has increased much in size, has entirely lost its sack-like character, and is furnished with a few hairs along the margins. The three branchial appendages have also increased much in size, and are lobed along the sides. The epignathus and branchial appendages are in the same stage as those upon the second pair of legs (plate XVII, fig. 3, enlarged 20 diameters).

The anterior legs (plate XVII, fig. 11, distal extremity of one, enlarged 20 diameters) have increased very much in size, and begin to resemble somewhat those of the adult, although they are still just alike on the two sides, and differ very conspicuously in the form of the propodus, which has the lower margin nearly straight, the upper margin convex, and the fingers thus somewhat deflexed, while in the earliest state of the adult form the lower margin is strongly convex and the fingers turned slightly upward. The endopodus reaches beyond the extremities of the other legs by the full length of the propodus, is proportionally very much stouter than they, and is furnished with only short spinules and hairs. The propodus is broad and stout, the inferior margin nearly straight, and the digital portion about two-thirds as long as the basal and tapering to an obtuse extremity. The dactylus is strongly curved downward toward the tip, which is slender but not acute. The exopodus is proportionally much smaller than in the second stage, being absolutely about as large and having the same number of segments in the flagelliform portion but furnished with shorter plumose hairs. The epipodus and the branchial appendages are like those of the external maxillipeds and have evidently begun to perform the same functions as in the adult.

The second and third pairs of legs (plate XVII, fig. 3, one of the second pair enlarged 20 diameters) have increased considerably in size and become truly cheliform. The inferior margin of the propodus is armed only with very small spines, but there is still, as in the earlier stages, a long spine armed with acute teeth, on each side at the base of the dactylus, and the digital portion is nearly as long as the dactylus, is minutely toothed along the inner edge and terminates in a very short styliform tip. The dactylus projects only slightly beyond the propodus and like it is toothed along the inner edge and terminates in a slender tip. The exopodus, epipodus and branchial appendages are like those parts in the anterior legs as well as in the fourth pair.

The fourth pair of legs are of the same length as the second and third, the spines upon the propodus are relatively a little shorter than in the second stage, while the dactylus itself is relatively longer, but is terminated by a shorter stylet.

The posterior legs (plate XVII, fig. 7, terminal portion of one, enlarged 40 diameters) have changed precisely in the same way as those of the fourth pair.

The abdomen is armed with the same number of dorsal spines as in the first and second stages, but they are all much smaller than in the second stage. The lateral angles of the second to the fifth segments project in sharp angular teeth, which are much shorter and broader than in the earlier stages and project obliquely backward and downward.

The telson (plate XIV, fig. *F*, enlarged 15 diameters, *a*, one of the plumose setæ, enlarged 75 diameters, and plate XVIII, fig. 3, enlarged 20 diameters) is of nearly the same form as in the second stage, but is proportionally much smaller—although absolutely fully as large—considerably broader at base, and the setæ and spines are very much smaller. The natatory legs of the second, third, fourth, and fifth segments (plate XVIII, fig. 6, one of the legs of the third segment, enlarged 30 diameters) have increased much in size, the lamellæ are fully twice as long as in the second stage, are somewhat lanceolate in form, and the margins of the distal half show a slight indication of segmentation and are furnished with very short rudimentary setæ clothed with very short hairs (fig. 6*a*, enlarged 100 diameters).

The appendages of the penultimate segment (plate XVIII, fig. 3, enlarged 20 diameters) are well developed, although relatively smaller and otherwise quite different from those of the adult. The outer lamella is broad; rudely oval, wholly without a transverse articulation near the extremity, and the outer margin is naked and nearly straight for two-thirds its length, then obliquely truncated at a slight angle and continuous in a regular curve with the posterior and inner margins, and clothed all the way, except near the base of the inner side, with long plumose setæ (plate XVIII, fig. 3*a*, enlarged 50 diameters) articulated to the margin but apparently not divided into segments like the setæ of the exopodal branches of the cephalothoracic legs. The inner lamella is a little smaller than the outer, more regularly ovate, and margined all round, except near the base, with plumose setæ like those upon the outer lamella.

The only specimens procured in this stage were taken July 8 and 15. In color they were less brilliant than in the earlier stages, the orange markings being duller and whole animal slightly tinged with greenish brown.

Early stages of the adult form.

Between this stage and the third larval stage there is possibly an intermediate form wanting. The changes in the whole appearance of the animal have been so much greater than between the first and second or between the second and third larval stages, that, although the difference in size is inconsiderable, the whole change did not perhaps take place at one molt.

In this stage the animal is about three-fifths of an inch (14 to 17^{mm}) long, has lost all its schizopodal characters, and has assumed the more important features of the adult lobster. It still retains, however, the free-swimming habit of the true larval forms, and was frequently taken at the surface, both in the towing and hand net. Although it resembles the adult in many features, it differs so much that, were it an adult, it would undoubtedly be regarded as a distinct genus.

The carapax has nearly the same form as in the adult, being longer and proportionally narrower than in the third larval stage, and not gibbous upon the sides posteriorly. The areolation is as distinct as in the adult. The tooth upon the anterior margin, just over the base of the antenna, is rather more prominent than in the adult, but there seems to be no small spine back of this on the side of the carapax as there is in the adult. The rostrum (plate XV, figs. 4 and 5, enlarged 10 diameters) is about two-fifths as long as the carapax including the rostrum, broad, expanded in the middle, and terminates in a slender bifid tip (fig. 4*a*, enlarged 25 diameters). The edges are clothed with plumose setæ (fig. 4*b*, enlarged 50 diameters) and three or four teeth on each side besides a small one near the base and a little way back from the margin, and in some specimens with a minute additional spine on each side near the slender terminal portion.

The ocular peduncles are elongated and of nearly the same form as in the adult.

The antennulæ (plate XV, fig. 10, enlarged 20 diameters) have assumed the form and character of those of the adult. The basal segment is broad and has a well developed auditory chamber containing otolithes and similar to that of the adult, although, in the alcoholic specimens examined, the chamber appeared to be open while in the adult it is closed. All the segments of the peduncle have a few hairs or setæ upon the outside, and the ultimate and penultimate on the inside also. The flagella are nearly equal in length, the outer being slightly longer, and extend only a little beyond the tip of the rostrum. The outer flagellum is very stout, composed of ten to twelve segments, most of which are as broad as long, and is furnished along the inner side, especially on the distal portion, with many short, stout and jointed setæ. The terminal segment is slender, scarcely half as thick as the others, much longer than broad, and obtusely rounded at the tip. The inner flagellum is slender and composed of nine or ten segments, which are nearly all twice as long as broad, and furnished at the distal end with several very short hairs. The terminal segment is slightly narrower than the others, and obtusely rounded and furnished with four short hairs at the tip.—In the full grown adult lobster the antennulæ differ in having much longer and more slender flagella, the inner being a little longer than the outer, and both extending for more than three-quarters of their length beyond the rostrum. The outer flagellum is composed of a great number of very short segments, and the terminal portion tapers to a long slender tip and is furnished along the inner side with numerous setæ as in the earlier stage. The inner flagellum is not so much more slender than the outer as in the earlier stage, and is composed of very numerous segments which are as broad, or nearly as broad, as long.

The antennæ (plate XV, fig. 12, enlarged 10 diameters) still retain some marked characters of the larval stage. The second segment of the peduncle projects into an angle on the outside at the base of the scale, not into a stout tooth as in the adult. The scale is still quite large and lamelliform, projecting half its length beyond the peduncle. and is furnished on the inner margin with long plumose setæ as in the larval stages, though in this stage the margin projects in a slender process at the insertion of each seta. The flagellum is slender, fully as long as the carapax to the tip of the rostrum, and is composed of thirty-six to forty segments which are as long as or much longer than broad, and furnished at the distal end with several short hairs or setæ.—In the full grown adult lobster the antennal scale is reduced to a stout tooth-like appendage extending scarcely beyond the fourth segment of the peduncle and with a thick expansion upon the inner side, and the stout tooth at its base is nearly as large as the scale itself. The flagellum is fully twice as long as in the young state, and is composed of very numerous short segments closely articulated together.

The mandibles (plate XV, fig. 19, enlarged 25 diameters, and fig. 20, left one seen from the inside, enlarged 40 diameters) have lost the lamelliform processes and approach in general form those of the adult, but the crowns are much less massive and their edges are conspicuously dentate. The palpi have the same form as in the adult, the terminal segment being broad, flattened, clothed with numerous setæ, and acting within the edges of the crowns as in the adult.

The first maxillæ (plate XVI, fig. 3, enlarged 20 diameters) have the proximal lobe (fig. 3, *a*) of the endognathus rounded at the extremity as in the adult but with much fewer setæ, while the distal lobe (fig. 3, *b*) is not expanded at the end as in the adult and, like the proximal lobe, has fewer setæ. The exognathus (fig. 3, *c*) is composed of two segments as in the adult, but the terminal segment is much shorter than the other, nearly straight, and naked to the extremity, which is tipped with three setæ of different lengths, while in the adult this terminal segment is as long as the basal, curved sinuously backward and outward, is ciliated along the inner or anterior margin, and tipped with numerous setæ.

The second maxillæ (plate XVI, fig. 5, enlarged 20 diameters) differ but slightly from those of the adult. The anterior of the four lobes (fig. 5, *a*) of the endognathus is rounded at the extremity, while in the adult it is subtruncate, and the extremities of all the lobes are armed with fewer setæ than in the adult. The exognathus (fig. 5, *b*) is relatively longer than in the adult, but is furnished with only a few hairs, while in the adult it is thickly ciliated along the inner edge and at the tip. The epignathus (fig. 5, *c*) is relatively a little smaller than in the adult.

In the first maxillipeds (plate XVI, fig. 8, enlarged 20 diameters) the endogathus (fig. 8, *a*) is slightly narrower than in the adult and has fewer marginal setæ. The terminal segment of the mesognathus (fig. 8, *b*) is narrow, tapers to an obtuse extremity and has but a very few marginal cilia, while in the adult it is ovate in outline and closely fringed with cilia. The exognathus (fig. 8, *c*) is a little shorter than in the adult, and the terminal flagelliform portion is composed of a few (seven or eight) segments as long as broad and furnished at the distal ends with long plumose hairs, while in the adult the segments are very short and numerous and the hairs quite short. The epignathus is not prolonged posteriorly into so long and slender a point as it is in the adult.

In the second maxillipeds (plate XVI, fig. 12, enlarged 20 diameters) the endognathus is only sparsely armed with spines and setæ, while in the adult it is thickly beset with them. The exognathus (fig. 12, *a*) is nearly as long as in the adult, but the flagelliform portion differs, as the same part in the first maxillipeds, in being composed of few segments with long plumose hairs, while in the adult the segments are very numerous and the hairs short. The epignathus (fig. 12, *b*) is much shorter than in the adult and the branchial appendage (fig. 12, *c*) is obtuse at the tip and has only a few lobes in the margin, while in the adult it is slender at the tip and is made up of numerous slender papillæ.

The endognathus of the external maxillipeds (plate XVI, fig. 14, enlarged 10 diameters) has nearly the same form and proportions as in the adult, but is furnished with fewer and longer setæ, and the teeth upon the inner angle of the ischium are fewer and more acute. The exognathus (fig. 14, *a*) is relatively no longer than in the adult, but the flagelliform portion is composed of fewer segments and is furnished with much longer plumose setæ. The epignathus (fig. 14, *b*) is much shorter than in the adult, and is not prolonged as there into a long and slender extremity. The three branchial appendages (fig. 14, *c*) are proportionally shorter and more obtuse than in the adult, and have comparatively few and short papillæ.

The anterior cephalothoracic legs (plate XVII, fig. 12, terminal portion of the right one, enlarged 10 diameters) are alike on the two sides, are considerably longer than the carapax to the tip of the rostrum, and are formed much like the smaller one in the adult, although considerably more slender and wanting the stout teeth upon the upper edge of the basal portion of the propodus.

The legs of the second and third pairs (plate XVII, figs. 4, and 4*a*, one of the second pair, enlarged 20 diameters) are of the same form and proportions as in the adult, but are armed with fewer and relatively longer spines and setæ.

The legs of the posterior and penultimate pairs (plate XVII, fig. 8, terminal portion of one of the posterior pair, enlarged 20 diameters), as well as those of the second and third pairs, are like those of the adult in form and proportions, but are armed with fewer spines and setæ.

The abdomen (plate XVIII, fig. 10, side view of the second to fifth segments, enlarged 8 diameters, and fig. 4, telson with the appendages of the penultimate segment on one side, enlarged 20 diameters) is scarcely as long as the cephalothorax, including the rostrum, while in the adult it is considerably longer. The lateral angles of the second, third, fourth, and fifth segments are prolonged downward into long and acute teeth, and the second segment is similar to the following ones and overlaps the first segment scarcely at all. In the full-grown adult, the sides of the second segment are broad, overlap the first segment, and are truncated below with the anterior angle rounded and the posterior right-angled, while the sides of the third, fourth, and fifth segments are narrow and have the postero-lateral angles projecting backward in a slight tooth. No appendages could be found upon the first segment. The natatory legs of the second, third, fourth and fifth segments (plate XVIII, fig. 7, one of the legs of the third segment, enlarged 20 diameters) are proportionally larger than in the adult, the terminal lamellæ especially being much longer and furnished with very long plumose and jointed setæ (plate XVIII, fig. 7*a*, enlarged 100 diameters).

The telson (plate XVIII, fig. 4, enlarged 20 diameters) is nearly quadrangular, as wide at the extremity as at the base, and the posterior margin is arcuate, but does not extend beyond the prominent, spiniform lateral angles, and is furnished with long plumose hairs. In the adult the telson is not quadrangular, but much narrowed toward the extremity, which is strongly arcuate, nearly semi-circular and projects far beyond the small dentiform lateral angles. The lamellæ of the appendages of the penultimate segment (fig. 4) are regularly oval and margined with long plumose hairs, and the outer lamellæ have a transverse articulation near the tip as in the adult, although the proximal side of this articulation is not armed as in the adult with numerous slender teeth, but with only a single obtuse one near the middle. In the adult the lamellæ are not regularly oval but broader distally and somewhat truncate at the extremities.

In color they resemble closely the adult, but the green of the back is lighter, and the yellowish markings upon the claws and body are proportionately larger.

In this stage, the young lobsters swim very rapidly by means of the abdominal legs, and dart backward, when disturbed, with the caudal appendages, frequently jumping out of the water in this way like shrimp, which their movements in the water much resemble. They appear to live a large part of the time at the surface, as in the earlier stages, and were often seen swimming about among other surface animals. They were frequently taken from the 8th to the 28th of July, and very likely occur much later.

Specimens in this stage vary considerably in size, and it is barely possible that they represent two different molts. The following measurements of three specimens taken at different dates illustrate these differences in size.

	July 15.	July 28.	July 20.
Length from tip of rostrum to extremity of telson,	14·0mm.	16·2mm.	16·8mm.
" of carapax to tip of rostrum,	6·8	8·2	8·4
" " rostrum,	2·7	3·2	3·2
Breadth of carapax,	2·4	2·9	3·0
Length of propodus of anterior leg, right side,	4·2	5·3	5·4
" " dactylus " " " "	2·0	2·5	2·5
" " propodus " " left side,	4·3	5·3	5·4
" " dactylus " " " "	2·0	2·6	2·5

From the dates on which the different forms were taken, and from the known rapidity with which the young of allied genera increase in size and come to the mature form, there can be no doubt that the young pass through all the stages I have described in the course of a single season, and it is probable that the largest of the young just mentioned had not been hatched from the egg more than six weeks and very likely only a much shorter time. How long the young retain their free-swimming habit after arriving at the lobster-like form, was not ascertained.

Specimens three inches in length have acquired nearly all the characters of the full grown adult. The rostrum is not more than a fourth of the length of the carapax including the rostrum, and in form is more like that of the second and third stages of the larvæ than that of the earliest stage of the adult form. It is regularly and very narrowly triangular, the terminal third slender, spiniform and unarmed as seen from above, but broader as seen in a lateral view and armed below with two small teeth directed forward, the middle portion armed each side above with two spiniform teeth, the posterior one slightly the smaller, and sometimes a third, still smaller one, back of the others.

The antennulæ are about two-thirds as long as the carapax including the rostrum, the peduncles reach nearly to tip of the rostrum, and the inner flagella are slightly longer than the outer. The flagella of the antennæ are nearly as long as the rest of the animal, and the peduncle reaches nearly to the tip of the rostrum. The antennal scale is still considerably larger proportionally than in the full grown adult, reaching nearly to the extremity of the peduncle, but it is reduced to a stout tooth-like appendage with a lamellar expansion upon the inner side.

The mandibles are nearly as massive as in the full-grown adult, and the posterior portion of the outer edges of the crowns are smooth and continuous and not dentate, as in the earlier stages.

The anterior cephalothoracic legs are relatively very much stouter than in the earlier stages and are unlike on the two sides, as in the full-grown, the propodus upon one side being much broader than upon the other and the prehensile edges of the propodus and dactylus wanting the dense clothing of short hairs or setæ which are conspicuous upon the other leg.

The sexual appendages upon the first segment of the abdomen are fully developed. The sides of all the abdominal segments, the telson, and the appendages are almost exactly as in the full-grown.

For convenience of comparison, the detailed measurements of the young in these different stages are arranged together on p. 378.

A comparison of the larval stages of the European lobster with those of our own species would be very important and interesting, but as far as I can learn, no complete figures or descriptions of the larval stages of the European lobster after leaving the egg have been published. Rathke's* figures of the embryo of the European lobster just before leaving the egg, indicate the base of the antennula as composed of three distinct segments, the branchial appendages of the external maxillipeds and the cephalothoracic legs as much further advanced than they are in the first larval stage of the American lobster described in this paper, and the appendages of the penultimate segment of the abdomen are already represented by small lobes beneath the abdomen. In the same stage of the embryo, the lateral spines upon the second to the fifth segments of the abdomen have appeared, but no dorsal spines are indicated in the figures. Kroyer's† figures of the embryo, apparently at nearly the same stage of development, represent some of the appendages very different. The anterior cephalothoracic legs are represented as truly cheliform, the lateral spines upon the segments of the abdomen are mistaken for abdominal legs and represented as each composed of two segments, while the telson is represented as quite different in form from either Rathke's figures or from those of any stage which I have observed in the American lobster.

Of all the larval stages of other genera of crustacea of which I have seen figures or descriptions, there are none which are closely allied to the early stages of the lobster. *Astacus*, according to Rathke, leaves the egg in a form closely resembling the adult, the cephalothoracic legs having no exopodal branches and the abdominal legs being already developed. Of the early stages of the numerous other genera of Astacidea and Thalassinidea scarcely anything is known, but as far as is known none of them appear to approach the larvæ of the lobster. Most of the species of Crangonidæ and Palæmonidæ—among the most typical of macrourans—of which the development is known, are hatched from the egg in the zoëa stage, in which the five posterior pairs of cephalothoracic appendages or decapodal legs are wholly

* Beiträge zur vergleichenden Anatomie und Physiologie, über die Rückschreitende Metamorphose der Theire, Danzig, 1842, p. 120, plate ii.

† Monografisk Fremstilling af Slægten Hippolyte's nordiske Arter, med Bidrag til Dekapodernes Udviklingshistorie (Kongl. Danske Vidensk. Selsk. naturvid. og mathem. Afhandlinger, ix Deel), Kjöbenhaven, 1842, p. 251, plate vi.

wanting, as are also the abdominal legs, while the two anterior pairs of maxillipeds, or all of them, are developed into locomotive organs.* In no period of their development do they have all the decapodal legs furnished with natatory exopodal branches. There are undoubtedly larval forms closely allied to those of *Homarus* in some of the groups of macrourans, although they appear to be as yet unknown.

Notwithstanding these larval forms of the lobster seen to have no close affinities with the known larvæ of other genera of macrourans, they do show in many characters a very remarkable and interesting approach to the adult Schizopoda, particularly to the Mysidæ. This appears to me to furnish additional evidence that the Schizopods are only degraded macrourans much more closely allied to the Sergestidæ than to the Squilloidea.

* The following short description of the young of *Palæmonetes vulgaris* (the common prawn or transparent shrimp of the southern coast of New England) soon after hatching and when about 3^{mm} long, will serve as an example of a common form of the early stage of the larvæ in these families: The cephalothorax is short and broad with a slender spiniform rostrum in front, an enormous compound eye each side at the anterior margin, and a small simple eye in the middle of the carapax. The antennulæ are quite rudimentary, being short and thick appendages projecting a little way in front of the head; the peduncle bears at its extremity a very short obtuse segment representing the primary flagellum, and inside, at the base of this, a much longer plumose seta. The antennæ are slightly longer than the antennulæ; the short peduncle bears a stout appendage, corresponding to the antennal scale, the terminal portion of which is articulated and furnished with long plumose setæ, and on the inside at the base of the scale, a slender process corresponding to the flagellum, terminated by a long plumose seta. The first and second pairs of maxillæ are well formed and approach those of the adult. The three pairs of maxillipeds are all developed into powerful locomotive appendages; the inner branches, or endognathi, being slender pediform appendages terminated by long spines, while the outer branches, or exognathi, are long swimming appendages like the swimming branches of the legs of the young lobsters in the first stage. Both branches of the first maxillipeds are considerably shorter than those of the following pairs, but otherwise like them, and the inner branch of the second pair is somewhat shorter than that of the third, but its outer branch is about as long as that of the third pair. The five pairs of cephalothoracic legs are wanting, or only represented by a cluster of minute sack-like processes just behind the outer maxillipeds. The abdomen is long and slender, wholly without appendages beneath, and the last segment is expanded into a short and very broad caudal lamina, the posterior margin of which is truncate with the lateral angles rounded; these angles each bear three, and the posterior margin itself eight more stout plumose setæ, the setæ of the posterior margin being longer than those upon the angles, and separated by broader spaces in which the margin is armed with numerous very small setæ. They arrive at the adult form before they are more than 5^{mm} long.

The following measurements of single specimens of the different stages of the larvæ, of the earliest stage of the adult form, and of two small specimens of different sizes of the adult, illustrate better than the descriptions and figures the relative increase in size in the whole animal and in some of the parts. The length of the rostrum is taken from the posterior margin of the orbit, the lengths of the external maxilliped and the cephalothoracic legs from the base of the epipodus or epignathus to the extremity of the dactylus, and the length of the propodus and dactylus includes in each case the terminal styliform portion.

	First larval stage.	Second larval stage.	Third larval stage.	Earliest form of adult.	Small adult, female.	Small adult, male.
Length from tip of rostrum to end of telson,	7·9^{mm}	10·6^{mm}	13·0^{mm}	14·0^{mm}	80·^{mm}	132·^{mm}
“ of carapax to tip of rostrum,	3·6	5·1	6·6	6·8	36·6	61·
“ “ rostrum,	1·7	2·5	3·0	2·7	9·5	16·0
Breadth of carapax,	1·6	2·2	2·7	2·4	16·4	26·2
Length of antennula,	1·0	1·2	1·6	2·9	24·	38·
“ “ inner flagellum of antennula,	0·0	·43	·66	1·6	18·0	28·
“ “ outer “ “ “	0·0	·62	·88	1·7	16·5	25·
“ “ flagellum of antenna,	·66	1·05	1·80	7·3	76·	120·
“ “ antennal scale.	1·00	1·25	1·40	1·2	5·0	8·1
“ “ external maxilliped,	2·7	3·3	3·6	4·1	23·6	34·0
“ “ first cephalothoracic leg, right,	2·5	3·3	4·6	9·0	58·	102·
“ “ its propodus,	·8	1·4	2·0	4·2	33·6	62·4
“ “ dactylus,	·7	·8	·9	2·0	17·1	34·2
Breadth of propodus,	·4	·5	·7	1·0	13·0	19·4
Length of first cephalothoracic leg, left,	2·5	3·3	4·6	9·0	60·	99·
“ “ its propodus,	·8	1·4	2·0	4·3	35·0	56·0
“ “ dactylus,	·7	·8	·9	2·0	19·2	27·9
Breadth of propodus,	·4	·5	·7	1·0	10·7	24·8
Length of second cephalothoracic leg,	2·5	2·9	3·7	6·2	38·	61·
“ “ its merus,	·45	·66	1·00	2·1	14·0	21·8
“ “ carpus,	·25	·36	·45	·8	5·6	9·3
“ “ propodus,	·70	·86	1·17	1·8	12·0	18·5
“ “ dactylus,	·72	·66	·60	·8	4·9	9·0
“ “ third cephalothoracic leg,	2·5	2·9	3·6	6·0	37·	60·
“ “ fourth “ “	2·4	2·8	3·6	6·0	38·	61·
“ “ fifth “ “	2·3	2·8	3·7	5·7	35·	55·
“ “ its merus,	·38	·54	·75	1·6	9·3	14·5
“ “ carpus,	·28	·35	·38	·7	4·2	7·2
“ “ propodus,	·50	·62	·75	1·6	9·1	14·2
“ “ dactylus,	·75	·82	·80	·8	4·8	7·1
“ “ abdomen,	4·4	5·4	6·4	7·2	44·	70·
“ “ telson,	1·7	2·0	2·2	2·0	10·3	17·0
Breadth of telson at base,	·6	·9	1·0	1·4	9·7	16·2
“ “ “ across its extremity,	2·1	2·2	2·2	1·5	6·5	11·5
Length of appendage of third segment,	0·0	·90	1·5	2·2	11·2	17·
“ “ its lamellæ,	0·0	·52	1·0	1·3	6·5	10·

EXPLANATION OF PLATES.

Plate XIV.

Figure *A*.—Lateral view of the larva, in the first stage, enlarged 10 diameters.

Figure *B*.—The same in a dorsal view, the abdomen held horizontally.

Figure *C*.—Antennula, enlarged 20 diameters.

Figure *D*.—One of the cephalothoracic legs of the second pair, enlarged 20 diameters; *a*, exopodus; *b*, epipodus; *c*, branchial appendages.

Figure *E*.—Lateral view of the larva in the third stage, enlarged 8 diameters.

Figure *F*.—Terminal portion of the abdomen seen from above, enlarged 15 diameters; *a*, one of the small spines of the posterior margin of the terminal segment, enlarged 75 diameters.

Figure *G*.—Basal portion of one of the cephalothoracic legs of the second pair, showing the epipodus and branchial appendages, enlarged 20 diameters.

Plate XV.

Figure 1.—Rostrum seen from above, first stage, enlarged 10 diameters.

Figure 2.—Same, second stage, enlarged 10 diameters.

Figure 3.—Same, third stage, enlarged 10 diameters.

Figure 4.—Same, earliest condition of the adult form, enlarged 10 diameters. 4*a*, tip, enlarged 25 diameters; 4*b*, one of the marginal setæ, enlarged 50 diameters.

Figure 5.—Outline of another specimen of the same with the marginal setæ omitted, enlarged 10 diameters.

Figure 6.—Antennula of the right side seen from above, first stage, enlarged 30 diameters.

Figure 7.—Same, from another specimen, at a little later period in the development, showing the antennula of the next stage formed within the integument, enlarged 30 diameters.

Figure 8.—Same, second stage, enlarged 20 diameters.

Figure 9.—Same, third stage, enlarged 20 diameters.

Figure 10.—Same, in the earliest condition of the adult form (when about 15^{mm} in length), enlarged 20 diameters.

Figure 11.—Antenna of the right side seen from above, first stage, enlarged 30 diameters. 11*a*, portion from near the middle of one of the plumose hairs from the edge of the scale, enlarged 100 diameters.

Figure 12.—Same, in the earliest condition of the adult form, enlarged 10 diameters.

Figure 13.—Mandibles in place as seen from beneath, first stage, enlarged 25 diameters.

Figure 14.—Mandibles of the left side, seen from beneath in a little different position from the last figure, enlarged 40 diameters; *a*, lamelliform process of the coronal margin; *b*, molar-like area.

Figure 15.—Mandibles in place as seen from beneath, third stage, enlarged 25 diameters. 15*a*, outline of the edges of the lamelliform processes of the coronal margins in the same position, enlarged 100 diameters.

Figure 16.—Entire coronal margins of the same mandibles seen in a little different position, enlarged 40 diameters.

Figure 17.—Left mandible, of the same stage, seen from the inside so as to show the crown, enlarged 40 diameters; *a*, recurved portion of the margin; *b*, molar-like area.

Figure 18.—Right mandible of the same specimen and seen in the same position.

Figure 19.—Outline of the mandibles in place as seen from beneath, from the earliest condition of the adult, enlarged 25 diameters.

Figure 20.—Left mandible of the same specimen, seen from the inside, enlarged 40 diameters.

PLATE XVI.

Figure 1.—First maxilla of the right side seen from beneath, first stage, enlarged 40 diameters; *a*, *b*, lobes of the endognathus; *c*, exognathus. 1*a*, tip of the exognathus, enlarged 100 diameters.

Figure 2.—Tip of the exognathus of the first maxilla of the right side, third stage, enlarged 100 diameters.

Figure 3.—First maxilla of the right side, earliest condition of the adult form, enlarged 20 diameters; *a*, *b*, *c*, refer to the same parts as in figure 1.

Figure 4.—Second maxilla of the right side seen from beneath, first stage, enlarged 40 diameters; *a*, lobes of the endognathus; *b*, exognathus; *c*, epignathus. 4*a*, tip of the exognathus, enlarged 100 diameters.

Figure 5.—Second maxilla of the right side, earliest condition of the adult, enlarged 20 diameters; *a*, *b*, *c*, refer to the same parts as in figure 4.

Figure 6.—First maxilliped of the right side seen from beneath, first stage, enlarged 40 diameters; *a*, endognathus; *b*, mesognathus; *c*, exognathus; *d*, epignathus. 6*a*, tip of mesognathus, enlarged 100 diameters. 6*b*, one of the plumose setæ from the margin of the exognathus, enlarged 200 diameters.

Figure 7.—First maxilliped of the right side, third stage, enlarged 40 diameters; *a*, *b*, *c*, *d*, refer to the same parts as in figure 6. 7*a*, tip of the mesognathus, enlarged 100 diameters.

Figure 8.—First maxilliped of the right side, earliest condition of the adult, enlarged 40 diameters; *a*, *b*, *c*, *d*, refer to the same parts as in figures 6 and 7.

Figure 9.—Second maxilliped, first stage, enlarged 40 diameters; *a*, exognathus; *b*, epignathus.

Figure 10.—Epignathus of the second maxilliped, second stage, enlarged 40 diameters; *c*, rudimentary branchial appendage.

Figure 11.—Same parts in the third stage, enlarged 40 diameters.

Figure 12.—Second maxilliped of the right side, earliest condition of the adult, enlarged 20 diameters; *a*, exognathus; *b*, epignathus; *c*, rudimentary branchial appendages.

Figure 13.—Third (external) maxilliped of the right side, first stage, enlarged 25 diameters; *a*, exognathus; *b*, epignathus; *c*, rudimentary branchial appendages.

Figure 14.—Same maxilliped, earliest condition of the adult, enlarged 10 diameters.

PLATE XVII.

Figure 1.—Base of one of the legs of the second pair, first stage, enlarged 20 diameters; *b*, epipodus; *c*, rudimentary branchial appendages. 1*a*, extremity of the same leg, enlarged the same amount.

Figure 2.—One of the legs of the second pair, second stage, enlarged 20 diameters; *a*, exopodus; *b*, epipodus; *c*, branchial appendages. 2*a*, one of the plumose setæ from terminal portion of the exopodus, enlarged 100 diameters.

Figure 3.—One of the legs of the second pair, third stage, enlarged 20 diameters.

Figure 4.—Base of one of the legs of the second pair, earliest condition of the adult, enlarged 20 diameters; *a*, *b*, *c*, refer to the same parts as in figure 2. 4*a*, terminal portion of the same leg, enlarged the same amount.

Figure 5.—One of the posterior cephalothoracic legs, second stage, enlarged 20 diameters; *a*, exopodus; *c*, branchial appendage; 5*a*, terminal portion of the same leg, enlarged 40 diameters.

Figure 6.—Terminal portion of same leg, first stage, enlarged 40 diameters.

Figure 7.—Same, third stage, enlarged 40 diameters.

Figure 8.—Same, earliest condition of the adult, enlarged 20 diameters.

Figure 9.—Terminal portion of the anterior cephalothoracic leg of the right side, first stage, enlarged 40 diameters.

Figure 10.—Same, second stage, enlarged 20 diameters.

Figure 11.—Same, third stage, enlarged 20 diameters.

Figure 12.—Same, earliest condition of the adult form, enlarged 10 diameters.

Plate XVIII.

Figure 1.—Extremity of the abdomen seen from above, first stage, enlarged 20 diameters. 1*a*, portion of one of the angles enlarged 40 diameters, showing the plumose marginal setæ.

Figure 2.—Same, second stage, enlarged 20 diameters.

Figure 3.—Right side of the same, third stage, showing the appendages of the penultimate segment, enlarged 20 diameters; 3*a*, marginal setæ of one of the appendages of the penultimate segment, enlarged 50 diameters.

Figure 4.—Terminal segment of the abdomen and appendages of the penultimate segment on one side, earliest condition of the adult form, enlarged 20 diameters.

Figure 5.—One of the appendages of the third segment of the abdomen, second stage, enlarged 30 diameters.

Figure 6.—Same, third stage, enlarged the same amount. 6*a*, one of the rudimentary marginal setæ, enlarged 100 diameters.

Figure 7.—Same, earliest condition of the adult form, enlarged 20 diameters. 7*a*, one of the marginal setæ enlarged 100 diameters.

Figure 8.—Lateral view of the fourth segment of the abdomen, showing the dorsal and lateral spines, first stage, enlarged 20 diameters.

Figure 9.—Diagram of a section of the same segment seen from behind, enlarged 30 diameters.

Figure 10.—Lateral view of the middle portion of the abdomen, earliest condition of the adult form, enlarged 8 diameters.

XIV. A Method of Geometrical Representation of the Thermodynamic Properties of Substances by means of Surfaces. By J. Willard Gibbs.

The leading thermodynamic properties of a fluid are determined by the relations which exist between the volume, pressure, temperature, energy, and entropy of a given mass of the fluid in a state of thermodynamic equilibrium. The same is true of a solid in regard to those properties which it exhibits in processes in which the pressure is the same in every direction about any point of the solid. But all the relations existing between these five quantities for any substance (three independent relations) may be deduced from the single relation existing for that substance between the volume, energy, and entropy. This may be done by means of the general equation,

$$d\varepsilon = t\,d\eta - p\,dv, \qquad (1)^*$$

that is,

$$p = -\left(\frac{d\varepsilon}{dv}\right)_\eta, \qquad (2)$$

$$t = \left(\frac{d\varepsilon}{d\eta}\right)_v, \qquad (3)$$

where v, p, t, ε, and η denote severally the volume, pressure, absolute temperature, energy, and entropy of the body considered. The subscript letter after the differential coefficient indicates the quantity which is supposed constant in the differentiation.

Representation of Volume, Entropy, Energy, Pressure, and Temperature.

Now the relation between the volume, entropy, and energy may be represented by a surface, most simply if the rectangular co-ordinates of the various points of the surface are made equal to the volume, entropy, and energy of the body in its various states. It may be interesting to examine the properties of such a surface, which we will call the thermodynamic surface of the body for which it is formed.†

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* For the demonstration of this equation, and in regard to the units used in the measurement of the quantities, the reader is referred to page 310 of this volume.

† Professor J. Thomson has proposed and used a surface in which the co-ordinates are proportional to the volume, pressure, and temperature of the body. (Proc. Roy. Soc., Nov. 16, 1871, vol. xx, p. 1; and Phil. Mag., vol. xliii, p. 227). It is evident,

To fix our ideas, let the axes of v, η, and ε have the directions usually given to the axes of X, Y, and Z (v increasing to the right, η forward, and ε upward). Then the pressure and temperature of the state represented by any point of the surface are equal to the tangents of the inclinations of the surface to the horizon at that point, as measured in planes perpendicular to the axes of η and of v respectively. (Eqs. 2 and 3). It must be observed, however, that in the first case the angle of inclination is measured upward from the direction of *decreasing* v, and in the second, upward from the direction of *increasing* η. Hence, the tangent plane at any point indicates the temperature and pressure of the state represented. It will be convenient to speak of a plane as representing a certain pressure and temperature, when the tangents of its inclinations to the horizon, measured as above, are equal to that pressure and temperature.

Before proceeding farther, it may be worth while to distinguish between what is essential and what is arbitrary in a surface thus formed. The position of the plane $v=0$ in the surface is evidently fixed, but the position of the planes $\eta=0$, $\varepsilon=0$ is arbitrary, provided the direction of the axes of η and ε be not altered. This results from the nature of the definitions of entropy and energy, which involve each an arbitrary constant. As we may make $\eta=0$ and $\varepsilon=0$ for any state of the body which we may choose, we may place the origin of co-ordinates at any point in the plane $v=0$. Again, it is evident from the form of equation (1) that whatever changes we may make in the units in which volume, entropy, and energy are measured, it will always be possible to make such changes in the units of temperature and pressure, that the equation will hold true in its present form, without the introduction of constants. It is easy to see how a change of the units of volume, entropy, and energy would affect the surface. The projections parallel to any one of the axes of distances between points of the surface would be changed in the ratio inverse to that in which the corresponding unit had been changed. These considerations enable us to foresee to a certain extent the nature of the general properties of the surface which we are to investigate. They must be such, namely, as shall not be affected by any of the changes mentioned above. For example, we may find properties which concern

however, that the relation between the volume, pressure, and temperature affords a less complete knowledge of the properties of the body than the relation between the volume, entropy, and energy. For, while the former relation is entirely determined by the latter, and can be derived from it by differentiation, the latter relation is by no means determined by the former.

the plane $v=0$ (as that the whole surface must necessarily fall on the positive side of this plane), but we must not expect to find properties which concern the planes $\eta=0$, or $\varepsilon=0$, in distinction from others parallel to them. It may be added that, as the volume, entropy, and energy of a body are equal to the sums of the volumes, entropies, and energies of its parts, if the surface should be constructed for bodies differing in quantity but not in kind of matter, the different surfaces thus formed would be similar to one another, their linear dimensions being proportional to the quantities of matter.

Nature of that Part of the Surface which represents States which are not Homogeneous.

This mode of representation of the volume, entropy, energy, pressure, and temperature of a body will apply as well to the case in which different portions of the body are in different states (supposing always that the whole is in a state of thermodynamic equilibrium), as to that in which the body is uniform in state throughout. For the body taken as a whole has a definite volume, entropy, and energy, as well as pressure and temperature, and the validity of the general equation (1) is independent of the uniformity or diversity in respect to state of the different portions of the body.* It is evident, therefore, that the thermodynamic surface, for many substances at least,

* It is, however, supposed in this equation that the variations in the state of the body, to which dv, $d\eta$, and $d\varepsilon$ refer, are such as may be produced *reversibly* by expansion and compression or by addition and subtraction of heat. Hence, when the body consists of parts in different states, it is necessary that these states should be such as can pass either into the other without sensible change of pressure or temperature. Otherwise, it would be necessary to suppose in the differential equation (1) that the proportion in which the body is divided into the different states remains constant. But such a limitation would render the equation as applied to a compound of different states valueless for our present purpose. If, however, we leave out of account the cases in which we regard the states as chemically different from one another, which lie beyond the scope of this paper, experience justifies us in assuming the above condition (that either of the two states existing in contact can pass into the other without sensible change of the pressure or temperature), as at least approximately true, when one of the states is fluid. But if both are solid, the necessary mobility of the parts is wanting. It must therefore be understood, that the following discussion of the compound states is not intended to apply without limitation to the exceptional cases, where we have two different solid states of the same substance at the same pressure and temperature. It may be added that the thermodynamic equilibrium which subsists between two such solid states of the same substance differs from that which subsists when one of the states is fluid, very much as in statics an equilibrium which is maintained by friction differs from that of a frictionless machine in which the

can be divided into two parts, of which one represents the homogeneous states, the other those which are not so. We shall see that, when the former part of the surface is given, the latter can readily be formed, as indeed we might expect. We may therefore call the former part the primitive surface, and the latter the derived surface.

To ascertain the nature of the derived surface and its relations to the primitive surface sufficiently to construct it when the latter is given, it is only necessary to use the principle that the volume, entropy, and energy of the whole body are equal to the sums of the volumes, entropies, and energies respectively of the parts, while the pressure and temperature of the whole are the same as those of each of the parts. Let us commence with the case in which the body is in part solid, in part liquid, and in part vapor. The position of the point determined by the volume, entropy, and energy of such a compound will be that of the center of gravity of masses proportioned to the masses of solid, liquid, and vapor placed at the three points of the primitive surface which represent respectively the states of complete solidity, complete liquidity, and complete vaporization, each at the temperature and pressure of the compound. Hence, the part of the surface which represents a compound of solid, liquid, and vapor is a plane triangle, having its vertices at the points mentioned. The fact that the surface is here plane indicates that the pressure and temperature are here constant, the inclination of the plane indicating the value of these quantities. Moreover, as these values are the same for the compound as for the three different homogeneous states corresponding to its different portions, the plane of the triangle is tangent at each of its vertices to the primitive surface, viz: at one vertex to that part of the primitive surface which represents solid, at another to the part representing liquid, and at the third to the part representing vapor.

When the body consists of a compound of two different homogeneous states, the point which represents the compound state will be at

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active forces are so balanced, that the slightest change of force will produce motion in either direction.

Another limitation is rendered necessary by the fact that in the following discussion the magnitude and form of the bounding and dividing surfaces are left out of account; so that the results are in general strictly valid only in cases in which the influence of these particulars may be neglected. When, therefore, two states of the substance are spoken of as in contact, it must be understood that the surface dividing them is plane. To consider the subject in a more general form, it would be necessary to introduce considerations which belong to the theories of capillarity and crystallization.

the center of gravity of masses proportioned to the masses of the parts of the body in the two different states and placed at the points of the primitive surface which represent these two states (i. e., which represent the volume, entropy, and energy of the body, if its whole mass were supposed successively in the two homogeneous states which occur in its parts). It will therefore be found upon the straight line which unites these two points. As the pressure and temperature are evidently constant for this line, a single plane can be tangent to the derived surface throughout this line and at each end of the line tangent to the primitive surface.* If we now imagine the temperature

* It is here shown that, if two different states of the substance are such that they can exist permanently in contact with each other, the points representing these states in the thermodynamic surface have a common tangent plane. We shall see hereafter that the converse of this is true,—that, if two points in the thermodynamic surface have a common tangent plane, the states represented are such as can permanently exist in contact; and we shall also see what determines the direction of the discontinuous change which occurs when two different states of the same pressure and temperature, for which the condition of a common tangent plane is not satisfied, are brought into contact.

It is easy to express this condition analytically. Resolving it into the conditions, that the tangent planes shall be parallel, and that they shall cut the axis of ε at the same point, we have the equations

$$p' = p'', \qquad (\alpha)$$

$$t' = t'', \qquad (\beta)$$

$$\varepsilon' - t'\eta' + p'v' = \varepsilon'' - t''\eta'' + p''v'', \qquad (\gamma)$$

where the letters which refer to the different states are distinguished by accents. If there are three states which can exist in contact, we must have for these states,

$$p' = p'' = p''',$$

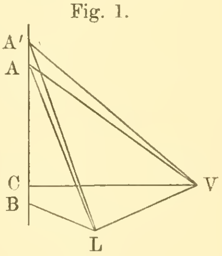
$$t' = t'' = t''',$$

$$\varepsilon' - t'\eta' + p'v' = \varepsilon'' - t''\eta'' + p''v'' = \varepsilon''' - t'''\eta''' + p'''v'''.$$

These results are interesting, as they show us how we might foresee whether two given states of a substance of the same pressure and temperature, can or cannot exist in contact. It is indeed true, that the values of ε and η cannot like those of v, p, and t be ascertained by mere measurements upon the substance while in the two states in question. It is necessary, in order to find the value of $\varepsilon'' - \varepsilon'$ or $\eta'' - \eta'$, to carry out measurements upon a process by which the substance is brought from one state to the other, *but this need not be by a process in which the two given states shall be found in contact*, and in some cases at least it may be done by processes in which the body remains always homogeneous in state. For we know by the experiments of Dr. Andrews (Phil. Trans., vol. 159, p. 575), that carbonic acid may be carried from any of the states which we usually call liquid to any of those which we usually call gas, without losing its homogeneity. Now, if we had so carried it from a state of liquidity to a state of gas of the same pressure and temperature, making the proper measurements in the process, we should be able to foretell what would occur if these two states of the substance should be brought together,—whether evaporation would take place, or condensation, or whether they would remain unchanged in contact,—although we had and pressure of the compound to vary, the two points of the primitive surface, the line in the derived surface uniting them, and the tangent plane will change their positions, maintaining the aforesaid relations. We may conceive of the motion of the tangent plane as produced by rolling upon the primitive surface, while tangent to it in two points, and as it is also tangent to the derived surface in the lines joining these points, it is evident that the latter is a developable and forms a part of the envelop of the successive positions of the rolling plane. We shall see hereafter that the form of the primitive surface is such that the double tangent plane does not cut it, so that this rolling is physically possible.

From these relations may be deduced by simple geometrical considerations, one of the principal propositions in regard to such compounds. Let the tangent plane touch the primitive surface at the two points L and V (fig. 1), which, to fix our ideas, we may suppose to represent liquid and vapor; let planes pass through these points perpendicular to the axes of v and η respectively, intersecting in the line AB, which will be parallel to the axis of ε. Let the tangent plane cut this line at A, and let LB and VC be drawn at right angles to AB and parallel to the axes of η and v. Now the pressure and temperature represented by the tangent plane are evidently $\frac{AC}{CV}$ and $\frac{AB}{BL}$ respectively, and if we suppose the

Fig. 1.



never seen the phenomenon of the coexistence of these two states, or of any other two states of this substance.

Equation (γ) may be put in a form in which its validity is at once manifest for two states which can pass either into the other at a constant pressure and temperature. If we put p' and t' for the equivalent p'' and t'', the equation may be written

$$\epsilon'' - \epsilon' = t'(\eta'' - \eta') - p'(v'' - v').$$

Here the left hand member of the equation represents the difference of energy in the two states, and the two terms on the right represent severally the heat received and the work done when the body passes from one state to the other. The equation may also be derived at once from the general equation (1) by integration.

It is well known that when the two states being both fluid meet in a curved surface, instead of (α) we have

$$p'' - p' = T\left(\frac{1}{r} + \frac{1}{r'}\right),$$

where r and r' are the radii of the principal curvatures of the surface of contact at any point (positive, if the concavity is toward the mass to which p'' refers), and T is what is called the *superficial tension*. Equation (β), however, holds good for such cases, and it might easily be proved that the same is true of equation (γ). In other words, the tangent planes for the points in the thermodynamic surface representing the two states cut the plane $v=0$ in the same line.

tangent plane in rolling upon the primitive surface to turn about its instantaneous axis LV an infinitely small angle, so as to meet AB in A′, dp and dt will be equal to $\frac{AA'}{CV}$ and $\frac{AA'}{BL}$ respectively. Therefore,

$$\frac{dp}{dt} = \frac{BL}{CV} = \frac{\eta'' - \eta'}{v'' - v'},$$

where v' and η' denote the volume and entropy for the point L, and v'' and η'' those for the point V. If we substitute for $\eta'' - \eta'$ its equivalent $\frac{r}{t}$ (r denoting the heat of vaporization), we have the equation in its usual form, $\frac{dp}{dt} = \frac{r}{t\,(v'' - v')}$.

Properties of the Surface relating to Stability of Thermodynamic Equilibrium.

We will now turn our attention to the geometrical properties of the surface, which indicate whether the thermodynamic equilibrium of the body is stable, unstable, or neutral. This will involve the consideration, to a certain extent, of the nature of the processes which take place when equilibrium does not subsist. We will suppose the body placed in a medium of constant pressure and temperature; but as, when the pressure or temperature of the body at its surface differs from that of the medium, the immediate contact of the two is hardly consistent with the continuance of the initial pressure and temperature of the medium, both of which we desire to suppose constant, we will suppose the body separated from the medium by an envelop which will yield to the smallest differences of pressure between the two, but which can only yield very gradually, and which is also a very poor conductor of heat. It will be convenient and allowable for the purposes of reasoning to limit its properties to those mentioned, and to suppose that it does not occupy any space, or absorb any heat except what it transmits, i. e., to make its volume and its specific heat 0. By the intervention of such an envelop, we may suppose the action of the body upon the medium to be so retarded as not sensibly to disturb the uniformity of pressure and temperature in the latter.

When the body is not in a state of thermodynamic equilibrium, its state is not one of those which are represented by our surface. The body, however, as a whole has a certain volume, entropy, and energy, which are equal to the sums of the volumes, etc., of its parts.* If, then, we suppose points endowed with mass proportional to the masses of the various parts of the body, which are in different thermodynamic states, placed in the positions determined by the states and motions of these parts, (i. e., so placed that their co-ordinates are equal to the volume, entropy, and energy of the whole body supposed successively in the same states and endowed with the same velocities as the different parts,) the center of gravity of such points thus placed will evidently represent by its co-ordinates the volume, entropy, and energy of the whole body. If all parts of the body are at rest, the point representing its volume, entropy, and energy will be the center of gravity of a number of points upon the primitive surface. The effect of motion in the parts of the body will be to move the corresponding points parallel to the axis of ε, a distance equal in each case to the *vis viva* of the whole body, if endowed with the velocity of the part represented;—the center of gravity of points thus determined will give the volume, entropy, and energy of the whole body.

Now let us suppose that the body having the initial volume, entropy, and energy, v', η', and ε', is placed (enclosed in an envelop as aforesaid) in a medium having the constant pressure P and temperature T, and by the action of the medium and the interaction of its own parts comes to a final state of rest in which its volume, etc., are v'', η'', ε'';—we wish to find a relation between these quantities. If we regard, as we may, the medium as a very large body, so that imparting heat to it or compressing it within moderate limits will have no appreciable effect upon its pressure and temperature, and write V, H, and E, for its volume, entropy, and energy, equation (1) becomes

$$dE = TdH - PdV,$$

which we may integrate regarding P and T as constants, obtaining

$$E'' - E' = TH'' - TH' - PV'' + PV', \qquad (a)$$

where E', E'', etc., refer to the initial and final states of the medium. Again, as the sum of the energies of the body and the surrounding medium may become less, but cannot become greater (this arises from the nature of the envelop supposed), we have

$$\varepsilon'' + E'' \leqq \varepsilon' + E'. \qquad (b)$$

* As the discussion is to apply to cases in which the parts of the body are in (sensible) motion, it is necessary to define the sense in which the word *energy* is to be used. We will use the word as *including the vis viva of sensible motions.*

Again, as the sum of the entropies may increase but cannot diminish

$$\eta''+H'' \geqq \eta'+H'. \qquad (c)$$

Lastly, it is evident that

$$v''+V''=v'+V'. \qquad (d)$$

These four equations may be arranged with slight changes as follows:

$$-E''+TH''-PV''=-E'+TH'-PV'$$

$$\varepsilon''+E'' \leqq \varepsilon'+E'$$

$$-T\eta''-TH'' \leqq -T\eta'-TH'$$

$$Pv''+PV''=Pv'+PV'.$$

By addition we have

$$\varepsilon''-T\eta''+Pv'' \leqq \varepsilon'-T\eta'+Pv'. \qquad (e)$$

Now the two members of this equation evidently denote the vertical distances of the points (v'', η'', ε'') and (v', η', ε') above the plane passing through the origin and representing the pressure P and temperature T. And the equation expresses that the ultimate distance is less or at most equal to the initial. It is evidently immaterial, whether the distances be measured vertically or normally, or that the fixed plane representing P and T should pass through the origin; but distances must be considered negative when measured from a point below the plane.

It is evident that the sign of inequality holds in (e) if it holds in either (b) or (c), therefore, it holds in (e) if there are any differences of pressure or temperature between the different parts of the body or between the body and the medium, or if any part of the body has sensible motion. (In the latter case, there would be an increase of entropy due to the conversion of this motion into heat). But even if the body is initially without sensible motion and has throughout the same pressure and temperature as the medium, the sign $<$ will still hold if different parts of the body are in states represented by points in the thermodynamic surface at different distances from the fixed plane representing P and T. For it certainly holds if such initial circumstances are followed by differences of pressure or temperature, or by sensible velocities. Again, the sign of inequality would necessarily hold if one part of the body should pass, without producing changes of pressure or temperature or sensible velocities, into the state of another part represented by a point not at the same distance from the fixed plane representing P and T. But these are the only suppositions possible in the case, unless we suppose that equilibrium subsists, which would require that the points in question should have a common tangent plane (page 386), whereas by supposition the planes tangent at the different points are parallel but not identical.

The results of the preceding paragraph may be summed up as follows:—Unless the body is initially without sensible motion, and its state, if homogeneous, is such as is represented by a point in the primitive surface where the tangent plane is parallel to the fixed plane representing P and T, or, if the body is not homogeneous in state, unless the points in the primitive surface representing the states of its parts have a common tangent plane parallel to the fixed plane representing P and T, such changes will ensue that the distance of the point representing the volume, entropy, and energy of the body from that fixed plane will be diminished (distances being considered negative if measured from points beneath the plane). Let us apply this result to the question of the stability of the body when surrounded, as supposed, by a medium of constant temperature and pressure.

The state of the body in equilibrium will be represented by a point in the thermodynamic surface, and as the pressure and temperature of the body are the same as those of the surrounding medium, we may take the tangent plane at that point as the fixed plane representing P and T. If the body is not homogeneous in state, although in equilibrium, we may, for the purposes of this discussion of stability, either take a point in the derived surface as representing its state, or we may take the points in the primitive surface which represent the states of the different parts of the body. These points, as we have seen (page 386), have a common tangent plane, which is identical with the tangent plane for the point in the derived surface.

Now, if the form of the surface be such that it falls above the tangent plane except at the single point of contact, the equilibrium is necessarily stable; for if the condition of the body be slightly altered, either by imparting sensible motion to any part of the body, or by slightly changing the state of any part, or by bringing any small part into any other thermodynamic state whatever, or in all of these ways, the point representing the volume, entropy, and energy of the whole body will then occupy a position *above* the original tangent plane, and the proposition above enunciated shows that processes will ensue which will diminish the distance of this point from that plane, and that such processes cannot cease until the body is brought back into its original condition, when they will necessarily cease on account of the form supposed of the surface.

On the other hand, if the surface have such a form that any part of it falls below the fixed tangent plane, the equilibrium will be unstable. For it will evidently be possible by a slight change in the original condition of the body (that of equilibrium with the surrounding medium and represented by the point or points of contact) to bring the point representing the volume, entropy, and energy of the body into a position *below* the fixed tangent plane, in which case we see by the above proposition that processes will occur which will carry the point still farther from the plane, and that such processes cannot cease until all the body has passed into some state entirely different from its original state.

It remains to consider the case in which the surface, although it does not anywhere fall below the fixed tangent plane, nevertheless meets the plane in more than one point. The equilibrium in this case, as we might anticipate from its intermediate character between the cases already considered, is neutral. For if any part of the body be changed from its original state into that represented by another point in the thermodynamic surface lying in the same tangent plane, equilibrium will still subsist. For the supposition in regard to the form of the surface implies that uniformity in temperature and pressure still subsists, nor can the body have any necessary tendency to pass entirely into the second state or to return into the original state, for a change of the values of T and P less than any assignable quantity would evidently be sufficient to reverse such a tendency if any such existed, as either point at will could by such an infinitesimal variation of T and P be made the nearer to the plane representing T and P.

It must be observed that in the case where the thermodynamic surface at a certain point is concave upward in both its principal curvatures, but somewhere falls below the tangent plane drawn through that point, the equilibrium although unstable in regard to *discontinuous* changes of state is stable in regard to *continuous* changes, as appears on restricting the test of stability to the vicinity of the point in question; that is, if we suppose a body to be in a state represented by such a point, although the equilibrium would show itself unstable if we should introduce into the body a small portion of the same substance in one of the states represented by points below the tangent plane, yet if the conditions necessary for such a discontinuous change are not present, the equilibrium would be stable. A familiar example of this is afforded by liquid water when heated at any pressure above the temperature of boiling water at that pressure.*

Leading Features of the Thermodynamic Surface for Substances which take the forms of Solid, Liquid and Vapor.

We are now prepared to form an idea of the general character of the primitive and derived surfaces and their mutual relations for a substance which takes the forms of solid, liquid, and vapor. The primitive surface will have a triple tangent plane touching it at the three points which represent the three states which can exist in contact. Except at these three points, the primitive surface falls entirely above the tangent plane. That part of the plane which forms a triangle having its vertices at the three points of contact, is the derived surface which represents a compound of the three states of the substance. We may now suppose the plane to roll on the under side of the surface, continuing to touch it in two points without cutting it. This it may do in three ways, viz: it may commence by turning about any one of the sides of the triangle aforesaid. Any pair of points which the plane touches at once represent states which can exist permanently in contact. In this way six lines are traced upon the surface. These lines have in general a common property, that a tangent plane at any point in them will also touch the surface in another point. We must say *in general*, for, as we shall see hereafter, this statement does not hold good for the critical point. A tangent plane at any point of the surface *outside* of these lines has the surface entirely above it, except the single point of contact. A tangent plane at any point of the primitive surface *within* these lines will cut the surface. These lines, therefore, taken together may be called the *limit of absolute stability*, and the surface outside of them, the *surface of absolute stability*. That part of the envelop of the rolling plane, which lies between the pair of lines which the plane traces on the surface, is a part of the derived surface, and represents a mixture of two states of the substance.

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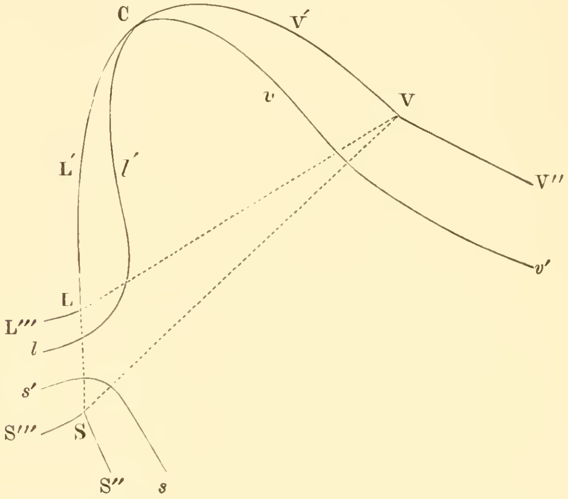
* If we wish to express in a single equation the necessary and sufficient condition of thermodynamic equilibrium for a substance when surrounded by a medium of constant pressure P and temperature T, this equation may be written

$$\delta\,(\varepsilon - T\eta + Pv) = 0,$$

when δ refers to the variation produced by any variations in the state of the parts of the body, and (when different parts of the body are in different states) in the proportion in which the body is divided between the different states. The condition of stable equilibrium is that the value of the expression in the parenthesis shall be a minimum.

The relations of these lines and surfaces are roughly represented in horizontal projection* in figure 2, in which the full lines represent lines on the primitive surface, and the dotted lines those on the derived surface. S, L, and V are the points which have a common tangent plane and represent the states of solid, liquid, and vapor

Fig. 2.



which can exist in contact. The plane triangle SLV is the derived surface representing compounds of these states. LL′ and VV′ are the pair of lines traced by the rolling double tangent plane, between which lies the derived surface representing compounds of liquid and vapor. VV″ and SS″ are another such pair, between which lies the derived surface representing compounds of vapor and solid. SS‴ and LL‴ are the third pair, between which lies the derived surface representing a compound of solid and liquid. L‴LL′, V′VV″ and S″SS‴ are the boundaries of the surfaces which represent respectively the absolutely stable states of liquid, vapor, and solid.

The geometrical expression of the results which Dr. Andrews (Phil. Trans., vol. 159, p. 575) has obtained by his experiments with carbonic acid is that, in the case of this substance at least, the derived surface which represents a compound of liquid and vapor is terminated as follows: as the tangent plane rolls upon the primitive surface, the two points of contact approach one another and finally fall

* A horizontal projection of the thermodynamic surface is identical with the diagram described on pages 330–338 of this volume, under the name of the volume-entropy diagram.

together. The rolling of the double tangent plane necessarily comes to an end. The point where the two points of contact fall together is the *critical point*. Before considering farther the geometrical characteristics of this point and their physical significance, it will be convenient to investigate the nature of the primitive surface which lies between the lines which form the limit of absolute stability.

Between two points of the primitive surface which have a common tangent plane, as those represented by L′ and V′ in figure 2, if there is no gap in the primitive surface, there must evidently be a region where the surface is concave toward the tangent plane in one of its principal curvatures at least, and therefore represents states of unstable equilibrium in respect to continuous as well as discontinuous changes (see page 392).* If we draw a line upon the primitive surface, dividing it into parts which represent respectively stable and unstable equilibrium, in respect to continuous changes, i. e., dividing the surface which is concave upward in both its principal curvatures from that which is concave downward in one or both, this line, which may be called the *limit of essential instability*, must have a form somewhat like that represented by *ll′Cvv′ss′* in figure 2. It touches the limit of absolute stability at the critical point C. For we may take a pair of points in LC and VC having a common tangent plane as near to C as we choose, and the line joining them upon the primitive surface made by a plane section perpendicular to the tangent plane, will pass through an area of instability.

The geometrical properties of the critical point in our surface may be made more clear by supposing the lines of curvature drawn upon the surface for one of the principal curvatures, that one, namely, which has different signs upon different sides of the limit of essential instability. The lines of curvature which meet this line will in general cross it. At any point where they do so, as the sign of their curvature changes, they evidently cut a plane tangent to the surface, and therefore the surface itself cuts the tangent plane. But where one of these lines of curvature touches the limit of essential instability without crossing it, so that its curvature remains always positive (curvatures being considered positive when the concavity is on the upper side of the surface), the surface evidently does not cut the tangent plane, but has a contact of the third order with it in the section of least curvature. The critical point, therefore, must be a point

* This is the same result as that obtained by Professor J. Thomson in connection with the surface referred to in the note on page 382.

where the line of that principal curvature which changes its sign is tangent to the line which separates positive from negative curvatures.

From the last paragraphs we may derive the following physical property of the critical state:—Although this is a limiting state between those of stability and those of instability in respect to continuous changes, and although such limiting states are in general unstable in respect to such changes, yet the critical state is stable in regard to them. A similar proposition is true in regard to absolute stability, i. e., if we disregard the distinction between continuous and discontinuous changes, viz: that although the critical state is a limiting state between those of stability and instability, and although the equilibrium of such limiting states is in general neutral (when we suppose the substance surrounded by a medium of constant pressure and temperature), yet the critical point is stable.

From what has been said of the curvature of the primitive surface at the critical point, it is evident, that if we take a point in this surface infinitely near to the critical point, and such that the tangent planes for these two points shall intersect in a line perpendicular to the section of least curvature at the critical point, the angle made by the two tangent planes will be an infinitesimal of the same order as the cube of the distance of these points. Hence, at the critical point

$$\left(\frac{dp}{dv}\right)_t=0, \qquad \left(\frac{dp}{d\eta}\right)_t=0, \qquad \left(\frac{dt}{dv}\right)_p=0, \qquad \left(\frac{dt}{d\eta}\right)_p=0,$$

$$\left(\frac{d^2p}{dv^2}\right)_t=0, \qquad \left(\frac{d^2p}{d\eta^2}\right)_t=0, \qquad \left(\frac{d^2t}{dv^2}\right)_p=0, \qquad \left(\frac{d^2t}{d\eta^2}\right)_p=0,$$

and if we imagine the isothermal and isopiestic (line of constant pressure) drawn for the critical point upon the primitive surface, these lines will have a contact of the third order.

Now the elasticity of the substance at constant temperature and its specific heat at constant pressure may be defined by the equations,

$$e=-v\left(\frac{dp}{dv}\right)_t, \qquad s=t\left(\frac{d\eta}{dt}\right)_p;$$

therefore at the critical point

$$e=0, \qquad \frac{1}{s}=0,$$

$$\left(\frac{de}{dv}\right)_t=0, \qquad \left(\frac{de}{d\eta}\right)_t=0, \qquad \left(\frac{d\frac{1}{s}}{dv}\right)_p=0, \qquad \left(\frac{d\frac{1}{s}}{d\eta}\right)_p=0.$$

The last four equations would also hold good if p were substituted for t, and *vice versa*.

We have seen that in the case of such substances as can pass continuously from the state of liquid to that of vapor, unless the primitive surface is abruptly terminated and that in a line which passes through the critical point, a part of it must represent states which are essentially unstable (i. e., unstable in regard to continuous changes,) and therefore cannot exist permanently unless in very limited spaces. It does not necessarily follow that such states cannot be realized at all. It appears quite probable, that a substance initially in the critical state may be allowed to expand so rapidly, that, the time being too short for appreciable conduction of heat, it will pass into some of these states of essential instability. No other result is possible on the supposition of no transmission of heat, which requires that the points representing the states of all the parts of the body shall be confined to the isentropic (adiabatic) line of the critical point upon the primitive surface. It will be observed that there is no instability in regard to changes of state thus limited, for this line (the plane section of the primitive surface perpendicular to the axis of η) is concave upward, as is evident from the fact that the primitive surface lies entirely above the tangent plane for the critical point.

We may suppose waves of compression and expansion to be propagated in a substance initially in the critical state. The velocity of propagation will depend upon the value of $\left(\frac{dp}{dv}\right)_\eta$, i. e., of $-\left(\frac{d^2\varepsilon}{d^2v}\right)_\eta$. Now for a wave of compression the value of these expressions is determined by the form of the isentropic on the primitive surface. If a wave of expansion has the same velocity approximately as one of compression, it follows that the substance when expanded under the circumstances remains in a state represented by the primitive surface, which involves the realization of states of essential instability. The value of $\left(\frac{d^2\varepsilon}{dv^2}\right)_\eta$ in the derived surface is, it will be observed, totally different from its value in the primitive surface, as the curvature of these surfaces at the critical point is different.

The case is different in regard to the part of the surface between the limit of absolute stability and the limit of essential instability. Here, we have experimental knowledge of some of the states represented. In water, for example, it is well known that liquid states can be realized beyond the limit of absolute stability,—both beyond the part of the limit where vaporization usually commences (LL′ in figure 2), and beyond the part where congelation usually commences (LL″). That vapor may also exist beyond the limit of absolute stability, i. e., that it may exist at a given temperature at pressures greater than that of equilibrium between the vapor and its liquid meeting in a plane surface at that temperature, the considerations adduced by Sir W. Thomson in his paper "On the equilibrium of a vapor at the curved surface of a liquid" (Proc. Roy. Soc. Ed., Session 1869–1870, and Phil. Mag., vol. xlii, p. 448), leave no room for doubt. By experiments like that suggested by Professor J. Thomson in his paper already referred to, we may be able to carry vapors farther beyond the limit of absolute stability.* As the resistance to deformation characteristic of solids evidently tends to prevent a discontinuous change of state from commencing within them, substances can doubtless exist in solid states very far beyond the limit of absolute stability.

The surface of absolute stability, together with the triangle representing a compound of three states, and the three developable surfaces which have been described representing compounds of two states, forms a continuous sheet, which is everywhere concave upward except where it is plane, and has only one value of ε for any given values of v and η. Hence, as t is necessarily positive, it has only one value of η for any given values of v and ε. If vaporization can take place at every temperature except 0, p is everywhere positive, and the surface has only one value of v for any given values of η and ε. It forms the *surface of dissipated energy*. If we consider all the points representing the volume, entropy, and energy of the body in every possible state, whether of equilibrium or not, these points will

* If we experiment with a fluid which does not wet the vessel which contains it, we may avoid the necessity of keeping the vessel hotter than the vapor, in order to prevent condensation. If a glass bulb with a stem of sufficient length be placed vertically with the open end of the stem in a cup of mercury, the stem containing nothing but mercury and its vapor, and the bulb nothing but the vapor, the height at which the mercury rests in the stem, affords a ready and accurate means of determining the pressure of the vapor. If the stem at the top of the column of liquid should be made hotter than the bulb, condensation would take place in the latter, if the liquid were one which would wet the bulb. But as this is not the case, it appears probable, that if the experiment were conducted with proper precautions, there would be no condensation within certain limits in regard to the temperatures. If condensation should take place, it would be easily observed, especially if the bulb were bent over, so that the mercury condensed could not run back into the stem. So long as condensation does not occur, it will be easy to give any desired (different) temperatures to the bulb and the top of the column of mercury in the stem. The temperature of the latter will determine the pressure of the vapor in the bulb. In this way, it would appear, we may obtain in the bulb vapor of mercury having pressures greater for the temperatures than those of saturated vapor.

form a solid figure unbounded in some directions, but bounded in others by this surface.*

The lines traced upon the primitive surface by the rolling double tangent plane, which have been called the limit of absolute stability, do not end at the vertices of the triangle which represents a mixture of those states. For when the plane is tangent to the primitive surface in these three points, it can commence to roll upon the surface as a double tangent plane not only by leaving the surface at one of these points, but also by a rotation in the opposite direction. In the latter case, however, the lines traced upon the primitive surface by the points of contact, although a continuation of the lines previously described, do not form any part of the limit of absolute stability. And the parts of the envelops of the rolling plane between these lines, although a continuation of the developable surfaces which have been described, and representing states of the body, of which some at least may be realized, are of minor interest, as they form no part of the

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* This description of the surface of dissipated energy is intended to apply to a substance capable of existing as solid, liquid, and vapor, and which presents no anomalies in its thermodynamic properties. But, whatever the form of the primitive surface may be, if we take the parts of it for every point of which the tangent plane does not cut the primitive surface, together with all the plane and developable derived surface, which can be formed in a manner analogous to those described in the preceding pages, by fixed and rolling tangent planes which do not cut the primitive surface,—such surfaces taken together will form a continuous sheet, which, if we reject the part, if any, for which $p < 0$, forms the surface of dissipated energy and has the geometrical properties mentioned above.

There will, however, be no such part in which $p < 0$, if there is any assignable temperature t' at which the substance has the properties of a perfect gas except when its volume is less than a certain quantity v'. For the equations of an isothermal line in the thermodynamic surface of a perfect gas are (see equations (B) and (E) on pages 321–322 of this volume.)

$$\varepsilon = C$$
$$\eta = a \log v + C'.$$

The isothermal of t' in the thermodynamic surface of the substance in question must therefore have the same equations in the part in which v exceeds the constant v'. Now if at any point in this surface $p < 0$ and $t > 0$ the equation of the tangent plane for that point will be

$$\varepsilon = m\eta + nv + C'',$$

where m denotes the temperature and $-n$ the pressure for the point of contact, so that m and n are both positive. Now it is evidently possible to give so large a value to v in the equations of the isothermal that the point thus determined shall fall below the tangent plane. Therefore, the tangent plane cuts the primitive surface, and the point of the thermodynamic surface for which $p < 0$ cannot belong to the surfaces mentioned in the last paragraph as forming a continuous sheet.

surface of dissipated energy on the one hand, nor have the theoretical interest of the primitive surface on the other.

Problems relating to the Surface of Dissipated Energy.

The surface of dissipated energy has an important application to a certain class of problems which refer to the results which are theoretically possible with a given body or system of bodies in a given initial condition.

For example, let it be required to find the greatest amount of mechanical work which can be obtained from a given quantity of a certain substance in a given initial state, without increasing its total volume or allowing heat to pass to or from external bodies, except such as at the close of the processes are left in their initial condition. This has been called the *available energy* of the body. The initial state of the body is supposed to be such that the body can be made to pass from it to states of dissipated energy by reversible processes.

If the body is in a state represented by any point of the surface of dissipated energy, of course no work can be obtained from it under the given conditions. But even if the body is in a state of thermodynamic equilibrium, and therefore in one represented by a point in the thermodynamic surface, if this point is not in the surface of dissipated energy, because the equilibrium of the body is unstable in regard to discontinuous changes, a certain amount of energy will be available under the conditions for the production of work. Or, if the body is solid, even if it is uniform in state throughout, its pressure (or tension) may have different values in different directions, and in this way it may have a certain available energy. Or, if different parts of the body are in different states, this will in general be a source of available energy. Lastly, we need not exclude the case in which the body has sensible motion and its *vis viva* constitutes available energy. In any case, we must find the initial volume, entropy, and energy of the body, which will be equal to the sums of the initial volumes, entropies, and energies of its parts. ('Energy' is here used to include the *vis viva* of sensible motions). These values of v, η, and ε will determine the position of a certain point which we will speak of as representing the initial state.

Now the condition that no heat shall be allowed to pass to external bodies, requires that the final entropy of the body shall not be less than the initial, for it could only be made less by violating this condition. The problem, therefore, may be reduced to this,—to find the amount by which the energy of the body may be diminished without increasing its volume or diminishing its entropy. This quantity will be represented geometrically by the distance of the point representing the initial state from the surface of dissipated energy measured parallel to the axis of ε.

Let us consider a different problem. A certain initial state of the body is given as before. No work is allowed to be done upon or by external bodies. Heat is allowed to pass to and from them only on condition that the algebraic sum of all heat which thus passes shall be 0. From both these conditions any bodies may be excepted, which shall be left at the close of the processes in their initial state. Moreover, it is not allowed to increase the volume of the body. It is required to find the greatest amount by which it is possible under these conditions to diminish the entropy of an external system. This will be, evidently, the amount by which the entropy of the body can be increased without changing the energy of the body or increasing its volume, which is represented geometrically by the distance of the point representing the initial state from the surface of dissipated energy, measured parallel to the axis of η. This might be called the capacity for entropy of the body in the given state.*

Thirdly. A certain initial condition of the body is given as before. No work is allowed to be done upon or by external bodies, nor any heat to pass to or from them; from which conditions bodies may be excepted, as before, in which no permanent changes are produced. It is required to find the amount by which the volume of the body

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* It may be worth while to call attention to the analogy and the difference between this problem and the preceding. In the first case, the question is virtually, how great a weight does the state of the given body enable us to raise a given distance, no other permanent change being produced in external bodies. In the second case, the question is virtually, what amount of heat does the state of the given body enable us to take from an external body at a fixed temperature, and impart to another at a higher fixed temperature. In order that the numerical values of the available energy and of the capacity for entropy should be identical with the answers to these questions, it would be necessary in the first case, if the weight is measured in units of force, that the given distance, measured vertically, should be the unit of length, and in the second case, that the difference of the reciprocals of the fixed temperatures should be unity. If we prefer to take the freezing and boiling points as the fixed temperatures, as $\frac{1}{273} - \frac{1}{373} = 0.00098$, the capacity for entropy of the body in any given condition would be 0.00098 times the amount of heat which it would enable us to raise from the freezing to the boiling point (i. e., to take from a body of which the temperature remains fixed at the freezing point, and impart to another of which the temperature remains fixed at the boiling point).

The relations of these quantities to one another and to the surface of dissipated energy are illustrated by figure 3, which represents a plane perpendicular to the axis can be diminished, using for that purpose, according to the conditions, only the force derived from the body itself. The conditions

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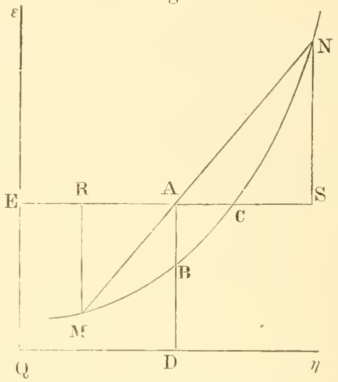
of v and passing through the point A, which represents the initial state of the body. MN is the section of the surface of dissipated energy. $Q\varepsilon$ and $Q\eta$ are sections of the planes $\eta = 0$ and $\varepsilon = 0$, and therefore parallel to the axes of ε and η respectively. AD and AE are the energy and entropy of the body in its initial state, AB and AC, its available energy and its capacity for entropy respectively. It will be observed that when either the available energy or the capacity for entropy of the body is 0, the other has the same value. Except in this case, either quantity may be varied without affecting the other. For, on account of the curvature of the surface of dissipated energy, it is evidently possible to change the position of the point representing the initial state of the body so as to vary its distance from the surface measured parallel to one axis without varying that measured parallel to the other.

Fig. 3.



As the different senses in which the word *entropy* has been used by different writers is liable to cause misunderstanding, it may not be out of place to add a few words on the terminology of this subject. If Professor Clausius had defined *entropy* so that its value should be determined by the equation

$$dS = -\frac{dQ}{T},$$

instead of his equation (Mechanische Wärmetheorie, Abhand. ix, § 14; Pogg. Ann., July, 1865)

$$dS = \frac{dQ}{T},$$

where S denotes the entropy and T the temperature of a body and dQ the element of heat imparted to it, that which is here called *capacity for entropy* would naturally be called *available entropy*, a term the more convenient on account of its analogy with the term *available energy*. Such a difference in the definition of *entropy* would involve no difference in the form of the thermodynamic surface, nor in any of our geometrical constructions, if only we suppose the direction in which entropy is measured to be reversed. It would only make it necessary to substitute $-\eta$ for η in our equations, and to make the corresponding change in the verbal enunciation of propositions. Professor Tait has proposed to use the word entropy "in the opposite sense to that in which Clausius has employed it," (Thermodynamics, § 48. See also § 178), which appears to mean that he would determine its value by the first of the above equations. He nevertheless appears subsequently to use the word to denote available energy (§ 182, 2d theorem). Professor Maxwell uses the word entropy as synonymous with available energy, with the erroneous statement that Clausius uses the word to denote the part of the energy which is not available, (Theory of Heat, pp. 186 and 188). The term entropy, however, as used by Clausius does not denote a quantity of the same kind (i. e., one which can be measured by the same unit) as energy, as is evident from his equation, cited above, in which Q (heat) denotes a quantity measured by the unit require that the energy of the body shall not be altered nor its entropy diminished. Hence the quantity sought is represented by the distance of the point representing the initial state from the surface of dissipated energy, measured parallel to the axis of volume.

Fourthly. An initial condition of the body is given as before. Its volume is not allowed to be increased. No work is allowed to be done upon or by external bodies, nor any heat to pass to or from them, except a certain body of given constant temperature t'. From the latter conditions may be excepted as before bodies in which no permanent changes are produced. It is required to find the greatest amount of heat which can be imparted to the body of constant temperature, and also the greatest amount of heat which can be taken from it, under the supposed conditions. If through the point of the initial state a straight line be drawn in the plane perpendicular to the axis of v, so that the tangent of the angle which it makes with the direction of the axis of η shall be equal to the given temperature t', it may easily be shown that the vertical projections of the two segments of this line made by the point of the initial state and the surface of dissipated energy represent the two quantities required.*

These problems may be modified so as to make them approach more nearly the economical problems which actually present themselves, if we suppose the body to be surrounded by a medium of constant pressure and temperature, and let the body and the medium together take the place of the body in the preceding problems. The results would be as follows:

If we suppose a plane representing the constant pressure and temperature of the medium to be tangent to the surface of dissipated energy of the body, the distance of the point representing the initial state of the body from this plane measured parallel to the axis of ε will represent the available energy of the body and medium, the distance of the point to the plane measured parallel to the axis of η will represent the capacity for entropy of the body and medium, the distance of the point to the plane measured parallel to the axis of v will represent the magnitude of the greatest vacuum which can be produced in the body or medium (all the power used being derived from

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of energy, and as the unit in which T (temperature) is measured is arbitrary, S and Q are evidently measured by different units. It may be added that entropy as defined by Clausius is synonymous with the thermodynamic function as defined by Rankine.

* Thus, in figure 3, if the straight line MAN be drawn so that $\tan \text{NAC} = t'$, MR will be the greatest amount of heat which can be given to the body of constant temperature and NS will be the greatest amount which can be taken from it.

the body and medium); if a line be drawn through the point in a plane perpendicular to the axis of v, the vertical projection of the segment of this line made by the point and the tangent plane will represent the greatest amount of heat which can be given to or taken from another body at a constant temperature equal to the tangent of the inclination of the line to the horizon. (It represents the greatest amount which can be given to the body of constant temperature, if this temperature is greater than that of the medium; in the reverse case, it represents the greatest amount which can be withdrawn from that body). In all these cases, the point of contact between the plane and the surface of dissipated energy represents the final state of the given body.

If a plane representing the pressure and temperature of the medium be drawn through the point representing any given initial state of the body, the part of this plane which falls within the surface of dissipated energy will represent in respect to volume, entropy, and energy all the states into which the body can be brought by reversible processes, without producing permanent changes in external bodies (except in the medium), and the solid figure included between this plane figure and the surface of dissipated energy will represent all the states into which the body can be brought by any kind of processes, without producing permanent changes in external bodies (except in the medium).*

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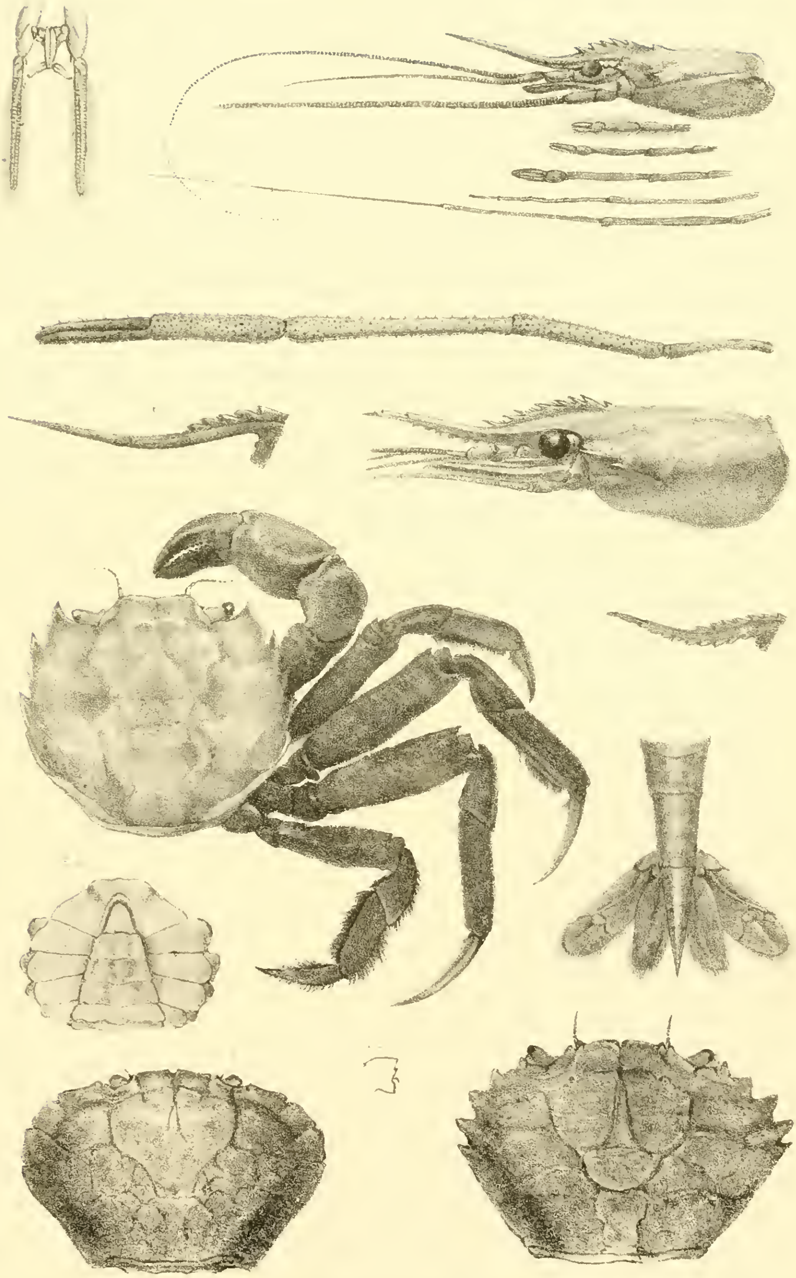
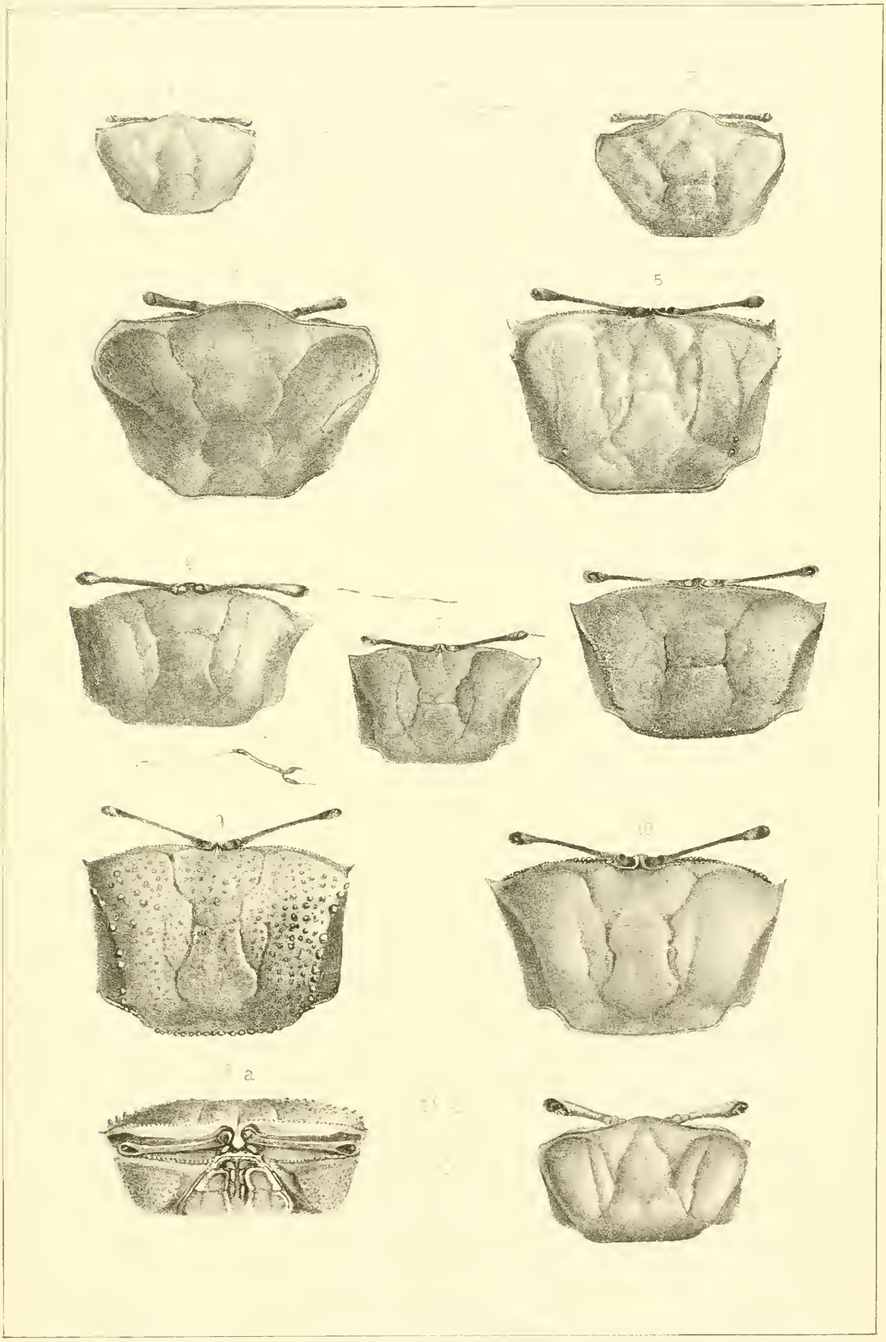
* The body under discussion has been supposed throughout this paper to be homogeneous in substance. But if we imagine any material system whatever, and suppose the position of a point to be determined for every possible state of the system, by making the co-ordinates of the point equal to the total volume, entropy, and energy of the system, the points thus determined will evidently form a solid figure bounded in certain directions by the surface representing the states of dissipated energy. In these states, the temperature is necessarily uniform throughout the system; the pressure may vary (e. g., in the case of a very large mass like a planet), but it will always be possible to maintain the equilibrium of the system (in a state of dissipated energy) by a uniform normal pressure applied to its surface. This pressure and the uniform temperature of the system will be represented by the inclination of the surface of dissipated energy according to the rule on page 383. And in regard to such problems as have been discussed in the last five pages of this paper, this surface will possess, relatively to the system which it represents, properties entirely similar to those of the surface of dissipated energy of a homogeneous body.

INDEX.

ERRATA.

Page 1, line 13, for "Flordia," read Florida.
" 11, " 35. " "immargination," read emargination.
" 16, " 26, " "spistome," read epistome.
" 31, " 18, " "*Podopthalmia*," read *Podophthalmia*.
" 35, " 9, " "*Eucrete*," read *Eucrate*.
" 35, last line but one, for "margin," read margins.
" 106, line 4, from foot, for "Norton Street," read Blake Street.
" 108, " 11, " " "twenty rods," read twenty-one rods.
" 118, " 11, for "styiferus," read styliferus.
" 138, " 11, " "immargination," read emargination.
" 139, " 11, " "immarginate," read emarginate.
" 153, first line of foot note, for "is marked 3," read is marked 3e.
" 162, above "*Euryplax*," insert CARCINOPLACIDÆ.
" 188, line 8, for "spinosus," read spinosum.
" 197, " 31, " "palpaster," read polpaster.
" 343, in title of paper, for "1873," read 1872.
" 343, under No. 5, for "varible," read variable.
" 346, No. 24, line 7, for "Montague," read Montagne.
" 348, No. 44, for "Euteromorpha," read Enteromorpha.

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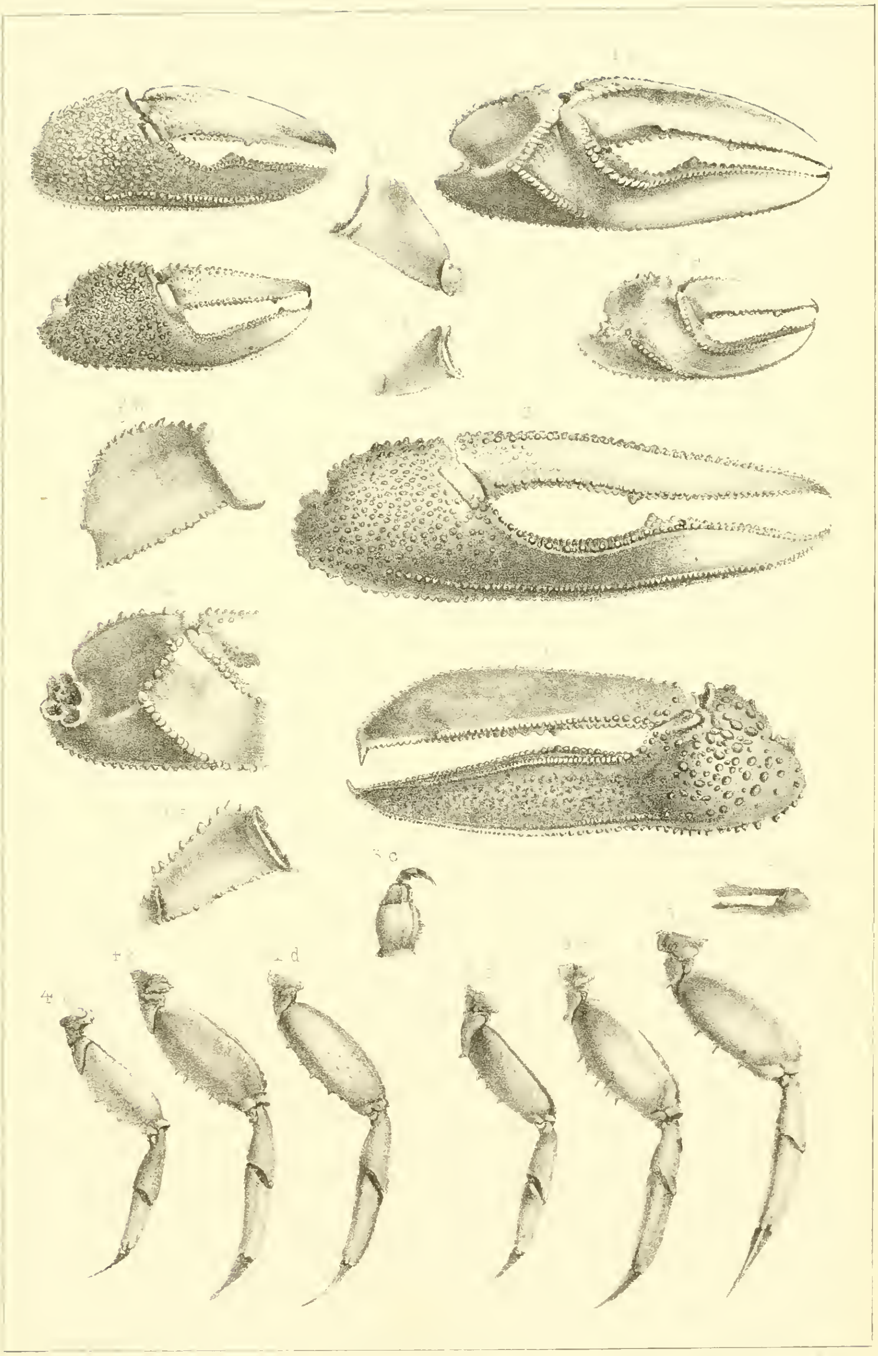

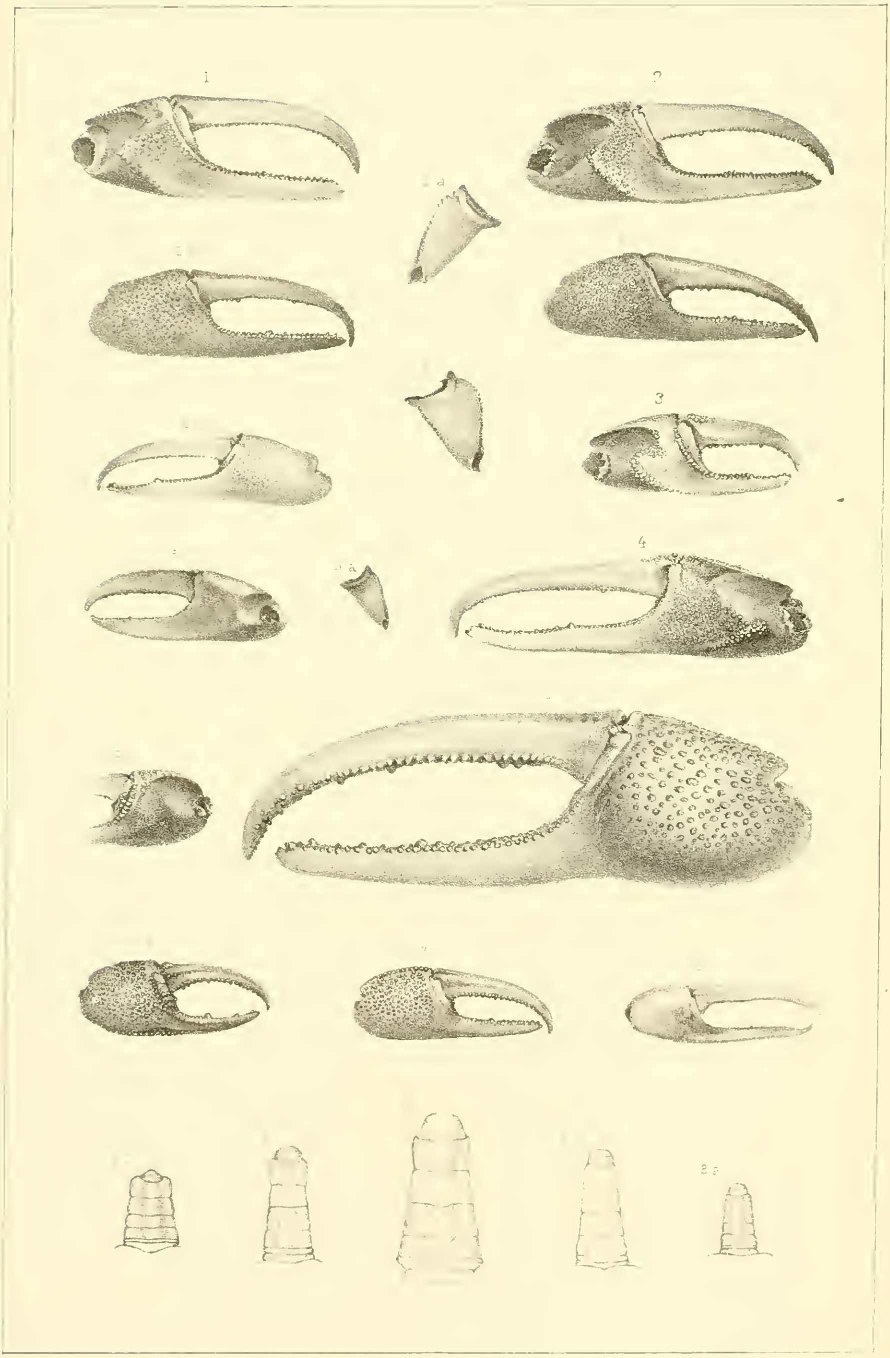
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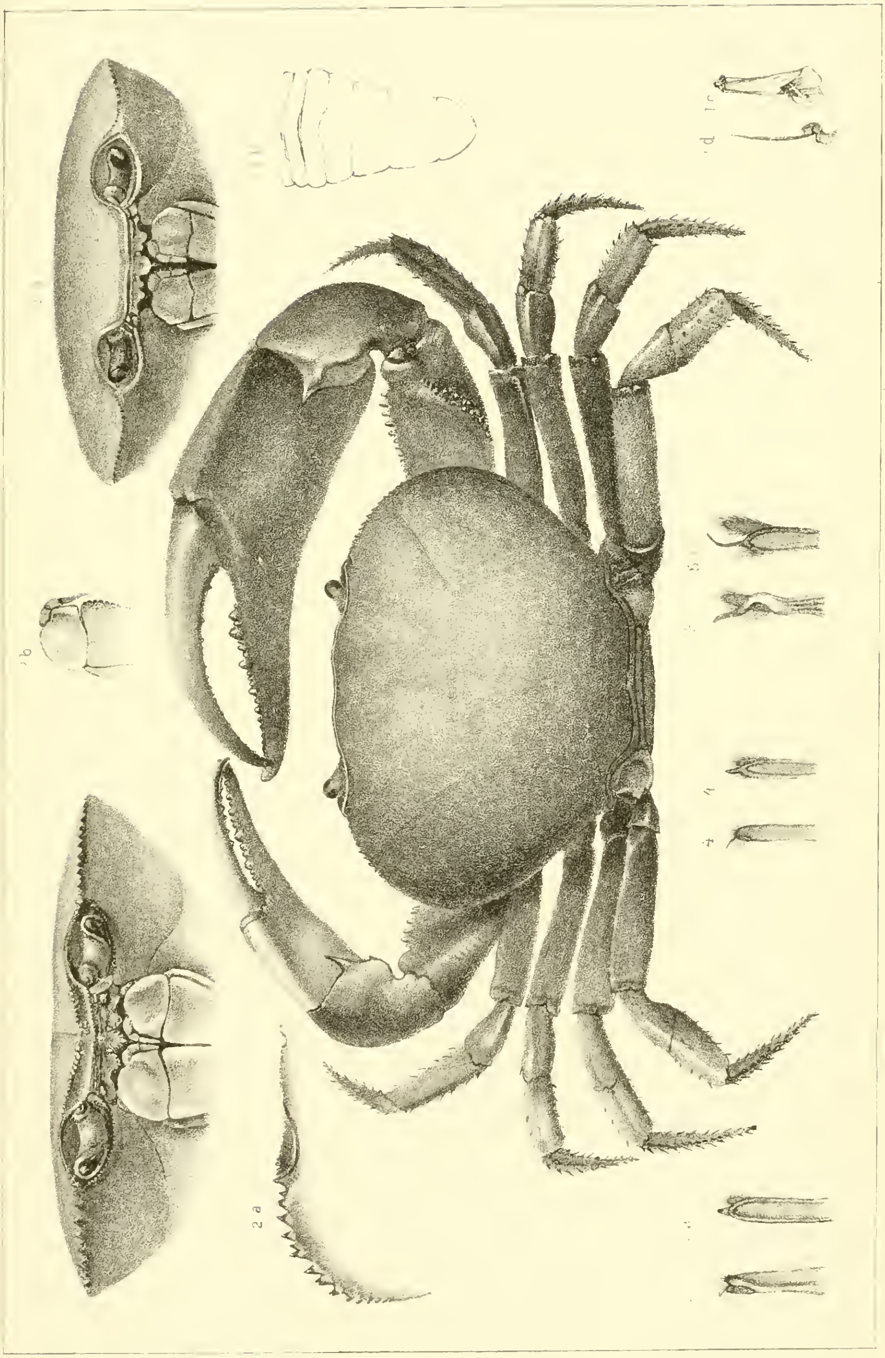

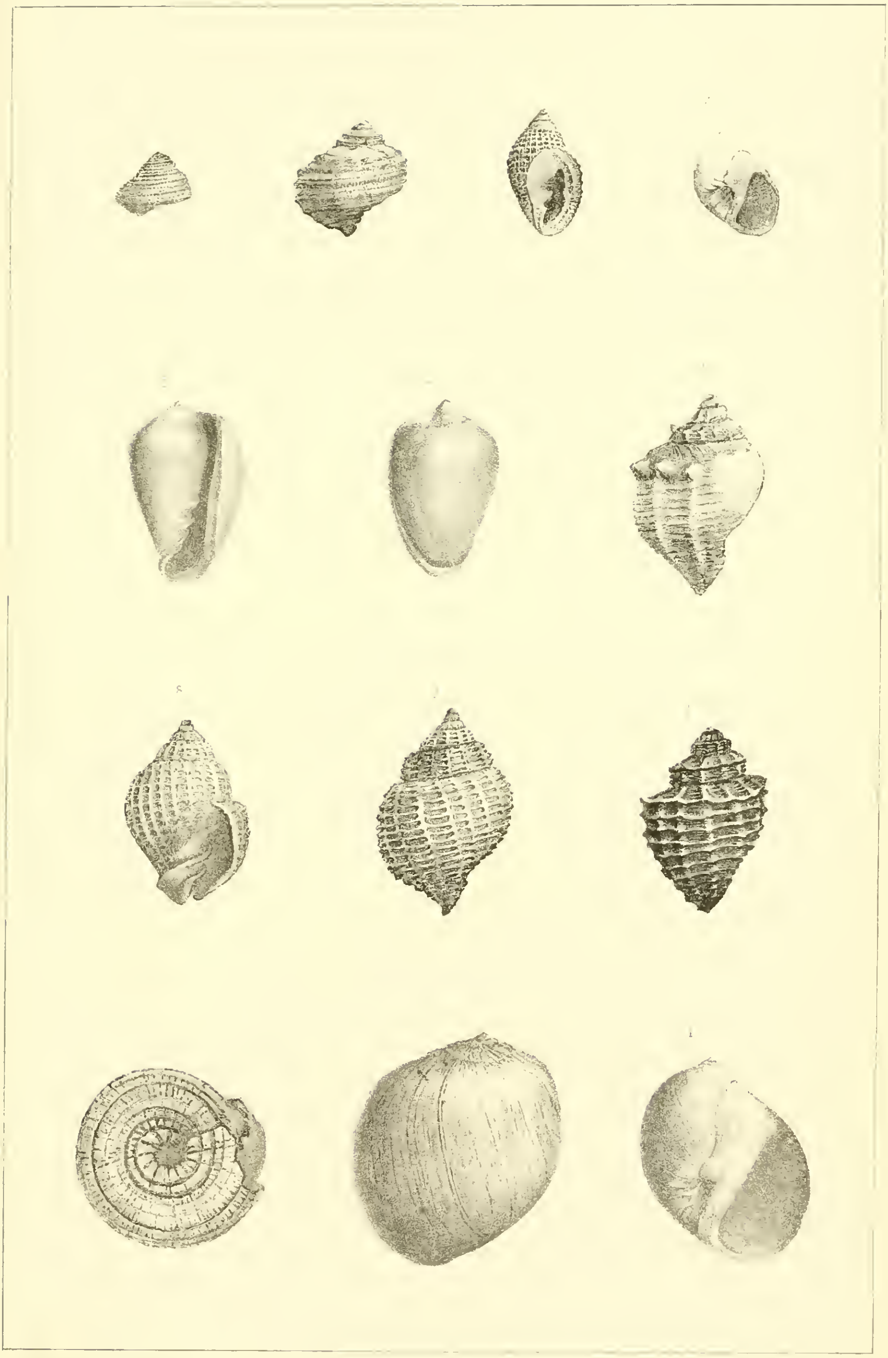

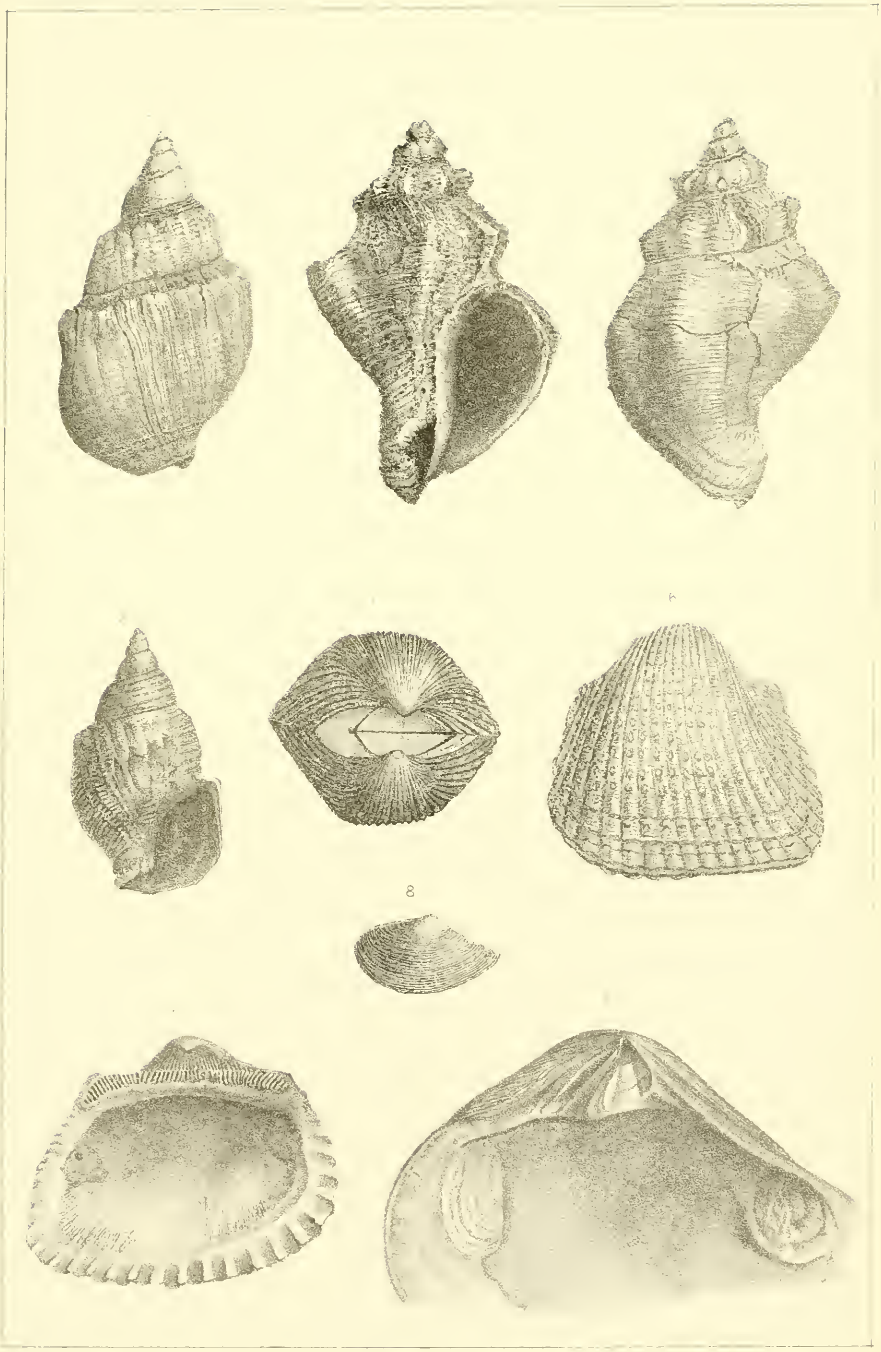
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Plate VIII. DIURNAL CHANGE IN THE DIRECTION

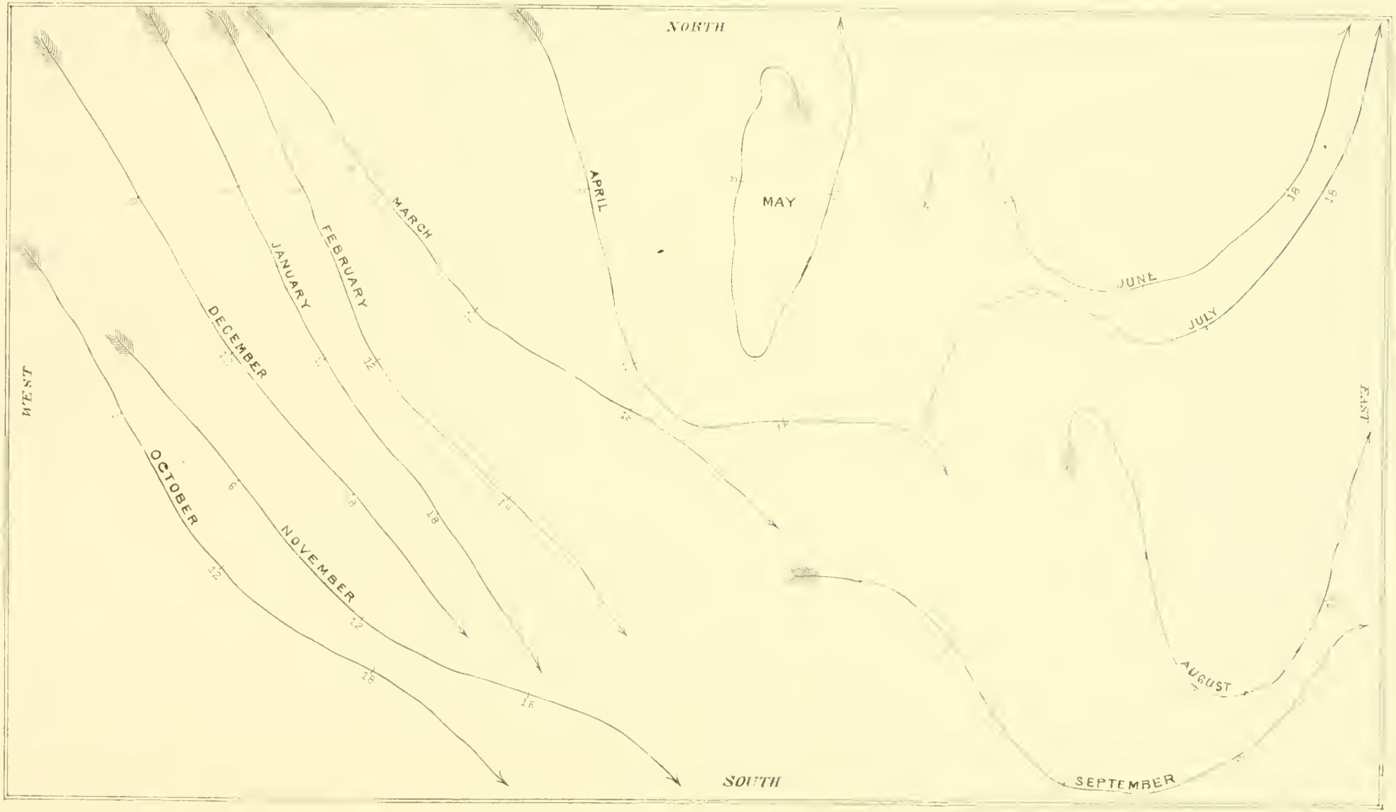
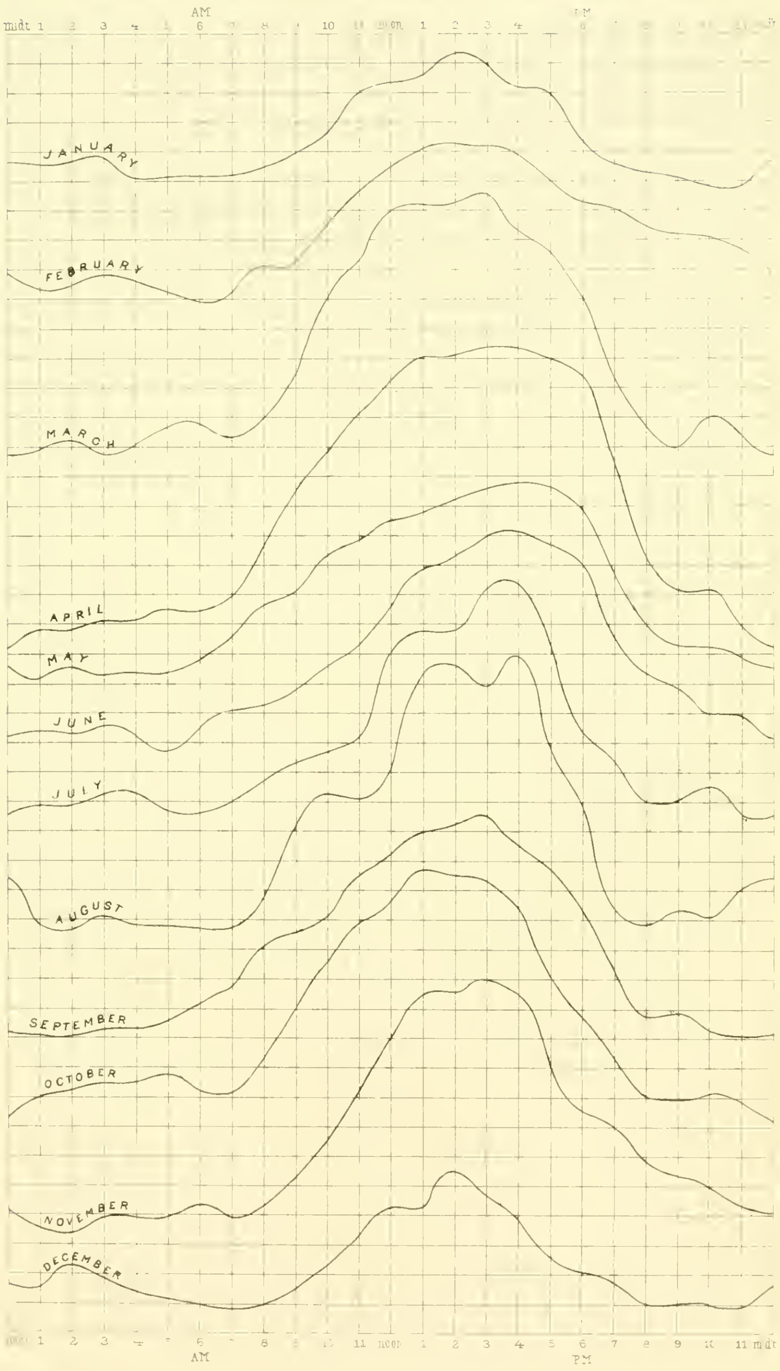


Plate IX. DIURNAL CHANGE IN THE FORCE OF THE WIND, [illegible]



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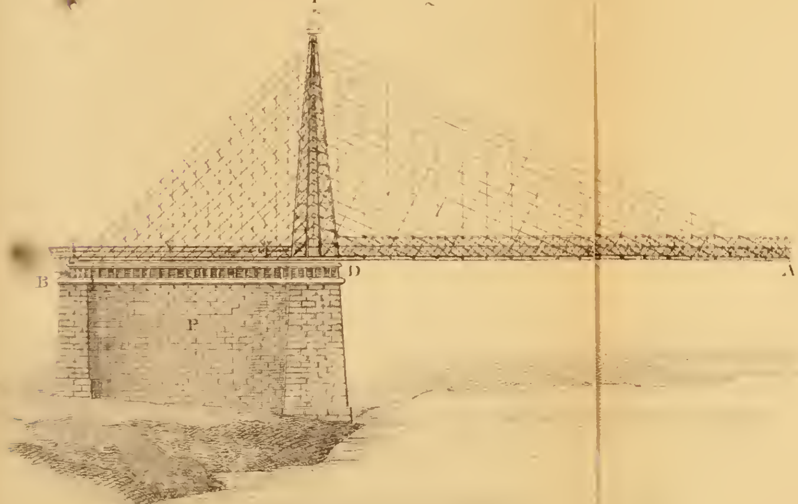

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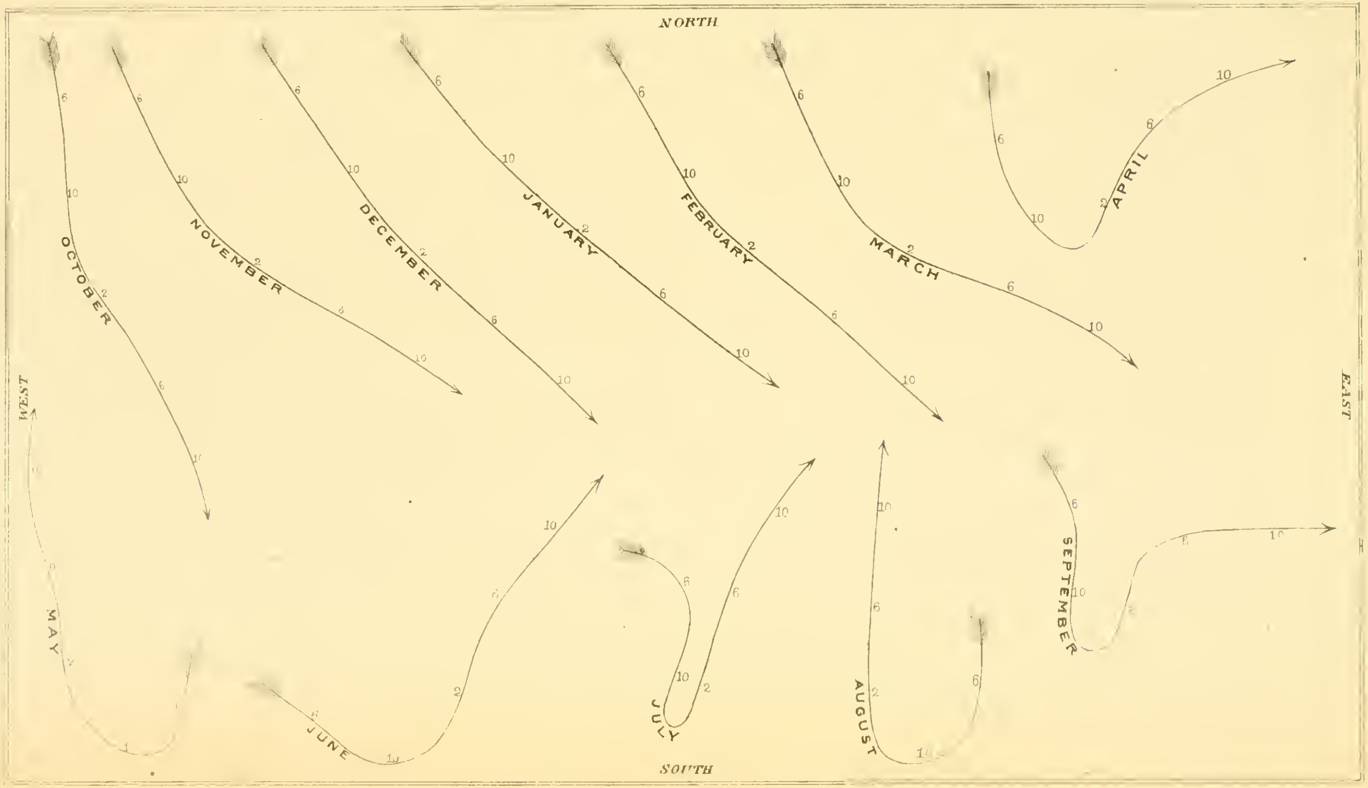
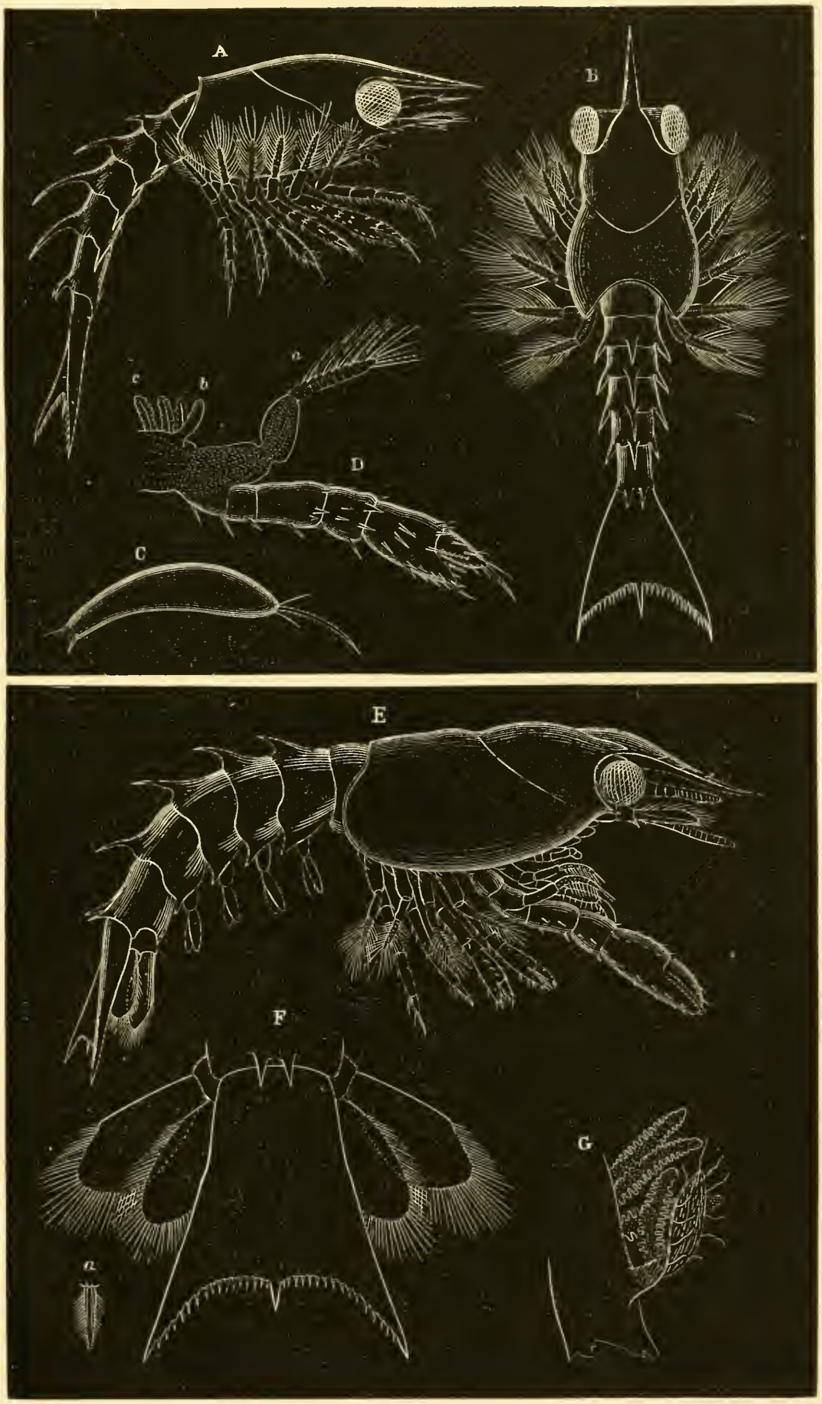
Plate XI DIURNAL CHANGE IN THE DIRECTION OF THE WIND AT NEW HAVEN CONN





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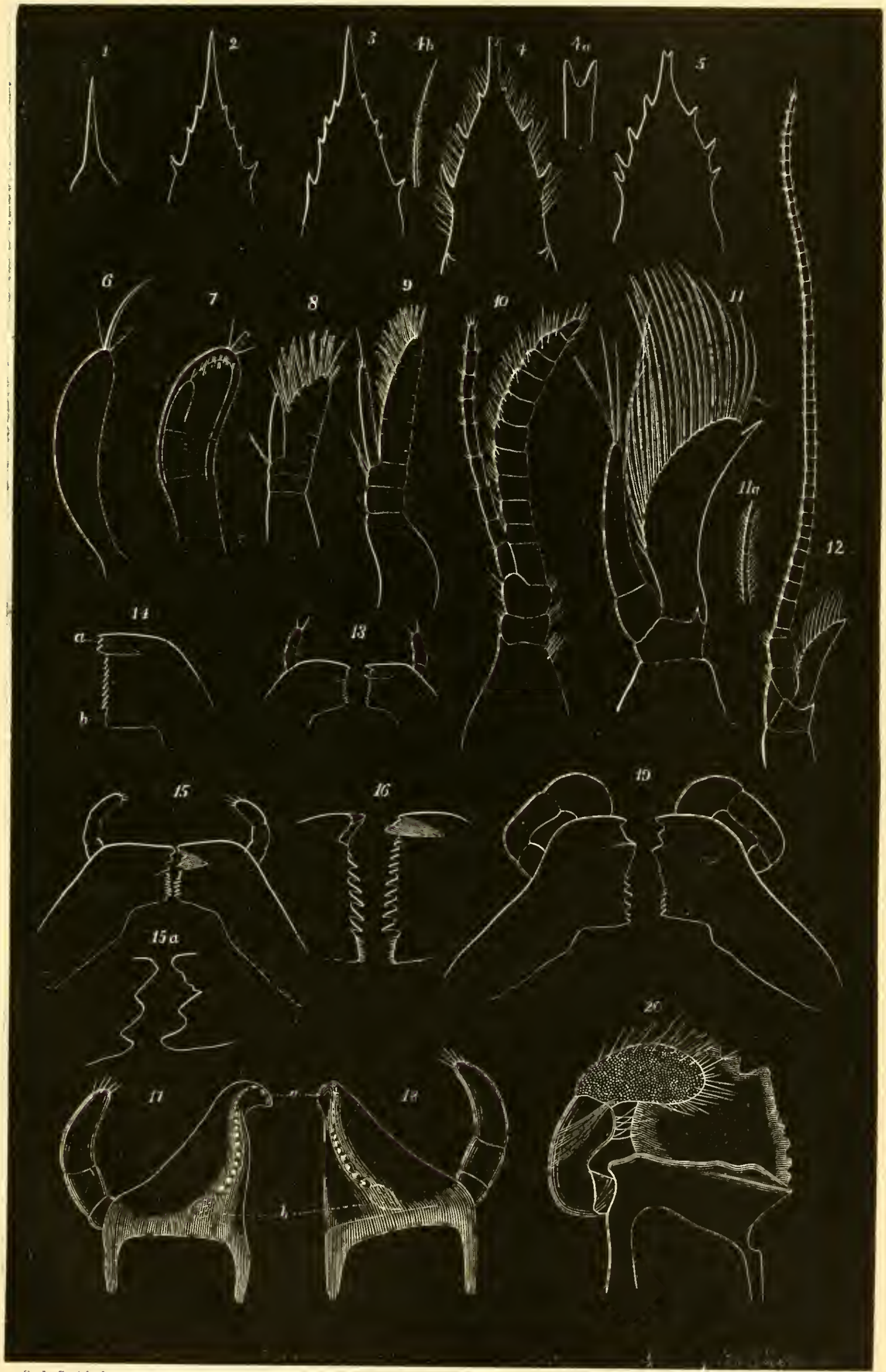

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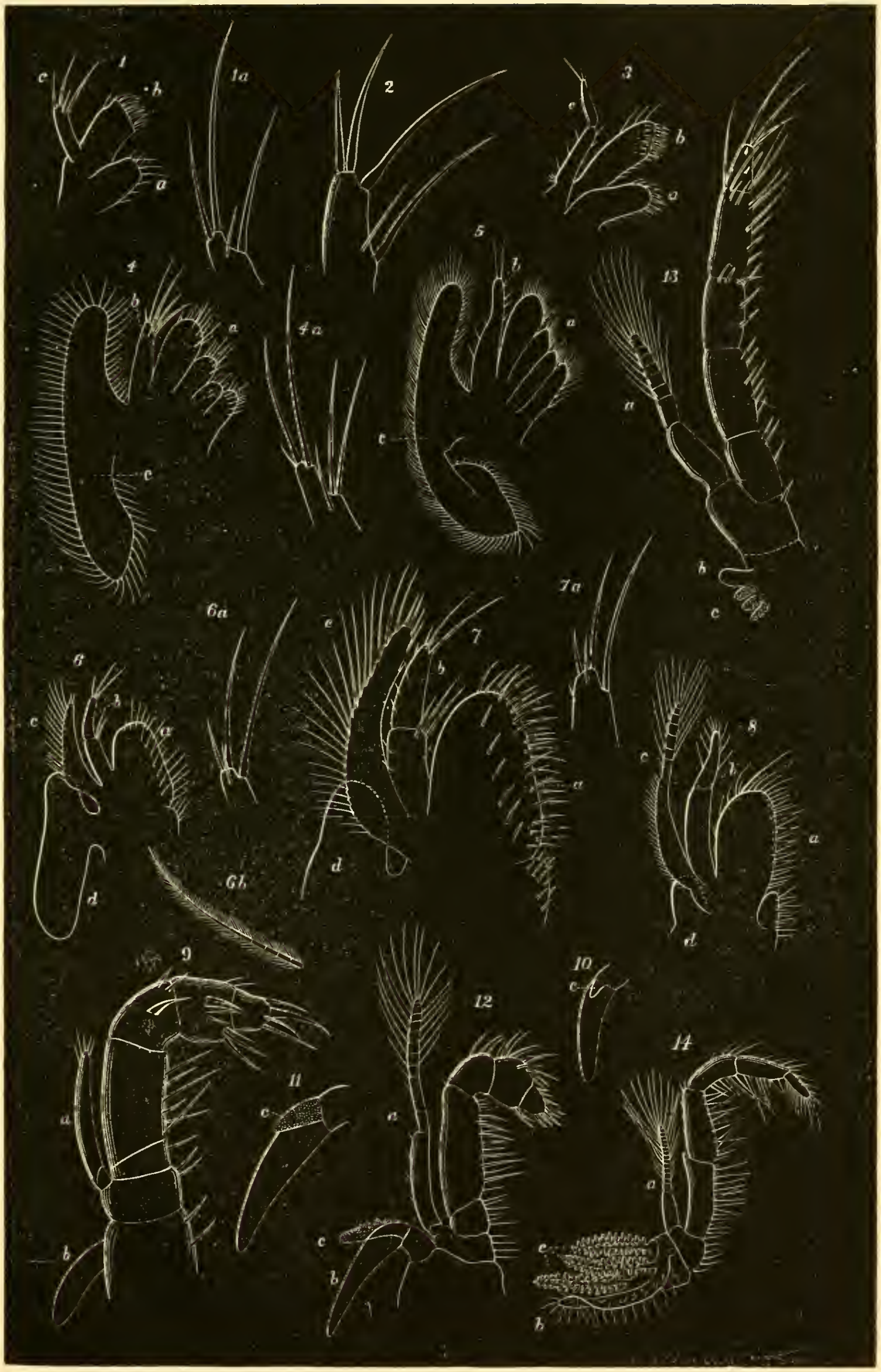

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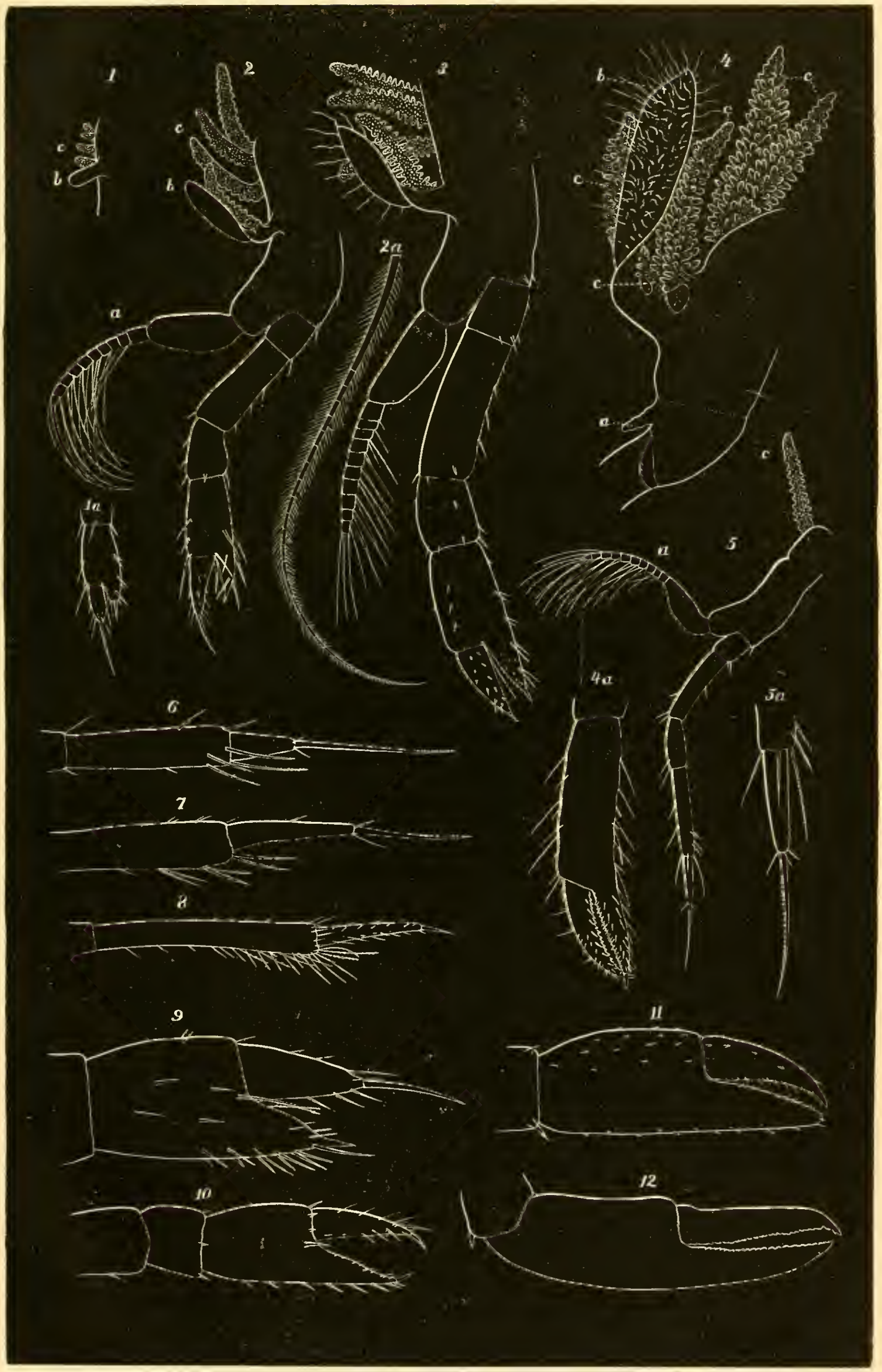

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