

their general usefulness must be world-wide. Their field of investigation even is not to be confined by the artificial limits of the United States, though much remains to be known of our own flora, even that of the more carefully explored eastern region, and especially among the hordes of lower plants that are just beginning to be disclosed. The whole American continent, from Alaska to Cape Horn, with all that immense dark continent of South America, must be the working field of the American botanist. The investigators of the Old World are naturally more concentrated on the study of their own continent, and are generally agreed to leave America to the Americans. The Spanish Americans have accomplished almost nothing in the development of the knowledge of their own floras or the possibilities of their economic vegetal products. The Anglo-Saxon blood in the New World, as in the Old, must originate and direct all exploration and development, and this will form one portion of the work of American botanical gardens. But the scientific study of the flora is only the foundation, the very necessary first step for subsequent work. The study of the active properties of plants, medicinal or otherwise useful to man, deserves close attention, as the recent discovery of numerous important economic products will testify. The question of extending the already prodigious work of transporting the more abundant products of the tropical zone to the region of the highest civilization forms another problem in which the botanical expert is needed to cooperate; then there are important problems of ecology, of plant physiology and of plant diseases, all of which have a direct bearing on the constant and ever-increasing supply of food and shelter for the human race, and these can only be worked out in the presence of such conditions and such extensive collections of plants as a large botanical garden will afford. An extensive garden, with a

director at its head who is primarily a botanist with the widest possible acquaintance with plants and who understands in in what directions botanical science needs to be developed so as to prove most beneficial to the race at large, and with departments of research so endowed that skilled botanical experts in their exclusive specialties can prosecute their investigations free from galling questions of personal support—such a garden is capable of becoming even more influential in democratic America than Kew has become throughout the length and breadth of the Queen's dominions.

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ABSORPTION IN VERTEBRATE INTESTINAL CELLS.

THE lining membrane of the vertebrate intestine consists of a single layer of cells. These cells are of two kinds. Designating them according to their form, the accepted nomenclature is Cylinder cells and Goblet cells. Certain authors have, however, adopted a nomenclature based on physiological differences and term them Protoplasm cells and Mucus cells.

The Cylinder or Protoplasm cells are typical epithelial elements. They have the form of five- or six-sided pyramids, the broad end facing the lumen of the intestine and the narrower end resting upon connective tissue (*Tunica propria*). Oppel (*Lehrbuch der Vergl. Mikr. Anat.*) calls the attached end the base and the free end the apex. The apex is characterized by the possession of a striated border, a structure having the appearance of a bunch of cilia. Its true nature is still in doubt. The nucleus is relatively large and situated near the basal end. The cells have no membrane. They are usually several times as numerous as the goblet cells.

The Goblet or Mucus cells have typically a goblet shape, but show great variation in this respect. They are usually described as

consisting of two parts: the Foot, attached to the Tunica propria, narrow, protoplasmic and containing the nucleus; and the Theca, opening into the lumen of the intestine, broad and filled with a secretion termed mucus. The protoplasm of the goblet cells is much denser in texture than that of the cylinder cells, and their nuclei stain more intensely. Two of these cells never occur in juxtaposition, cylinder cells being always interposed.

Closely associated with these two elements, although having only a topographical relation with them, are Leucocytes or wandering cells. These occur in various positions within the mucus membrane, either between or beneath the epithelium cells. In the former position they usually lie in a line with the nuclear row; rather less frequently nearer the lumen of the intestine. In the latter position they are scattered throughout the connective tissue stroma, and may, in the higher vertebrates, form dense aggregations, termed nodules. A nodule consists of a connective tissue frame-work, inclosed by a delicate membrane, the whole closely packed with leucocytes. The nodules may occur singly or in groups, in which latter case they constitute follicles. Peyer's patches are a familiar example of these structures. Their actual position is within the mucosa, but they encroach, on one side, upon the submucosa, and, on the other, may break through the mucus membrane and project into the cavity of the intestine.

The three elements above described make up, in its entirety, the lining of the vertebrate intestine, and it is through them and by their means that food, after being acted upon by digestive fluids, is absorbed and eventually distributed throughout the various parts of the body. Three phases may then be distinguished in digestion: First, the sifting-out of the useful constituents of the food from the useless and the reduction

of the former to a condition in which they may pass through the intestinal mucus membrane. Concerning these processes a considerable fund of accurate information has been collected. There is much difference in detail in different groups of animals; but in general, nitrogenous bodies are transformed into peptone, carbohydrates into mono-saccharides, while fats are apparently broken up into a soap and glycerine. The change in the nitrogenous bodies is brought about by pepsin and trypsin. Carbohydrates are acted upon by ptyalin and amylopsin. Concerning fats the customary statement is that they are first emulsified by bile and then analyzed by steapsin. It is noteworthy that the pancreas furnishes enzymes capable of digesting all classes of food. The above doctrine is that generally accepted, and, beyond any doubt, it is entirely correct so far as it goes. But there are reasons for believing that the cylinder cells of the intestine are also of great importance in the furnishing of digestive fluids. Howell (*American Text-book of Physiology*, 1896), speaking of 'succus entericus,' says: "Upon proteids and fat it is said to have no specific action, * * * Upon carbohydrates the secretion has an important action." Foster (*A Text-book of Physiology*, Philadelphia, 1895) also mentions the succus entericus, but ascribes very little importance to it. On the other hand, Landois (*Lehrbuch der Physiologie des Menschen*, 9 aufl., 1896) summarizes the action of intestinal juice (*Darmsaft*) as follows:

1. Diastatic action.
2. Metamorphosis of maltose into glucose.
3. Conversion of fibrin, fresh casein, raw and cooked meat and plant albumin into peptone.
4. Analysis of fat.
5. Metamorphosis of di- into mono-saccharides.
6. Coagulation of milk.

Thus there are dissenting opinions amongst physiologists, but in this connection it is to be remembered that it is practically impossible to obtain normal intestinal juice. The method consists in cutting out a portion of the intestine and attaching this by both ends to a fistula made in the body wall. In this way admixture with gastric or pancreatic juice is prevented, but the conditions are highly abnormal and negative results with fluid obtained in such a way are of little weight. Moreover, physiologists usually make their experiments on mammals, whereas a study of the lower groups gives support to the view that intestinal cells can secrete ferments having the same properties as those of the stomach and pancreas. Thus, the Cyprinoid fishes lack a stomach and extracts of their intestines can digest fibrin. The alimentary canal of the Cyclostomes is a straight tube, entirely wanting in diverticula. It is, therefore, probably safe to conclude that the view expressed by Landois is essentially correct, although it is not to be understood by this that the succus entericus has anything like so powerful an action as the enzymes from stomach or pancreas. Its properties are the same in kind as these, but much feebler in degree.

The third class of foods consists of fats. These, unlike proteids and sugars, are apparently insoluble in the various digestive fluids. It seems, however, that steapsin is able to saponify fat. That this process actually takes place has been proven by chemical analysis made on the contents of the intestine of animals fed on fat. For this reason, and for others to be given below, it is generally supposed that fat enters the intestinal epithelium as soap and glycerine. The evidence is, however, somewhat contradictory, and this question can hardly be considered absolutely settled.

The second phase of the digestive process, absorption, consists of the passage of the

prepared food through the epithelium of the intestine; in reality, its entrance into the body, for hitherto it has been outside. This food, as has been seen, is in solution, and the older physiologists considered its entrance to be either a mere soaking through or else an osmotic process. But it has been shown that this view is erroneous. Without discussing what the actual process may be in intravital staining, it is known that living protoplasm behaves differently with different stains. Living spermatozoa can be stained differentially, while protozoa will take up certain anilines and wholly resist the action of others. That is, protoplasm has the power of resisting the entrance of certain substances. This power is clearly demonstrated by the epithelium of the intestine. The laws of diffusibility do not hold true. For example, if a solution containing equal parts of sodium sulphate and glucose be allowed to act on the living intestinal mucus membrane, the glucose will be almost entirely absorbed and the sodium sulphate scarcely at all. Yet the salt is much more diffusible than the carbohydrate. The epithelial cells, then, possess a selective power which is obviously dependent upon the activity of their protoplasm. That this is of great importance to the organism needs no emphasizing.

The entrance of proteids and sugars has not been studied cytologically. Such an investigation, although of the utmost importance, presents extreme difficulties. The preliminary process essential to mounting would probably take out of the cells all such substances, and the work would necessarily have to be done on fresh cells. But proteid reactions are obscure and indefinite, and this, along with the technical difficulties in the way, a magnification of 750–1,000 diameters being necessary, has evidently discouraged such researches, and our actual knowledge on this point is nil. Having entered, however, it has been satisfactorily

demonstrated that proteids and carbohydrates are taken up by the blood and that they do not enter the lymphatic system.

Natural fats are mixtures of the three chemical compounds—Olein, Palmatin and Stearin. Of these, the first is a liquid, the other two are solids. Consequently, the proportions in which these three ingredients are mixed conditions the melting point of the fat. Tallow and lard are high in stearin, while cod-liver oil is high in olein. Thus the melting point of fat enables us to form an idea as to what animal produced it. But all fats, of whatever nature, reduce osmic acid, producing an intense black coloration, and this clear and distinctive test furnishes the reason why the absorption of fat has been a favorite study with cell-physiologists. In passing a piece of intestine tissue through the various processes necessary for its microscopical study all nitrogenous bodies in solution in the cells are very probably dissolved out by the alcohols, but fat is only very slightly soluble in alcohol and not particularly so in cedar oil, and accordingly preparations that still contain a large part of their original fat contents may be studied. The error is more likely to be in the other direction; osmic acid is reduced by all organic matter, and it is extremely probable that many cell aggregates, not fat at all, have, by virtue of their having actually reduced osmic acid, been mistaken for fat.

Taking up now in detail what has been learned concerning the absorption of fat, we find that there are three conflicting theories. These are:

1. Fat enters between the epithelial cells.
2. Fat enters the epithelial cells.
3. Fat enters both ways.

Concerning the first of these views, that the only entrance path of fat is between the cells, it has had, in so far as I have been able to learn, but one advocate (Watney, 1877), and the appearances are so strongly

against it that we are probably entirely safe in rejecting it in toto.

With regard to the other views the matter at issue is much more comprehensive than the mere entrance of fat. One of these, the second, holds that the sodium salt of a fatty acid (a soap) and glycerine enter the cell in solution. The reasons for believing this are, first, the general reason that the solids have never been known to enter the intestinal epithelium, and, second, the appearances in the fixed cell. The striated border and a narrow band running across the cell just beneath the striated border are always free of fat.* It first appears lower down in the cell and arises as exceedingly minute globules, which roll together and fuse and eventually come to form masses, which may be so large that two or three fill the entire cell. That is, the soap and glycerine are synthesized, and fat appears in an exceedingly minute state of division. The increase in size of these particles is a merely mechanical phenomenon and has been observed in living cells. At the expiration of a certain period after the commencement of absorption a second process is inaugurated. This has been studied the most carefully in those forms which possess intestinal villi, and the following is applicable to only such. A very fine canal system has been described by some, consisting of vessels that extend from the base of the cell into the lacteal, but more accurate observation has shown that such does not exist. The fat merely passes from the cell, the determining factor in its movement being protoplasmic activity, and becomes scattered throughout the stroma of the villus, lying in a peri-cellular fluid which occupies the spaces between the connective tissue cells and fibers. Heidenhain (1888) has given a very clear expla-

*This has been disputed. Some writers have described fat both in and just beneath the striated border.

nation of the method by which it enters the lacteal. The villus is enclosed externally by the epithelial layer, and its center is occupied by the lacteal. In the space outside of the lacteal and inside of the epithelium there is the connective tissue (in which the fat is scattered) and muscle fibers. These muscle fibers lay along the length of the villus. They are attached to the connective tissue at the base of the villus and inserted in the inside of the epithelial row and in the walls of the lacteal. Now, when the muscle contracts it will pull upon the connective tissue fibers that bind it to the lacteal and to the epithelium, and these, in their turn, pull the epithelium inwards and the wall of the lacteal outwards. The force is the same in both cases, but the epithelium is far more resistant than the wall of the lacteal, and the result is that the volume of the vessel is increased. This causes a negative pressure within the lacteal (valves prevent its filling up from the large lymphatic vessels) and a positive pressure in the stroma between it and the epithelium, and in consequence the peri-cellular fluid, with its fat, is forced to enter it. From the lacteal it, of course, enters the lymphatic system and eventually the blood.

The other theory gives to the leucocytes the primary rôle in the absorption of fat. This holds, in general, that fat, and other food as well, is taken from or from between the cylinder cells by leucocytes and by them carried into the circulatory system. The details are held to be as follows: The eating of a meal brings about great activities on the part of the leucocytes. The number of them in the intestinal walls increases manyfold. This increase is brought about in two ways. There is active cell-division on the part of those leucocytes present in the nodules and scattered throughout the mucosa, and, in addition, there is a migration from other parts of the body. The

facts upon which this belief is based are the great increase in size of the nodules during absorption and the presence of innumerable mitoses in the cells themselves. One observer (Schäfer) describes the process for the frog as follows: Beneath the epithelial row the leucocytes divide, the new cell consisting of a nucleus with a minute quantity of protoplasm. It moves either close up to or between the epithelial cells and ingests food. During this process it increases enormously in size and eventually carries the load of food back into the connective tissue, where it enters a lymph capillary. That it is food which the leucocyte carries back, seems to be proved by fat feeding, following which the returning leucocytes contain granules that give the osmic-acid test.

These two theories are contradictory, but not mutually exclusive, for it is conceivable that both processes may take place side by side. Leucocytes are known to ingest foreign substances while in the blood, and, although there are reasons for supposing that this phenomenon is of the utmost benefit to the organism as a whole, it is not supposable that leucocytes have been evolved for the particular function of disposing of pathogenic bacteria. Similarly, in the intestine, the proximity or actual contact of foreign substances in the form of fat globules would undoubtedly provoke activities on the part of the leucocytes. They would ingest such particles freely, but rather for their own individual benefit than for that of the organism as a whole. This would, of course, be of benefit to the organism as a whole, since the return of the leucocytes to the lymphatic system and their death there would increase the amount of food in the lymph, but this conception differs very materially from that which holds that leucocytes function as fat carriers and that without them fat could not enter the lymph. There is, moreover, direct evidence which bears on

this point. Heidenhain has observed that in suckling mammals, which must necessarily be absorbing fat, there are very few leucocytes present in the intestinal mucus membrane. He also throws doubt on the fatty nature of the granules observed returning leucocytes that respond to the osmic-acid test, observing, with considerable point, "Nicht alles ist Fett, was in Osmium säure dunkelt." It is thus possible to bring such observations as these of Schäfer's quoted above into line with the views advanced by Heidenhain. Leucocytes may, as described, divide, migrate out near the surface of the mucus membrane, take up food and convey it back into the lacteal, but the rest of the organism is not dependent upon them.

The third phase of digestion is that which takes place in the cells, and consists in building-up of food substance into protoplasm. This process is of chemical nature and consequently wholly beyond the reach of direct observation. The advances that are being made in the province of organic chemistry lead to the hope that the albumen formula may eventually be discovered, and were this done the synthesis of protoplasm would be at least a theoretical possibility. At present, however, our knowledge of the actual conditions that exist in living matter is so slight that even speculation is useless.

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SCIENTIFIC BOOKS.

Zoological Results based on Material from New Britain, New Guinea, Loyalty Islands and Elsewhere, collected during the years 1895, 1896 and 1897. By ARTHUR WILLEY. Cambridge, Eng., the University Press. 4to. Part I., 1898; pp viii+120; pls. 11. Part II., 1899; pp. 85; pls. 12.

The zoological materials collected by Dr. Arthur Willey during his search for the Pearly Nautilus have been distributed to specialists

and will form the basis for a series of five or six published parts, the first two of which have already appeared. These of themselves are a substantial acknowledgment to the Board of Managers of the Balfour Studentship and to the Government Grant Committee of the Royal Society, by whose generosity Dr. Willey was enabled to prosecute his researches.

Part I. opens with an account, by Dr. Willey himself, of the anatomy and development of a new species of *Peripatus* from New Britain. The species hitherto described, as Sedgwick has shown, fall into three natural groups, corresponding to their geographical distribution: Neotropical, Australasian and Ethiopian. For each of these Pocock has proposed new generic names. Dr. Willey's new species represents a fourth geographical group, which may be called the Melanesian, and for which he proposes the generic or subgeneric name of *Paraperipatus*, the species being *P. novæ-britanniæ*. As Dr. Willey justly remarks, it is not to be expected that a new species of *Peripatus* would throw much light on the vexed question: Is *Peripatus* an annelid or an arthropod? What is probably needed is something between *Peripatus* and other forms rather than more *Peripatus*.

The Phasmidæ, or walking sticks, have been reported by Dr. D. Sharp. Upwards of twenty species were collected, of which fourteen seem new to science. The report contains an extended account of the eggs and pre-adult stages of these insects.

The scorpions, pedipalpi and spiders were represented by forty-nine species, of which sixteen are stated by Pocock to be species novæ. The descriptions of these include a number of interesting biological notes. The cocooning habits of *Fecenia* and *Ordgarius* are described, and a species of *Conothele* which has subvertical mandibles is shown for the first time to build its nest on trees in the same way as other trap-door spiders that have this structural peculiarity. In a new species of *Plexippus* the mandibles and maxillæ form a stridulating organ.

Besides this report, Pocock has also contributed an account of the centipedes and millipedes, of which there were twenty-one species, thirteen new to science.

The first part also contains the description of