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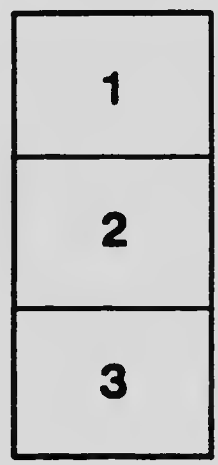
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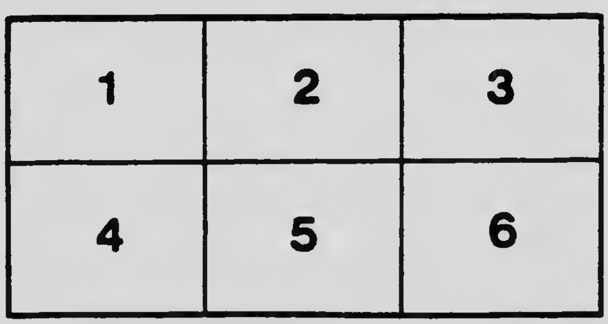
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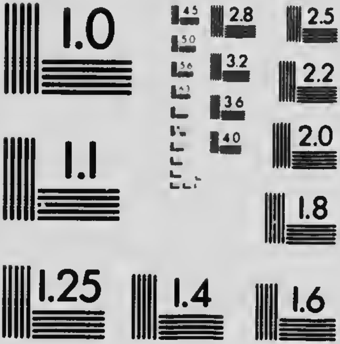

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PAPERS FROM THE PETER REDPATH MUSEUM

BIONOMICAL LEAFLETS

No. 1. Organisms and Organization
by
A. WILLEY.

No. 2. Alaskan Glacier Worms (Oligochaeta)
by
PAUL S. WELCH.

No. 3. Scope of Biology
by
A. WILLEY.

MONTREAL, 1917.

I. *Organisms and Organization.*—That the animal and vegetable kingdoms exhibit higher and lower grades of organization has been recognized by philosophers from the dawn of literature. But exactly how these grades are related to one another is a problem which no ancient or modern writer has been able to solve. Explanations, which have been offered from time to time, have found acceptance in proportion as they have been based upon adequate limits of knowledge and sound intuition. It is one of the functions of morphology and classification to build up, from the innumerable data secured by dissection, a certain number of types of structure which can be grasped by the human intellect. The result of continued analysis is at once to extend the lines of our science and to broaden the horizon of our ignorance; as with Pascal's maggot which, in the small compass of its body, consists of parts incomparably smaller, legs with joints, veins in the leg, blood in the veins, humours in the blood, droplets in the humours, vapours in the drops, and so on until our conceptions are exhausted. It is therefore a simple matter of necessity to connect our facts of observation by some bond of principle which must be subjective, is almost certain to be ephemeral, and may be wholly artificial.

Pascal's maggot

There is no term in biology, involving an abstraction or a generalization, that is used in precisely the same sense by any two investigators. The nexus of associations in the human brain is as impossible to duplicate as are the patterns of finger prints. It is for this reason that the 'jargon' or 'cipher-code' or 'technical terminology' of science has been invented, in a vain attempt to express some of the many shades of meaning which every idea carries with it. These inherent ambiguities are apt to become vexatious and impertinent except under the conditions of philosophical controversy. The word 'grade,' as employed in classification, meant for Aristotle and his followers a transition or promotion from a lower to a higher organization, and the various grades intervening between polyp and man constituted a series of steps or a *scala naturæ*. Few ideas of nature have been so erroneous, and few have lasted so long or penetrated so deeply as this. The grades exist, but you cannot pass from one to another and think you are following in the track of evolution. In our day the term 'grade' is used, with or without an ideal signification, to denote a definite rank in the scheme of systematic or phylogenetic classification. See on this point the chapter on *The Enterocœla and the Cœlomocœla* in Lankester's

Scala naturae

Lankester's grades *Treatise on Zoology*, Part II, pp. 1–37, London (A. & C. Black), 1900. Phylogeny (phulon, race; genesis, origin) attempts to discriminate between mere gradations of type and real transitions by descent. But whatever view we may take of the relations between organisms, it is sure to be a partial one, just as when, in the course of a single dissection, we may see many anatomical parts and very few connections.

It is often an advantage to obtain a partial view of a complex field, and for this purpose we may shut out the sponges and flatworms, whose special characteristics are such as to merit separate consideration. With this reservation it is possible to discern, in the animal kingdom, three leading types of organization, irrespective of the nature of the skeletal framework, namely, the protozoic (Th. v. Siebold, 1841), the cœlenterate (R. Leuckart, 1848), and the cœlomate (E. Hæckel, 1872). They are comparable in regard to the parallel degrees of differentiation which they present in their plan of composition. In the protozoon we have a single nucleated protoplasmic unit, revealing an astonishing diversity of form, but reducible fundamentally to a surface layer of *ectoplasm* and an interior mass of more fluid *endoplasm*. The cœlenterate organism is furnished with a single body-cavity, the gastrovascular or primary digestive cavity (cœlenteron), circumscribed by a body wall consisting of two superposed cellular membranes: an outer protective envelope, the *ectoderm*, and an inner nutritive lining, the *endoderm*. The cœlomate organism has a muscular body wall, the *ectosome*, and a muscular splanchnic wall (splanchnon, entrail), the *endosome*, separated from one another by the interposition of a secondary body cavity, the cœlom, which is lined throughout by a mesodermal cœlomic epithelium. The cœlomate standard of organization is represented in a number of morphological types, e.g., in the annelid, arthropod, molluscan, echinoderm, and vertebrate phyla or lines of descent. Within these phyla the cœlom appears under various states of extension, modification, and reduction. For the justification of ectosome and endosome see K. C. Schneider's *Histologiches Praktikum der Tiere*, Jena (G. Fischer), 1908. Ectosome had been applied previously by W. J. Sollas [*Report on the Tetractinellida*, Challenger Rep. Zool. XXV., 1888] to the dermal layer of sponges and has been accepted by subsequent writers in this sense, but that need not interfere with its utilization here; on the contrary, it opens up an example of parallelism or convergence, the ectosome and choanosome (zone of flagellated chambers) of higher sponges offering a distant analogy to the ectosome and endosome of Cœlomata.

Ectosome and endosome

The terms employed above, descriptive of the twofold stratification of the body, might seem to suggest a simple evolutionary series, and a novice might get the impression that ectoplasm is alleged to have become transformed into ectoderm, and the latter into ectosome. What we have here is only one of those numerous gradations of type which so often deceptively simulate a natural course of evolution. The most that can be formulated in the interests of brevity is that in the cœlenterate phase an ectodermal epithelium is substituted for the protozoic ectoplasm,

Gradations of type

and that in the cœlomate phase a fleshy ectosome replaces a membranous ectoderm. This substitution is accompanied by an increasing complication of the sensori-motor system and, in the segmented invertebrates (annelids and arthropods), the ventral portion of the ectosome includes, besides the body wall, the ventral nerve-chain. In the frog the ventral ectosome comprises the skin, the subcutaneous lymph space and the abdominal musculature.

Kleinenberg's fibres

In the simplest living cœlenterate animal, the freshwater polyp, *Hydra*, the largest cells of both ectoderm and endoderm are drawn out at their juxtaposed bases into smooth, contractile filaments called muscle-processes or Kleinenberg's fibres, those of the ectoderm running lengthwise, the others around the body. Such cells, combining the qualities of epithelial and muscular elements, are called epithelio-muscular cells ('myoepithelial cells'; 'musculo-epithelial cells'; 'muscle-tail cells'). Their muscle-processes are comparable to the axial filament ('myophan axis'), which is a prolongation of the ectoplasm, in the contractile stalk of Vorticella, the bell animalcule. The passage from an epithelio-muscular to a dermo-muscular condition of the body wall, though we cannot comprehend its *modus operandi*, is nevertheless suggestive and easily grasped by the imagination.

Myophan mechanisms

Myophan ('muscle-seeming') mechanisms represent the beginnings of muscular contractility, and it is worthy of note that they exist in some Protozoa side by side with ciliary mechanisms, as in *Vorticella*, which has a permanent stalk, and in *Stentor*, the trumpet animalcule, which has the power of temporary fixation. *Vorticella* procures its food by ciliary action; *Stentor* does that and also swims freely by the same mechanism. Muscular contractility, in its earliest manifestations, is thus intimately bound up with the relation or reaction of the organism to the substratum; whilst ciliary action has opposite tendencies. In *Vorticella* the cilia are confined to the rim of the bell-shaped body. *Hydra*, with its sedentary habit and looping gait, has no vibratile cilia at the surface. Amongst higher forms we find, in the order of development, that the ciliary precedes the myophan period, the latter not coinciding with the *gastrula* or cœlenterate phase, but commencing only after the establishment of the cœlomate ('myocœlomic') phase.

Intercellular bridges

In every cell of the Metazoon or multicellular animal, and probably in the Metaphyta (multicellular plants) as well, the distinction between ectoplasm and endoplasm can be more or less clearly drawn, and, in many tissues, the ectoplasm is produced into intercellular bridges connecting neighbouring cells together. These are seen at their best in *Volvox*, the globe animalcule or sphere alga, whose free-swimming revolving spheres consist of numerous biflagellate zooids assembled in a common mucilaginous matrix surrounding a central cavity containing water. It is undecided whether *Volvox* stands at the threshold of the Metazoa as some would have it [cf. Richard Hesse: *Der Tierkörper als selbständiger Organismus*, Leipzig u. Berlin (B. G. Teubner), 1910, p. 502] or whether it is a downright green alga. In *Principles of Botany*, by Joseph Y. Bergen and

Bradley M. Davis, Boston (Ginn), 1906, p. 180, the authors follow Goebel in placing *Volvox* amongst the Chlorophyceæ or green algæ and add: "The fact that zoologists have found *Volvox* and its relatives of interest should not deter botanists from making use of their own." Whether or not it is better to call *Volvox* a flagellate infusorian or a flagellate alga, the spherical colony is a cœnobium (koinos, common; bios, life) and the elementary organisms or cœnocytes (kutos, cell) which compose it, ranging in number, in *V. globator*, from a minimum of 1500 to a maximum of 22,000 (A. Meyer, Bot. Ztg., 1896), are connected with each other by protoplasmic strands which radiate out from the circumference of each zooid.

Protosome Coenosome Diplosome

The gastrula is the didermic, the blastula the monodermic embryo of Metazoa. *Volvox* has, approximately, the structure of a blastula, *i.e.*, a spherical aggregate of cells surrounding a central cavity. If the body of a solitary protozoon be described as a protosome (soma, body), the wall of the *Volvox* colony may be appropriately styled cœnosome, and this term could serve equally well for the wall of the blastula embryo. The gastrular and cœlenterate wall then becomes diplosome (diploos, double).

Coenobium and Syncytium

The difference between *Volvox* and the metazoic blastula is that the former is a polyzoic (or polyphytic) colony, *i.e.*, a cœnobium, whilst the latter is a multicellular embryo, *i.e.*, a syncytium. This distinction involves a fundamental conception of the metazoic organization—not that the individual is a colony of elementary organisms, but that it is, as the word implies, an undivided whole, whose cellular structure is an incident of organization, not a manifestation of polyzoism. The syncytial theory of metazoic organization was adumbrated by J. Heitzmann in 1873, though, as remarked by E. B. Wilson [*The Cell in Development and Inheritance*, 2nd edit. New York, 1900; see p. 58: *The cell in relation to the multicellular body*], on "insufficient evidence." It was developed as a definite theory by Adam Sedgwick during a number of years (1885-1895) and received strong support and recognition from Yves Delage [*La Conception polyzoïque des êtres*, Revue Scient., 4me sér., t.v, 1896, pp. 641-653].

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II. *Alaskan Glacier Worms (Oligochæta).**—The existence of rather delicate, soft-bodied worms which live in the snow and ice of the glaciers of Alaska, of the glaciers of certain high mountains, and perhaps in certain arctic regions, is still little known, although they were first discovered almost twenty years ago. Recently, the writer was permitted to study a number of these "ice-worms" which were collected by Mr. W. M. Dennis, July 4, 1912, on Grand Pacific Glacier, Glacier Bay, Alaska, and sent to Peter Redpath Museum, McGill University, Montreal. Large numbers of these annelids were found in and on the snow which overlies the ice of the glacier and in water in the ice, remote horizontally and vertically from any other kind of environment. They proved to be partially mature specimens of *Mesenchytræus solifugus* Emery, an annelid belonging to the family Enchytræidæ.

This species, the first "ice-worm" to be discovered, was originally described by C. Emery ['98, Atti della R. Accad. dei Lincei, (5), 7: 110–111] from specimens collected on Malaspina Glacier, Mt. St. Elias, Alaska, as a new genus and a new species, *Melanenchytræus solifugus*, the generic name being suggested by the conspicuous black colour of the worms. Later, J. P. Moore ['99, Proc. Acad. Nat. Sci. Philadelphia, pp. 125–144] reported on this species from specimens collected on the same glacier, describing, in addition, another species, *Mes. nivus*. He also examined the validity of Emery's genus *Melanenchytræus*, which the latter had separated from *Mesenchytræus*, already established, because of the pigmented hypodermis, absence of spermathecal openings into the digestive tract, elongated sperm ducts, and the intraclitellar origin of the dorsal blood-vessel. However, Moore found that the pigmentation "although very remarkable, can hardly be given generic value"; that the spermathecæ do connect with the digestive tract; that certain species of the same genus exhibit variability in the length of the sperm duct and that the intraclitellar origin of the dorsal blood-vessel occurs in species of *Mesenchytræus* other than *solifugus*. Later studies confirm these points, and while the definition of *Mesenchytræus* has been modified slightly to contain certain species somewhat recently discovered, it still includes without difficulty all of the "ice-worms" known thus far.

Identity of glacier worms

Spermathecæ open into digestive tract

Some years later, G. Eisen ['05, Harriman Alaska Expedition, 12: 59–61] studied and identified as *Mes. solifugus*, specimens collected on Muir Glacier and on La Perouse Glacier, Alaska. Since Malaspina, Muir, La Perouse, and Grand Pacific Glaciers all occur in the same region of Alaska and some of them in relatively close proximity, it is not surprising to find that the Grand Pacific Glacier specimens prove also to be *Mes. solifugus.*

Harriman Alaska Expedition

* Contribution from the Entomological Laboratory, Kansas State Agricultural College, No. 27.

The writer ['16, Trans. Am. Micr. Soc., 35: 85–124] described a new species (*Mes. gelidus*) and a new variety (*Mes. solifugus* var. *rainierensis*) from the snow-fields and glaciers of Mt. Rainier, Washington. Vague and indefinite reports of "worms" on the snow and ice-fields of the arctic regions and of high altitudes lead to the expectation that still other species await discovery.

Habitat and adjustment The unique character of the habitat of these worms is of interest. Mr. Dennis' report of "great numbers" on Grand Pacific Glacier agrees with the observations of previous collectors on the other Alaskan glaciers. Mr. J. B. Flett, who collected "ice-worms" on Mt. Rainier for the writer, found them very numerous at times. The abundance of these worms in situations which seem to preclude escape from the ice and snow at any time of year indicates that the adaptation to these unusual conditions must be successful. They exist in active form and multiply under freezing conditions, in a medium of ice and snow—a point of interest since it has recently been shown by experimental means that within certain limits the internal temperature of many groups of invertebrates, including Oligochæta, approaches very closely the temperature of the surrounding medium.

Food Only indefinite evidence concerning the food of these worms from Grand Pacific Glacier was secured, since the meager amount of material in the digestive tract in the specimens examined was composed mainly of angular, irregular, hyaline particles, apparently mineral in nature. In addition, there was a quantity of granular, organic, disorganized material which could not be identified. The writer [*l. c.* p. 102] found evidence that at least a part of the food of *Mes. gelidus* consists of the microscopic algæ which occur in quantities on the snow of Mt. Rainier glaciers. Since this alga (or a similar one) occurs in some abundance on the Alaskan glaciers, it is possibly one source of food supply for *Mes. solifugus*.

Pigmentation The conspicuous black coloration of the body is due to a striking abundance of pigment in the hypodermis. This pigment occurs also in the internal organs, particularly in the dorsal thickening of the pharynx, the chloragogue cells, the lymphocytes, and the spermathecæ. All glacier enchytræids known at present are heavily pigmented, at least in the mature stage, although this feature is not exclusively confined to the worms living in such a peculiar habitat.

Setæ The setæ are small, delicate bristles, deeply set in the body-wall so that only a very small part of the length projects free from the body, which, together with the opaque, black character of the body, renders them easily overlooked. The protruding points are often broken off but when intact are sharply pointed and abruptly bent, while the inner ends are broadly curved in the opposite direction, the shape of the setæ as a whole being lightly sigmoid, much as in the common earthworm. Setæ of the stout, nearly straight form figured for *Mes. solifugus* by Emery ['00, *The Ascent of Mount St. Elias (Alaska) by H. R. H. Prince Luigi Amedeo di Savoia, Duke of the Abruzzi*, Appendix D, figs. 10 and 13] have not been observed in the preparations. The usual number of setæ per bundle is 2–3, the latter being the maximum.

The average length of the seventeen alcoholic specimens examined is 9.3 mm., the extremes being 6.5 and 13.5 mm. This length corresponds closely with that reported by Emery and Eisen but is lower than that given by Moore. Since the difference is mainly one of length rather than the number of somites (except in the more immature specimens), the state of contraction or extension at time of killing is probably responsible for the difference. The number of somites of the more mature specimens is about 53, close to that reported previously. It is interesting to note that none of the specimens from Grand Pacific Glacier shows the ruptures at the intersegmental grooves which other observers have described. None of the specimens shows a clitellum although sections of one approaching maturity exhibit a very slight thickening of the hypodermis on XII–XIII. **Size**

Although subject to slight variation in size, typical measurements of the brain are as follows: length, 0.13 mm.; maximum width, 0.108 mm.; maximum thickness, 0.108 mm. In the sections examined, it is almost circular in transverse section. Some variation exists in the shape of the posterior margin from slightly convex to straight to slightly concave. Otherwise it is as previously described. **Brain**

Aside from the origin of the dorsal blood-vessel and the occurrence of the cardiac body, the circulatory system has not been described. Since the contents of the blood-vessels take the artificial stains readily and since the principal blood-vessels are rather large throughout most of their course, it has been possible to follow them out without difficulty, except for a short distance anterior to the junction of the two ventral trunks. The dorsal vessel arises from the perivisceral blood-sinus in XII. From its origin to the posterior part of V, it is large and conspicuous in sections, having a diameter of about 0.08 mm., except at the constrictions which correspond with the septa. It extends cephalad, parallel and dorsad to the digestive tract. In the posterior part of V, it suddenly decreases in diameter from about 0.052 mm. to about 0.024 mm., maintaining this dimension to I. Under the anterior part of the brain, it bifurcates, the two resulting vessels extending to the latero-ventral side of the digestive tract to form the right and left ventral trunks. They extend caudad as well-developed vessels to V where they diminish markedly in diameter, so much so that they are very difficult to follow. They unite in the region of VII, forming the ventral blood-vessel which is distinct throughout most of its course. In the vicinity of IV/V, a branch extends dorsad from each of the ventral trunks to connect with the dorsal vessel at a similar level, thus forming the one and only pair of transverse vessels. The dorsal vessel, from its origin in XII to its sudden decrease in diameter in the posterior part of V, contains a small cardiac body. Most of the transverse sections through this region show this body to be composed of one to two distinct cells, although at intervals about five cells appear in a closely packed aggregation. The perivisceral blood-sinus appears just caudad of the origin of the dorsal vessel in XII and extends to the caudal end of the body. **Circulatory system** **Ventral vessels** **Cardiac body**

Septal glands

Associated with septa IV/V, V/VI, and VI/VII, are large, loosely constructed septal glands which agree closely with Emery's figure ['00, fig. 11] of "unicellular glands," the identity of which he regarded with considerable uncertainty. The examination of the Grand Pacific Glacier material confirms the writer's previous suggestion [*l.c.* p. 110] that they were in reality the usual series of septal glands.

Identity of Mes. nivus

Mention has already been made of the description of *Mes. nivus* by Moore from material collected with *Mes. solifugus* on Malaspina Glacier in 1897. Although at first thinking them immature specimens of *Mes. solifugus*, on re-examination Moore found three lighter coloured specimens which he regarded as another species, *nivus*. The major character of distinction from *solifugus* was the different form of the spermathecæ which were "much smaller than those of *M. solifugus* and lack the diverticula entirely; they are simple club-shaped sacs, without specially enlarged ampullæ, and communicate neither with one another nor with the œsophagus." Other characters mentioned are as follows: "The epidermis about the spermathecal openings is not thickened. The male genital organs also differ; the saccus ejaculatorius is smaller, the walls of the atria less thick, and the external pore much less conspicuous. The posterior border of the supra-œsophageal ganglion is concave." W. Michaelsen ['00, *Das Tierreich*, 10 Lief., p. 87] suggests that *nivus* ("corr. *niveus*") is perhaps the young of *solifugus*. Evidence accumulated by the writer from the Grand Pacific Glacier material and from other sources virtually establishes the identity of *nivus* with *solifugus*—that *nivus* is an immature stage of the latter. With respect to the spermathecæ, Emery found in almost mature material that all of the parts of these organs were present, save the connection with the alimentary canal. In the immature material from Grand Pacific Glacier, the writer finds that the spermathecæ are present, unite dorsad of the digestive tract in the posterior part of V and then connect with it, but lack the diverticula. Evidence is available [Welch, '14, Bull. Ill. State Lab. Nat. Hist., 10: 163] that in some Enchytræidæ, the spermathecæ are among the last of the reproductive organs to reach maturity and that the order of development seems to be (1) development of the duct, (2) development of the ampulla, and (3) development of the diverticula. It thus seems that the spermathecæ of *nivus* are accounted for as an undeveloped stage of *solifugus*. The thickened "epidermis" about the ectal openings of the spermathecæ does not appear in the immature Grand Pacific Glacier material; likewise the penial bulb ("*saccus ejaculatorius*") is smaller in the partly developed state, and the penial invagination ("external pore") is less apparent. As to the concave posterior margin of the brain, it has already been pointed out that there is a variation from a slightly concave through the straight to the slightly convex in the same material. The lighter colour can also be explained on the grounds of immaturity since there is evidence that the earlier stages of some "ice-worms" lack wholly or in part the conspicuous pigmentation of the adult. On these grounds the writer is convinced that *nivus* was described from immature stages of *solifugus*.

Spermathecae

PAUL S. WELCH.

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III. *Scope of Biology.*—It may seem difficult to assign limits to the "science of life." Life has existed from the beginning of the habitable globe, "biology" from the beginning of the nineteenth century. Nor are the essentials of life in any way identical with the essentials of biology. There are certain axioms, regarded as fundamental, which have acquired such a preponderance in their application to problems of public health, that it is found practicable to define the ground covered by biology without including in the definition a metaphysical explanation of life. Those who would read the signs of life and assimilate the harmless and necessary principle of evolution, without upsetting their mental equilibrium, may consult with profit Dr. Joseph McFarland's *Biology, General and Medical*, third edition, Philadelphia (W. B. Saunders), 1916. One may still, on American soil and in the twentieth century, pick up popular books in which such expressions as "blight of evolution" and "evolutionary piffle" are to be found defacing the printed page. To these sad and morbid perversions, Dr. McFarland's volume affords a wholesome corrective. **McFarland's Biology**

Taking protoplasmic irritability as that property of living matter which lies at the root of all vital manifestation, the author proceeds to name some of the principal vegetative tropisms, *i.e.*, irritable responses to external stimuli. The eighteen chapters of which the book is composed deal with cell division, blood relationship, parasitism, infection and immunity, grafting, regeneration, and much besides. We may here focus attention upon Chapter IV, entitled "The Manifestations of Life." Tropism means a turning towards or away from a source of stimulation; the movement of attraction is called positive, that of aversion, negative tropism.

Thermotropism is the name given by a botanist, P. van Tieghem, in 1882 (Traité de Botanique, Paris, 1882-4), to the response to thermal stimulation, or reaction to variations of temperature. Under experimental conditions it was found that when Cress-seedlings were exposed to radiant heat, they showed their negative thermotropism by curving away from the source of heat, while Maize-seedlings proved to be positively thermotropic (J. Wortmann, Bot. Ztg. 41, 1883). Some of the effects of temperature are to be seen in the encystment of lower forms of life and in the hibernation of higher animals, though in naturally recurring habits more than one tropism is involved. The extreme range of temperature which any organism can endure begins at a minimum, ascends to its optimum of vital activity, and declines towards a maximum critical point of viability, beyond which an increase is fatal. The spores of certain bacteria (*vide* McFarland, p. 38) can survive exposure for an hour to the temperature of liquid hydrogen (-225°C); at 25°C they reach their optimum rate of germination and division; at about 40°C sporulation may recommence and some of these spores will survive exposure for an hour to the temperature of boiling water **Thermotropism** **Spores of Bacteria** and even, for a few minutes, to 120°C. The corresponding data for developing frog spawn and chick incubation, given in C. B. Davenport's *Experimental Morphology*, third edit. New York (Macmillan), 1908, p. 459-460, are:

Critical points

	Minimum	Optimum	Maximum
Frog spawn..............	3°C	30°C	40°C
Chick incubation.........	25°C	38°C	42°C

Thigmotropism or thigmotaxis (thigema, a touch) is the term introduced by Max Verworn (1889) to denote response to contact or mechanical stimulation, as with the sensitive tendrils of climbing plants. A few years later somewhat similar reactions of animals were independently classified under stereotropism (stereoma, a solid foundation) by J. Loeb. These terms are not mere synonyms, inasmuch as stereotropism carries with it a more general connotation. Examples of thigmotropic irritability amongst plants are the leaves of the Sensitive Plant (*Mimosa pudica*)which is a wayside weed in parts of Ceylon, and the tentacles of the Sundew (*Drosera rotundifolia*), a wild flower in damp parts of Canada.

Thigmotropism and Stereotropism

The protrusion of pseudopodia by *Amoeba*, when creeping on the bottom of a pond or on a glass slide, is a display of stereotropic activity, a very primitive property of living substance, *i.e.*, adhesion to surfaces which may or may not be associated with movements of translation upon them. But when *Amoeba* is touched or shaken, it tends to round up by a thigmotropic response. On the other hand, it is well known that the most luxuriant irradiation of pseudopodia occurs when *Amoeba* is floating in mid-water and exhibiting, for the time being, negative stereotropism. *Vorticella* possesses a permanent stereotropic mechanism in its stalk; the bell has a delicate thigmotropic sensibility and a periodical pleotropic tendency. The sudden contraction to a corkscrew spiral of the stalk of *Vorticella* when the bell is touched or jarred is a special case of thigmotropism; the fixation by means of its contractile stalk is due to stereotropism; furthermore the bell with its ciliated peristomial area (disc and peristome) exhibits centrifugal tendencies when, for purposes of generation or regeneration, it thrusts out an accessory circlet of cilia and breaks away from its stalk as a free-swimming organism.

Pleotropism

I applied the term pleotropism to the centrifugal tendencies of aquatic animals (Willey: *Convergence in Evolution*. London (John Murray) 1911, p. 43). The tentacles of *Hydra* exhibit thigmotropic response to the impact of small crustacea, just as the tentacles of *Drosera* do to alighting insects, but the basal or pedal disc of *Hydra* is a stereotropic organ of attachment.

Chemotropism

Chemotropism or response to chemical stimulation is considered under three sets of reactions; sitotropism or response to the stimulating influence of food, hydrotropism or response to the proximity of water, and oxytropism or response to the presence of oxygen. According to Davenport (*op.cit.* p. 335) the earliest observations in chemotropism, based upon experiments on plants, were recorded by C. Darwin in his *Insectivorous Plants*, London (John Murray) 1875, and this line of experimentation was pursued with much success by W. Pfeffer (1883 et seq.), who introduced capillary tubes filled with solutions of certain substances (malates, etc.) into drop cultures of swarm-spores and antherozooids and thus made the discovery of chemotaxis in directing the movement of ciliated organisms. Sitotropism, employed by Dr. McFarland in his first edition (1910), seems to fill a gap in the terminology of vital reactions. In this connection he quotes the case of caterpillars, hatched upon the trunk of a tree, climbing to the branches in order to reach the leaves upon which they feed. But the behaviour of insects is not merely tropistic, it is also instinctive, and our author indirectly suggests that a complex instinct may be the integration of a multitude of relatively simple cell-tropisms. Sitotropic behaviour is shown in the orientation of the commensal sea-anemone, *Adamsia palliata*, with reference to its hermit-crab, *Eupagurus prideauxi*, as described by L. Faurot in his *Etude sur les associations entre les Pagures et les Actinies* (Arch. zool. expér. 5me. sér V, Paris, 1910, pp. 421-486) and in J. E. Duerden's account of the *Habits and Reactions of Crabs bearing Actinians in their claws* (P. Zool. Soc., London, April, 1906). In the Adamsia-Eupagurus complex, the organisms become associated in their youth and grow up together. The young polyp, when about one centimetre in height, is found attached to stones in the regular manner, having a cylindrical body with a broad pedal disc. As soon as it has been found by its natural companion and coaxed by palpation on to the shell, the polyp places itself in a particular position with its mouth and crown tentacles below and a little behind the mouth of the hermit crab. It then becomes deformed by wrapping its pedal disc right and left around the shell until the edges join in a suture above. The hermit crab has no need to follow the usual custom of pagurines of exchanging its shell from time to time for a larger one, because the polyp grows outwards like a mantle from the mouth of the shell forming a tube round the body of the crustacean, always keeping its mouth fixed in the same position relatively to the hermit's mouth, so that it may receive particles of food as they are minced by the mouth-parts of its host. The pedal disc actually sc[illegible]s a membrane of solidified mucus which may remain on th[illegible]ell as a tunnel prolonged outwards from the mouth of the shell after the polyp has been removed. When once the alliance has been formed, the two beings are so completely adapted to each other's ways that they behave as if they were one individual.

Sitotropism

Adamsia and Eupagurus

Hydrotropism, introduced by C. Darwin in 1880 (*The Power of Movement in Plants*), is seen in the growth of roots which sometimes insinuate themselves between the joints of water conduits and block up the passage. A case in point is illustrated by G. E. Stone in a paper on *The Clogging of Drain Tile by Roots*. Torreya XI, pp. 51-55, New York, 1911. The Carolina Poplar, which is planted as a shade tree in the United States, has the habit of working its roots through the joints of drain tiles. In the city

Hydrotropism

Poplar roots

Pear roots

of Newark, N.J., in 1909, there were 15 stoppages and in 1910 there were 23 stoppages, all caused by poplar trees. In 1909, a drain pipe, 12 inches in diameter, was clogged by the roots of a pear tree in the town of Belmont, Mass. The growth originated from a single offshoot of a pear tree seven feet away. The root, about [illegible] inch in diameter, with five annual rings, on entering the tile became subdivided into innumerable rootlets forming a matted tangle of pear roots. The mass of roots was 61 feet long; counting the separate branches gave a total of 8,498 feet or 1.61 miles. "This enormous development from a single root of a pear tree is greatly in excess of what would take place in the soil, since the conditions of the drain tile stimulate root development very materially."

Heliotropism and Phototaxis

Bird Migration

Heliotropism or response to the stimulation of light was, according to Professor W. Pfeffer, first used by A. P. de Candolle in 1835. It is commonly exhibited by window plants under unilateral illumination. It is a very important reaction in animals and plants, occurring both positively and negatively. Phototaxis (Verworn) might seem to be a redundant term, were it not for a certain *nuance* which serves to differentiate them. Moths are nocturnal Lepidoptera and therefore negatively heliotropic, avoiding sunlight. Dr. McFarland (p. 59) says: "The attractive influence of a lamp upon the nocturnal insects is a striking example of positive heliotropism, many of the insects actually flying into the light to meet destruction." These insects are at once negatively heliotropic and positively phototactic. An interesting application of heliotropism in conjunction with sitotropism has been used to account for the north-south migrations of birds by Sir E. A. Schäfer *On the incidence of daylight as a determining factor in bird-migration* (Nature, December 19, 1907). The gist of the argument is that the true north-south migrants have been driven to seek the prolonged daylight of the northern summer in order to procure a sufficiency of food for themselves and their offspring. Incidentally it may be recalled that lighthouses are a source of great danger and disaster to birds when migrating at night:

> As the beacon-blaze allures
> The bird of passage, till he madly strikes
> Against it, and beats out his weary life.
>
> TENNYSON: *Enoch Arden.*

Geotropism

The last tropism which need be mentioned is geotropism or the reaction to gravity, the term being due to the botanist, A. B. Frank (1870). In seedling plants the primary shoot is negatively geotropic and the tap-root is positively geotropic. The historical sequence of terms makes it clear that the theory of tropisms is grounded in plant physiology whence it has been extended to account for many of the reactions of animals.

A. WILLEY.