SYNOPSIS OF ANIMAL PARASITOLOGY

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INTRODUCTION.

Parasitism is a condition of widespread occurrence in both plant and animal kingdoms, though much more characteristic of certain groups than of others. Its basis is to be sought chiefly in a nutritive relation in which one organism, the **parasite**, obtains its food-supply directly from the living tissues of another organism which in this way becomes the **host**. In this condition it is purely a matter of the degree of parasitism whether the infesting organism, naturally a smaller species, occupies a superficial position on the body of the host, as an **ectoparasite**, or as an **endoparasite**, penetrates into its interior.

This parasitic association is one of the results of competition among organisms, and is accompanied by structural changes analogous to those taking place in other directions in free-living organisms by adaptation and specialization. All organisms tend to utilize the available resources of food-supply, but a fundamental difference exists between those possessed of carbohydrate-building power, after the plan of the green plants, and those which, lacking this property, are dependent for their supply of organic food on preformed material. It is the latter group, comprising all animals and many plants, to which the developments of parasitism especially apply; since while the majority of species, the free-living animals, so called, as well as the **saprophytes** among plants, obtain their food-supply from dead organic material, whatever its original source, many others as parasites form a direct association with the tissues of a living host. The utilization of this source of food-supply and the adaptations produced must accordingly be interpreted in the same manner as for free-living organisms. The evolutionary development of all organisms has its beginnings in free-living habit, and accordingly the classification of organisms into natural groups is based mainly on the characters of free-living forms. All parasites belong to these same major groups and this fact facilitates their classification, especially when degenerative changes, which conmonly take place in portions of their organization, have obscured their relationships. Many natural groups contain parasitic members, but the occurrence of greater proportions of parasitic forms in such groups as the Platyhelminthes and Nemat-

helminthes among animals and the Fungi among plants is an indication that parasitic adaptations have been much easier of accomplishment in these groups than in others.

The direct structural adaptations of parasites to their hosts are exceedingly various. Fungus parasites among plants commonly exhibit absorptive or haustorial filaments by which they set up a more intimate association with the cellular materials of the host, while animal parasites frequently exhibit special organs of attachment and a protecting cuticle for the surface of the body. Such adaptations, however, are of minor significance in comparison with others which ensure the production of a large number of young and the transfer of the parasite in one stage or another to its proper host.

To all organisms the risks of life, or constructively the mechanism of survival, is of prime importance. But it is especially significant in parasites where there is added to ordinary risks the isolation of the parasite when established in the body of the host. Access on the part of the offspring to the body of a new host must in this case become more than a matter of mere chance. Parasites accordingly exhibit various adaptations for increasing the number of young, and make use of peculiar associations on the part of the host to ensure continuity from one generation to another. It is also on this account that parasites commonly exhibit an intricate life-history, involving considerable differences in successive generations, and alternate **primary** and **secondary hosts**.

Parasites usually also give indications in their structure of degenerative changes when compared with free-living members of the groups to which they belong. These changes are adaptations in the sense that they make way for other adaptations of more positive nature, of importance in the economy of the organism. Such modifications include among animals the reduction of the nervous system, especially the organs of special sense, and of the muscular and digestive systems; among fungous plants degeneration of the normal thallus form.

There is doubtless a more fundamental relation existing between parasites and their hosts than is implied by adaptations of a structural or mechanical nature. The fact that certain parasites attach themselves to particular hosts, and to no others, or the **specificity** of the organisms, has in all probability a chemical basis in the composition of their respective tissues. This kind of relation has been more thoroughly studied in the case of the pathogenic bacteria and is becoming more and more important in practical methods of serum therapy.

Parasitic animal organisms are distributed through various natural phyla, the chief of which are:

(1) Protozoa, or Unicellular animals;
(2) Platyhelminthes, or Flatworms;
(3) Nemathelminthes, or Roundworms;
(4) Annulata, or Segmented worms;
(5) Arthropoda, or Joint-footed animals.

PROTOZOA.

The **Protozoa** are the lowest of animal organisms in the sense that the functions and specializations of the individual are not expressed by aggregation of mutually dependent cells. Four natural classes are distinguished, viz.,

(a) **Rhizopoda.** Organisms with protoplasmic extensions of the cell, **pseudopodia.**

(b) **Mastigophora.** Organisms with one or two large **flagella** for locomotion.

(c) **Infusoria.** Organisms with the cell surface occupied uniformly or in part by **cilia,** the latter sometimes (**Tentaculifera**) present only in the embryo.

(d) **Sporozoa.** Organisms specialized as parasites and having **partition cells** or **spores,** produced in large numbers.

Among the **Rhizopoda** are forms resembling ordinary *amoebae,* but living in the human alimentary canal, especially the large intestine. One of these, *Endamoeba coli,* lives as a **commensal** in the first portion of the large intestine while *E. histolytica* (*Amoeba dysenteriae*) is the causative agent of amoebic dysentery, characteristic of the warmer zones, associated with inflammatory conditions, haemorrhage and ulceration of the intestinal wall from penetration and destruction of the mucosa. Both organisms have sporulation stages suggesting those of Sporozoa. Other species of amoebae are sometimes found on the oral, pulmonary and urino-genital surfaces.

The parasitic **Mastigophora** are commonly differentiated as **Trypanosomes** and **Herpetomonads,** and the **Spirochaetes** and **Treponemata** are cometimes included.

Trypanosomes are elongated spindle-shaped organisms, with a longitudinal **undulating membrane** and an accessory **parabasal body** giving origin to a flagellum which is closely associated with the undulating membrane. They are blood-parasites occurring in a great variety of vertebrates. Many appear to be harmless to the host, the latter in all probability having become immune to their presence. There is usually a secondary invertebrate host.

Trypanosoma lewisi from the blood of the rat has been thoroughly

studied and is commonly taken as the type. It is non-pathogenic and is transmitted from one animal to another through the bite of the rat-flea (*Ceratophyllus fasciatus*) or dog-flea (*Ctenocephalus canis*).

The most important human trypanosome disease is sleeping sickness, distributed through equatorial Africa from Uganda westwards. The organism, *T. gambiense*, is transmitted through the bite of a **tsetse fly,** *Glossina palpalis*. The incubation period lasts from ten days to three weeks, and the disease may be carried for some months. It is characterized by nervous changes, producing muscular fatigue and torpor, especially marked during the day.

A similar disease affecting African domesticated animals, and carried in the blood of native animals is known as **nagana.** It is transmitted through the bite of another species of tsetse fly, *G. morsitans*, the direct causative agent being *T. brucei*. The carrier, *G. morsitans*, has also been shown to be capable or transmitting both *T. gambiense* and *T. rhodesiense*, the causative organism of the "Rhodesian" type of sleeping sickness. **Dourine,** a trypanosome disease of horses, the causative agent of which is *T. equiperdum*, is significant because of its presence in Western Canada, following introduction into North America in imported Percheron stock.

The **herpetomonads** form a composite group consisting of elongated cells with parabasal body and terminal free flagellum (*Herpetomonas*), similar cells with a free undulating membrane attached to the flagellum (*Crithidia*), and simple cells without flagellum or membrane, occurring as intracellular parasites, but having flagellated phases as in *Herpetomonas*. The cell forms are significant for their resemblances to the trypanosome and ordinary flagellate (*Euglena*) forms. *Herpetomonas* and *Crithidia* are intestinal parasites of arthropods. The intracellular form, known as *Leishmania*, includes *L. donovani*, the organism of Indian kala-azar, and *L. tropica*, the organism of Delhi boil.

In kala-azar the parasites are found inside the endothelial cells of the capillaries, for the most part, of visceral organs. The parasitic cell (Leishman-Donovan body) is rounded or oval in shape, and contains two chromatin bodies, of which one, much smaller than the other, is a parabasal body. When grown on a culture medium the organism assumes a flagellated form like *Herpetomonas*, indicating that the intracellular form is an adaptively fixed or "resting" stage.

Delhi boil is a cutaneous disease contributed chiefly in India and the Orient, but also more or less generally in the tropics. The boils occur commonly about the face. The parasite is found in the

endothelial and lymph cells. Both Delhi boil and kala-azar are thought to be transmitted by insects. Infection of vertebrate hosts by *Herpetomonas* and *Crithidia* yields pathogenic results for mammals. The organisms assume both flagellated and non-flagellated forms resembling *Leishmania*.

Spirochaetes are slender wavy cells, with lateral non-undulating membrane. The nucleus is represented by a series of chromatin bodies, and there is a characteristic formation of internal spores, indicating that the cells may be bacterial and not protozoan. Several species have been studied in freshwater and marine molluscs and in birds and mammals. *Spirochaeta duttoni* is the causative agent of African tick fever, an important human disease distributed through the Congo State and elsewhere in Africa. The organism is found in the blood and is transmitted through the medium of a tick, *Ornithodorus moubata*. In the body cells of the latter the spirochaete breaks up, releasing a large number of minute "coccoid" bodies which pass out with the excretions of the tick and appear to reach the human host in this way. These bodies are also present in the eggs of the intermediate host.

Recurrent or Relapsing fever of European countries is also a spirochaete disease, the organism being *S. recurrentis*. It is presumably transmitted from the bodies of lice which are crushed on an excoriated surface rather than through the bites of the insects themselves.

Two forms of spirochaetes, *S. buccalis* and *S. dentium*, are known to occur in the human mouth, neither one being, however, pathogenic.

The **treponemata** are slender wavy or spiral threads without membrane. The chief form is *Treponema pallidum*. It is the causative agent of the loathsome but widespread disease of the urinogenital organs, syphilis. *T. pertenue* is the agent in the human disease of warm countries known as framboesia or yaws, characterized by raspberry-like excrescences of the face and other parts of the body.

The parasitic **Infusoria** may for convenience be considered in two divisions: (a) The natural group **Tentaculifera**, as distinguished from ordinary Infusoria or Ciliata, contains peculiarly specialized tentacle-bearing forms (*Acineta*, etc.), the embryos of which are ciliated and become parasites in the cells of other protozoa. (*b*) Ciliates parasitic in various higher animals, including man. The chief human parasite is *Balantidium coli*. It is an oval ciliated organism, with an oral depression at the anterior end of the cell, meganucleus and micronucleus, and two contractile vacuoles. It is the chief causative agent in ciliate (balantidian)

dysentery, an intestinal disease of man, characterized by alternate diarrhoea and constipation, intestinal catarrh, and sometimes ulceration of the wall. The organism occurs in the pig, with similar forms in amphibia and annulates. *Opalina ranarum*, parasitic in the rectum of frogs, resembles *Balantidium*, but is multinucleate.

The **Sporozoa** are entirely parasitic. Their chief feature is reduction of motile structures and, in many cases at least, development of a more resistant cell membrane. Of prime significance, however, is the adaptation of the life cycle to rapid reproduction, attained by means of multiple cell division or "sporulation".

The group contains a number of early recognized forms known as **Gregarinida**, sometimes as "gregarine worms", of which some are simple spindle-shaped or elongated organisms living in the body-cavities of invertebrates, *e.g.*, *Monocystis* in the seminal vesicles of the earthworm, while others show a transverse division of the cell, differentiating a head lobe or **epimerite** which serves for attachment and may be lacking in some stages, *e.g.*, gregarines of the digestive tract of insects, notably *Gregarina blattarum* of the intestine of the cockroach.

Coccidium types or **Coccidia** are intracellular parasites of the epithelial cells of various animals. *Eimeria stiedae* (= *Coccidium cuniculi*) of the liver of the rabbit was one of the first studied. *Eimeria schubergi* from the intestinal epithelium of the centipede *Lithobius* is commonly taken as the type. The organism penetrates the epithelial cell in the **sporozoite** stage. It reaches maturity at the expense of the host cell. There are two main phases or cycles in the life history, one adapted for distribution of the parasite in cells of the host, the other for transmission to another host animal of the same species. The processes are as follows:

(*a*) Re-infection of host. The adult cell undergoes multiple division into **merozoites**, each of which gains access to a new epithelial cell. The process is purely asexual and is known as **schizogony.**

(*b*) Preliminary stages to transmission. After the period of schizogony the adult cells become differentiated into sperm and egg mother cells. The latter becomes an **oocyte** or **macrogamete** by extrusion of a certain amount of the chromatin. The former undergoes multiple division resulting in the formation of a large number of bi-flagellate **sperms** or **microgametes.** The fertilization is followed by membrane consolidation around the egg which thus becomes an **oocyst.** There is then an internal division into four spores each enclosed by a thick encystment membrane. The protoplasm of each spore undergoes division into two sickle-shaped **sporozoites.** The development is now finished unless the liberated

spores or the oocyst reach the intestine of another animal, in which case the cyst membranes are dissolved by the digestive juices and the sporozoites are set free to infect the host cells.

The **Haemosporidia** are sporozoa parasitic in the blood of various hosts. They are of several types, the most important being that of the **Plasmodium** group of malaria organisms.

Malaria as a disease is of three principal kinds, known as tertian, quartan, and quotidian or aestivo-autumnal fever. The organism of tertian fever is *Plasmodium vivax*. The fever phase in malaria is periodic, occurring every 48, 72 or 24 hours (third day, fourth day, daily) according to the type of infecting organism, or in the quotidian kind resulting from multiple infection. Transmission takes place through the bites of mosquitoes of the genus *Anopheles*, ordinary mosquitoes of the genus *Culex* not carrying the organism.

The life history resembles that of *Coccidium* in most respects. The two phases are as follows:

(*a*) Re-infection of the host. The organism penetrates the red blood cells. Multiple division or schizogony follows with production of merozoites. These are set free by destruction of the host corpuscle and each is able to penetrate a new cell. The formation of the merozoites is coincident with the fever phase of the disease, and it is in this phase that the use of quinine as a specific is effective.

(*b*) Transmission stages. Macrogametes and microgametes are formed, the latter being thread-like cells given off from the side of the parent cell which, after the sperms are formed, becomes a residual body. Fertilization takes place only in the body of the mosquito host. The fertilized eggs are motile vermicules, **ookinetes**, which penetrate the wall of the intestine, and taking a position behind the epithelium give rise to large oocysts. These contain, as a result of repeated division, hundreds or even thousands of pointed sporozoites. They escape from the cyst and are found distributed through the tissues of the mosquito host, including those of the salivary glands. Salivary secretion thrown from the glands into the oral tube of the mosquito is the medium by which a second human host is infected.

The association of malaria with low-lying regions is determined by the breeding habits of the *Anopheles* host, the larvae of which are aquatic. Removal of malaria infection is made possible by drainage, use of kerosene, which prevents the larvae from breathing the surface air on which they depend for respiration, and introduction of small fishes which feed on the larvae.

Febrile conditions are periodic because of uniform times of

sporulation. The quotidian form, however, may be the result of double or triple infections having different times of sporulation.

PLATYHELMINTHES.

Organisms with leaf-like or ribbon-like form of body, associated with low organization of the mesoderm, which consists of primitive **mesenchyme** and **inter-cellular spaces** but no continuous coelom. A high grade of specialization of the reproductive organs associated in most cases with **hermaphroditism.** The group shows a range of specialization extending from free-living to highly modified parasitic types, the latter showing progressive development of life history adaptations to the hosts, including structural devices, sucking discs and hooks, for attachment. There is corresponding degeneration of nervous system, sense organs, and intestine. Three classes are distinguished:

Turbellaria. For the most part free-living flatworms, with **ciliated epithelium** forming the surface layer of the body. Simple or **sacculated intestine** with oral but no anal aperture. Organisms of marine and fresh water, sometimes, but seldom, parasitic. Type *Planaria.*

Trematoda. Flatworms with **cuticle** and one, two (distom) or more **sucking discs.** Digestive tube somewhat as in turbellarians, but often reduced. Organisms **ectoparasitic** or **endoparasitic,** i.e., living on the surface or in the interior of various vertebrate hosts. Ciliated only in larval stage. **Alternation of generations** with **change of host.** Type *Fasciola hepatica;* Primary host, Sheep; secondary host, Pond-snail.

Cestoda. Flatworms without alimentary canal, usually segmented into **proglottides** with anterior **scolex.** Tapeworms. An intermediate stage in the life-history and change of hosts. Type *Taenia solium;* primary host, Man; intermediate host, Pig. Convenient for laboratory study is *Dipylidium caninum* from intestine of dog; intermediate host, dog-flea (*Ctenocephalus canis*).

Trematoda. The ectoparasitic forms are less specialized than the endoparasitic ones, and have also a direct development (**monogenetic**). The endoparasitic or **digenetic** forms present in this way a more advanced phase of the parasitic development.

Fasciola hepatica is a lanceolate worm of 20 to 30 mm. in length, living in the smaller bile-ducts of the sheep. The body is covered by a resistant cuticular membrane of uncertain derivation. There are two suckers, one anterior, encircling the mouth, the other central. Older individuals show the coils of the uterus gorged with fertilized eggs. The latter develop only in water into which

they have been discharged after passing through the bile-ducts and intestine of the host. The **egg** produces a **ciliated embryo** (miracidium) with eye-spots, apparently reflecting the free-living ancestral stage, but with a boring organ at the enterior end of the body. The embryo enters a pond snail (*Lymnaea truncatula*, Europe; *L. humilis*, North America), giving rise to **sporocyst, redia,** and **cercaria** stages, asexual or multiplication phases through which the permanent specialization is gradually attained and the number of young greatly increased. The tailed cercariae become encysted on blades of grass, from which position they reach the stomach of the sheep. The organism is accountable for the disease known as "liver-rot" which has destroyed vast numbers of animals in Europe, notably France.

Many species of "flukes" and "distoms", as the trematodes are commonly called, are parasitic on the epithelial surfaces of the digestive tube and its appendages, lungs, and urinogenital organs in vertebrates, a few occurring in man. *Fasciolopsis buski*, the largest species, is very like the liver-fluke of the sheep both in appearance and development. It inhabits the small intestine of man and the pig in China, India and other parts of the Orient. *Paragonimus westermani* is a common lung parasite of China and Japan. *Clonorchis sinensis*, also Oriental, occurs in the liver ducts, producing profound modifications of the liver substance. *Schistosoma haematobium* and *S. japonicum* are two remarkable blood-parasites of man and mammals, the former widely distributed in Africa, the latter in China, Japan and the Phillipines. *S. haematobium* is unisexual, the male, an organism of 12 to 14 mm. in length, having the body greatly flattened and the sides rolled in ventrally so as to form a tube. The female, much more slender and 20 mm. in length, is found more or less completely enrolled in the tube formed by the body of the male. The eggs appear in the urinary bladder. They develop in the water into embryos, which require certain species of water snails for further growth and reproduction. From the snail cercariae escape into water through which they are transmitted to man. The structure and history of the Japanese form are similar.

Cestoda. *Taenia solium* is one of two chief species having the adult stage in man, the other being *T. saginata*. They differ in their intermediate hosts, that of the former being the pig, and of the latter the ox. *T. solium* is about 3 m. in length in average cases, and lives on the epithelial wall of the human intestine. The **rostellum** has a doubtlet circlet of hooks. There are four muscular **suckers.** Passing backwards from the head or **scolex** there is a gradual differentiation of **proglottides,** and of the formed proglottids every stage is discernible from the appearance of the gonads

and ducts to the completion of the reproductive processes, ending in the production of ripe proglottides containing myriads of **fertilized eggs** and embryos. The **embryos,** enclosed by the egg membrane, reach the alimentary canal of the pig and are set free. The characteristic development takes place in the muscles where the **cysticercus** is formed. The latter is transmitted to the human intestine in uncooked or insufficiently cooked pork. The cysticercus is of considerable size, being 6 to 20 mm. in length.

The various genera of tapeworms are distinguished by differences in the **position of the genital pores.** In *Taenia* these alternate on the lateral margins of the proglottides. In *Dipylidium* they are paired. In *Diphyllobothrium* they occupy the middle points of the ventral surface.

Echinococcus granulosus, a small tapeworm of the intestine of the dog is significant on account of the large **cysts** produced in man through the development of the cysticercus stage. The adult form in the dog is a minute worm of 2.5 to 6 mm. in length, and composed of a scolex and three segments. The cyst phase develops in human beings, for the most part in the liver, and is distributed among those who have habitual association with dogs, especially Icelanders. The cysts contain innumerable scolices and reach a gross size of 4 inches or even more in diameter.

Hymenolepis nana is a slender tapeworm of 10 to 45 mm. in length reported from various European countries and North and South America. The parasites when present at all are present in large numbers, and the host effects are correspondingly severe.

Diphyllobothrium latum is a large tapeworm of 2 to 9 m. in length, significant as a human parasite and on account of its aquatic larval stage. The adult is found in the small intestine of dog, fox, cat and man. The eggs develop in water, giving rise to spherical **ciliated embryos.** These pass through a minute crustacean host, but eventually reach the intestine of a fish, commonly the pike, where they bore into the muscles and are found as small yellowish encysted bodies known as **plerocercoids.** These are transmitted to the human intestine through the medium of insufficiently cooked infected fish.

NEMATHELMINTHES.

The **Roundworms** are cylindrical, **unsegmented worms,** having a **continuous body-cavity,** the latter lacking typically a lining membrane. The surface is covered by a smooth cuticle. There are three main divisions of the phylum, **Nematoda, Gordiacea,** and **Acanthocephala,** the first-named division being the character-

istic one. While most forms possess a digestive tube there are marked indications of its reduction, and in the Acanthocephala the tube is lacking. Some roundworms are free-living, others parasitic, the latter including forms parasitic only in larval or adult stage of the life history, and also **facultative** parasites. Most parasitic forms are intestinal, but important species occur in the muscles and connective tissues of the host. There is frequently some device for retaining position, such as thread-like or lance-like form or development of hooks.

Nematoda, typical round or thread worms, include a striking variety of forms and life histories, some of the more significant of which are described below. One of the oddities of the group is *Anguillula aceti*, the vinegar "eel", the female of which is 2.5 mm. in length, the male smaller. The organism lives in ordinary vinegar, subsisting on the fungus sometimes present. Similar forms live in soil or decaying matter.

The type of the group is commonly taken from *Ascaris*, the species of which are parasitic in the intestinal tube of various vertebrates, *A. megalocephala* occurring in the horse, *A. suum* in the pig, and *A. lumbricoides* in man. *Ascaris lumbricoides* is a yellowish cylindrical worm, the male 15 to 17 cm., the female 20 to 25 cm. in length. There are four longitudinal lines, respectively dorsal, ventral and lateral, the former two containing nerves and the latter excretory vessels. The mouth at the anterior end is enclosed by a trilobed lip. The genital aperture in the female is ventral, about one-third of the distance back from the head; in the male posterior and terminal, the end of the more slender body being curved ventrally and the aperture marked by the penial setae. There is a complete digestive tract. The muscles of the body wall are of a peculiar and in some respects primitive type, being transitional between protoplasmic cells and fibres or showing the features of both. The ovaries are paired and communicate with the outside, in the position indicated, through an unpaired vagina. The male gonad is a single thread opening posteriorly through a seminal vesicle into the posterior end of the intestine. Development is direct but there is a migration of the young from the intestinal cavity, by way of the portal system, to the heart and lungs, followed by a return through the respiratory tubes and oesophagus to the intestine. Infection takes place through the water from the soil. Occurs most commonly in young children.

Oxyuris vermicularis, a minute **pin-worm** parasitic in the human intestine, is typical of a group of worms having a pair of lateral flange-like extensions of the cuticle, which in the female

continue posteriorly into a lance-like point. The male is 3 to 5 mm., the female 10 mm. in length. The development is direct.

Trichuris trichiura (*Trichocephalus trichiurus*) lives parasitically in the human intestine. The male is 40 to 45 mm. in length, the female somewhat longer. The anterior part of the body is narrowed into a thin whip-like structure, from the presence of which the term **whip-worm** as applied to this species is derived.

Strongyloides stercoralis is a minute nematode occurring in two generations. A parasitic form in the human intestine, sometimes regarded as a female reproducing parthenogenetically, is of about 2.2 mm. in length, the eggs of which develop in the lumen of the intestine or mucosa of the host. A free-living form, differentiated as males and females, the latter of about 1 mm. in length, develops with higher temperatures outside the body, the females producing about 40 eggs which develop into larvae. The latter give rise to the parasitic phase.

The parasites known as **hookworms** include two important forms which occur commonly in the southern United States, by reason of having a general distribution in the warmer zones and doubtless introduced largely through the importation of negroes from Africa. The forms are *Ancylostoma duodenale* and *Necator americanus*. They are scarcely distinguishable externally but differ in small details of structure. *A. duodenale* is about 9 mm. in length in the male and 12 mm. in the female. There is an open buccal capsule, the aperture of which is directed dorsally, the interior containing small recurved hooks. The posterior end of the body in the male is modified into an expanded bursa supported by a number of rays. In the female the somewhat round end of the body is supplied with a short sharp spike formed from the cuticle. The organism lives in the human intestine, infection taking place through water, contaminated food or through wounds on the skin.

Many nematode parasites are adapted for living in the tissues. The disease, primarily of the muscles, known as "Trichinosis", is caused by a minute worm *Trichinella* (*Trichina*) *spiralis*. The male is about 1.5 mm., the female 3 to 4 mm. in length. They begin their parasitic phase in the intestine of the infected animal, the latter being one of the lower mammals and commonly the pig, from which the infection passes to man through insufficiently cooked pork. The male remains in the intestine of the host but the female burrows through the intestinal wall and produces live young to a number of about 1,000. The embryos pass around through the medium of the lymph spaces and ultimately find their way into the muscles where they become encysted. They may remain in this

condition for many years, but become active and sexually mature when liberated in the digestive tract of a new host.

The **guinea worm,** *Dracunculus medinensis,* is a remarkable tissue parasite occurring in warm countries, especially Arabia to Hindustan. The male, an organism of about 20 mm. in length, is seldom found. The female is a very slender thread-like organism of 50 to 80 cm. It is found associated with ulcerated patches on the body surface. This is the stage of discharging the young and takes place about a year after the primary infection. The ulcers are commonly found about the feet or ankles, the centre in each case being occupied by a projecting portion of the worm. The native method of extracting the worm is to catch the end between the edges of a split stick, exercising a slight pull by rolling the stick around. The process is continued for several days. If the worm is broken, however, the direct spread of the larvae may greatly increase the infection. Normally the larvae live in the water and pass through a crustacean host (*Cyclops*). They gain access to the human body through the ingestion of *Cyclops* with drinking water.

The **filariae** are somewhat similar forms which are widely distributed through various vertebrate hosts, occurring for the most part in the blood and lymph. *Filaria bancrofti* (*F. sanguinis hominis*) is a human parasite of the lymphatic glands and other organs, generally distributed through the warmer zones. The female is about 50 mm. in length, the male being scarcely half as long. The larvae are most common in the capillaries of the lungs, and usually appear in the surface capillaries at night, or when the patient sleeps. Infection takes place through species of mosquitos, the latter playing the *rôle* of secondary hosts.

Acanthocephala, "thorn-headed worms", include a small number of species in which the anterior end of the body is narrowed and rounded, and possesses an armature of curved hooks. The chief species is *Macracantharhynchus hirudinaceus,* of which the male is 10 to 15 cm., the female 30 to 50 cm. in length. It is found usually in the intestine of the pig but may occur in other mammals and in man.

Gordiacea, "hair worms", are fairly common as adults in fresh water, while their larvae are parasitic in insects or molluscs. Occasionally they occur in the human intestine. The common field cricket is often parasitized by the larvae of *Paragordius varius.*

ANNULATA.

Two characteristic invertebrate phyla, the **Annulata** and **Arthropoda,** are readily distinguishable from all others by the

segmented or **metameric** condition of the body. In the Annulata of which the beach-worm, *Nereis*, the earthworm, *Lumbricus*, and the leech, *Hirudo*, may be taken as examples, the segmentation is **homonomous**, each metamere being similar to the others, with the exception of an imperfectly developed **prostomium**, enclosing the brain and overlapping the mouth, a **peristomium**, surrounding the mouth, and a terminal metamere containing the anal aperture. Each metamere bears primitively a pair of flattened appendages, the **parapodia**; there is a **coelomic cavity** lined by a layer of **peritoneal cells**, a nervous system, the principal portion of which is in the form of a ventrally placed double nerve-cord, and there are segmental organs, **nephridia**, a pair in each segment, which provide a communication between the coelomic cavity and the outside of the body.

Most annulates are free-living, but the division of the **Hirudinea** is made up of forms which are partly parasitic. The medicinal leech, *Hirudo medicinalis*, formerly used for removing blood from the body of patients, shows externally a subsidiary segmentation in which five external rings correspond to one true or internal segment. The body is dorso-ventrally flattened. There is an anterior and terminal sucker, lodging the aperture of the mouth, and containing three cutting or lacerating jaws, a feature of the **Gnathobdellida** to which the medicinal leech belongs. A posterior sucker, also terminal but on the ventral side, is for attachment only. The anal aperture is placed above it. The digestive tube is expanded into a crop or reservoir for the reception of blood upon which the animal feeds.

The Hirudinea are for the most part parasites of lower aquatic vertebrates. In some (**Rhynchobdellida**) the mouth is borne on a protrusible proboscis, ordinarily found retracted into its sheath. *Limnatis nilotica*, an African form of 8 to 10 cm. in length, sometimes lives as a parasite in the human nose and pharynx, the young gaining access to the host through drinking water. *Haemadipsa*, a tropical genus, includes a number of species significant as human parasites, one of which, *H. ceylonica*, inhabiting Ceylon, lives in moist earth from which it ascends trees, afterwards dropping on the bodies of human beings or animals passing by.

ARTHROPODA.

The phylum Arthropoda, containing many parasites and carriers of parasites, has in many respects the fundamental organization of the annulate phylum from which its members are in all probability derived. The segmentation is, however, **heteron-**

omous, the metameres being differently modified in different parts of the body, and there is more or less extensive fusion of metameres, giving rise to patterns sometimes characteristic of large divisions. The appendages when present are also modified into organs of a great variety of functions, and are distinguished by their **jointed** character, associated with the development of a hard external or **exo-skeleton.**

The common crayfish, *Cambarus* (Eur. *Astacus*), may be taken as an example of the lower Arthropoda, the **Crustacea,** the members of which are for the most part aquatic, breathing by means of **gills.** In the crayfish and numerous closely allied crustaceans both the segmentation and limb modification are highly organized, but there are numerous forms less completely organized, more generally or partly segmented, some of which make up a large portion of the microscopic life or **plankton** of the water, while others are common parasites of the external surface and gills of fishes (parasitic **Copepoda**).

The **Myriapoda** or centipedes are terrestrial arthropods in which gills are replaced by **air-tubes** analogous to those of insects, but in which the segmentation and appendages are remarkably uniform as in annulates. A few have been known to live in the nasal cavity and intestine of man. Many are capable of inflicting painful and sometimes dangerous bites through the modification of an anterior pair of appendages into curved perforated poison claws, which carry the secretion of poison glands into the wound inflicted.

Arachnida, mites, ticks, spiders, and scorpions are air-breathing, for the most part terrestrial arthropods, provided, except in most of the mites, with air-tubes or with respiratory plates or **book-lungs.** The body is typically divided into a small anterior **cephalothorax** and a larger posterior **abdomen.** The cephalothorax contains **six** fused segments bearing characteristic appendages. The first appendages, **chelicerae,** are curved poison claws, the second, **pedipalpi,** are jointed appendages in relation to the mouth, the remaining **four** pairs are walking legs. The higher arachnids or spiders proper normally use their chelicerae for killing their insect prey but they are frequently able to attack larger animals and to inflict poisonous bites.

The **Acarina** are smaller arachnids, commonly known as **mites** and **ticks,** and significant both as parasites and as the carriers of protozoan parasites. The external division of the body into cephalothorax and abdomen is not in evidence, but the characteristic appendages are present though in a modified form. Thus the chelicerae and pedipalpi are modified for piercing and sucking,

the walking legs provided with bristles, claws or sucking discs for attachment.

Among the forms retaining more or less a free-living habit the more characteristic are the species of *Tyroglyphus*, especially *T. farinae*, known as cheese mites and living upon cheese, flour or fruit. Nearly all forms of acarines possess six-legged or **hexapod larvae,** the larva sometimes being the significant parasitic stage. Thus the harvest mite or "jigger", to be distinguished from the penetrating flea to which the name is more properly applicable, is the hexapod larva of *Trombidium*, and was formerly recognized as a distinct form to which in America the name *Leptus autumnalis* was applied. The larva becomes prevalent in the early autumn on low vegetation, from which it gains access to the human skin. It burrows into the skin, prodducing small red spots with a lighter centre, and bringing about considerable itching and irritation of the part affected.

The true **itch-mites,** Sarcoptidae, permanent parasites of the skin of birds and mammals, include the human itch-mite, *Sarcoptes scabiei*. The body is whitish, rounded or oval, considerably smaller in the male, the chelicerae pincer-like, and the pedipalpi jointed. The males are less commonly seen since they die off after copulation. The females burrow in the surface layer of the skin, forming tunnels, in the course of which the eggs are deposited. *Demodex folliculorum*, the mite of the hair-follicles, is an elongated worm-like form, showing, however, the typical structure of the acarines. It lives in the hair follicles and sebaceous glands of man, similar species being found in the lower mammals.

The Ixodidae or **ticks** are blood-sucking acarines, of larger size and with a somewhat leathery skin. They are common surface parasites of the mammals (*e.g.*, bush and cattle ticks). In the European dog-tick, *Ixodes ricinus*, the eggs produce a hexapod larva which attaches itself temporarily to a mammal host. Dropping off after a time it is metamorphosed into a nymph or pupal stage which repeats the performance. The nymphs finally give rise to adults, males and females, which gain access to the mammal host, where the former wander over the surface, while the latter attach themselves by the anterior end in the surface layer of the skin, the free part of the body becoming greatly distended. When fully mature the female becomes detached.

The parasitic habit of the ticks is responsible for their importance as carriers. Thus in the case of the African tick fever, the causative organism is a protozoan spirochaete (*S. duttoni*) but the transmitting organism is the tick, *Ornithodorus moubata*. In America a conspicuous example is afforded by the Rocky Mountain

spotted fever of sheep and cattle, to which human beings are, however, susceptible. The virus is a micro-organism *Dermacentroxenus rickettsi* and is transmitted by the tick *Dermacentor venustus*.

Insecta or **Hexapoda** constitute one of the largest groups not only of arthropods but of the whole animal kingdom. The plan of segmentation, which may be exemplified by any common insect, such as the cricket, *Gryllus*, exhibits a division of the body into three regions, the **head, thorax** and **abdomen.** The head bears a pair of **antennae** and the large **compound eyes,** together with **three pairs** of **mouth parts,** modified in the case of *Gryllus* for cutting plant material. The thorax bears **three pairs** of **walking legs,** associated with **three** divisions of the thorax itself, respectively the **prothorax, mesothorax** and **metathorax,** and there are typically **two pairs** of **wings,** the occurrence and form of which are subject to profound modifications. The abdomen is segmented consisting of some **ten** segments, lacking appendages except certain special ones serving the function of reproduction. Respiration is by means of air tubes or **tracheae,** but there are various modifications in forms which are aquatic.

An extensive **metamorphosis** is one of the outstanding features of the group, especially significant in its modifications in parasitic forms. Typically, as in the cabbage butterfly, *Pieris*, the female of the adult insect, here the air-living winged form, produces **eggs** which on hatching give rise to a **larva** "caterpillar" phase, the form of the body of which resembles rather closely that of the annulate worm. It is an actively feeding phase, a very destructive one in the case of many allied forms living on cultivated plants, which in time is replaced by a quiescent phase, known as a **pupa,** and often protected by an enclosing case or cocoon spun by the larva. From the pupa there emerges finally the **adult** or winged sexual form.

The life history with its seasonal, sex, and food modifications is exceedingly various in the insect group, and its details are of significance in the case of a very large number of species which are either parasitic or injurious otherwise. Of the parasites, some, such as various species of mosquitoes (*Culex*), blackflies (*Simulium*), and bed-bugs are temporary but irritating parasites of man. Others, such as the lice (*Pediculus, Phthirius*) and fleas (*Pulex*), are more or less permanent parasites of the skin, while many, such as the malarial mosquitoes (*Anopheles*) and the tsetse flies (*Glossina*) are significant both as surface parasites and as the carriers of disease, the primary agents of which are the lower organisms. Some species, such as the bot-flies, and screw-worm flies, have parasitic larval phases. In the bot-fly of the horse, *Gastrophilus equi*, the adult female deposits the eggs upon the hairs of the host

from which they pass into the stomach. The larvae attach themselves to the gastric mucosa, finally passing through the alimentary canal, and assuming the pupa stage outside the body of the host.

The classification of the insects, especially as regards parasitic and otherwise aberrant forms, is a matter of some difficulty, though some of the common free-living orders are readily recognizable. The features used in classification are principally those of the mouth parts and of the wings, of which there are typically present two pairs attached to the thoracic segments. **Orthoptera**, including the grasshoppers and cockroaches, have cutting mouth parts. The anterior wings are tough and leather-like, while the posterior wings are membranous, and when at rest folded. **Coleoptera** or beetles have the mouth parts of a cutting type, but the anterior wings are formed into hard protective elytra, which at rest meet in the middle line, though they can be spread apart so that the thin posterior wings may be expanded for flight. **Lepidoptera**, moths and butterflies, have suctorial mouth parts, and the wings, often beautifully coloured, are encased in a covering of minute scales. **Diptera** or flies have suctorial mouth parts, variously modified, the anterior wings well developed and membranous while the posterior ones are vestigal. **Hemiptera** or bugs have the mouth parts formed into a jointed sucking tube, the anterior wings typically hard at the base and membranous at the tip, though this condition applies more definitely to the so-called **Heteroptera**, there being some **Hemiptera homoptera** in which the wings are membranous throughout. Many of the parasitic forms belong to the Diptera and Hemiptera, though highly modified insects, such as the lice, are placed in a separate group of the **Anoplura**, while others, such as the fleas, are representative of the division of the **Siphonaptera**, the characters of these forms being described below.

The common housefly, *Musca domestica*, an example of the Diptera, owes its prevalence to the common occurrence of exposed waste material of an organic nature in which the eggs are deposited and the larval and pupal stages are passed through. The life history is analogous to that of *Pieris*, except that the larvae or "maggots" are **acephalous**, and the pupa is protected by the larval cuticle instead of by a coccon. Though not a biting fly, the mouth parts being suctorial in nature, the housefly is undesirable on account of its indiscriminate passage from food materials to waste and *vice versa*, waste materials being liable to bacterial infection, which may be thus communicated to food intended for human consumption.

The family *Muscidae*, however, contains many species in which

the mouth parts are adapted for piercing and sucking and in which the parasitic *rôle* may become of importance. One of the less significant forms is the stable fly, *Stomoxys calcitrans*, the resemblance of which to the housefly is responsible for the commonly held but erroneous notion that the latter is a biting type. *Stomoxys* has also been suspected of being the transmitting organism of certain important diseases, anthrax and infantile paralysis. One of the forms now definitely known to be of the greatest significance in the transmission of disease is the African tsetse fly, *Glossina*, of the various species of which distributed throughout Africa, two, *G. palpalis* and *G. morsitans*, are the carriers of the trypanosome parasite of sleeping sickness.

Other flies are significant because parasitic in the larval or "maggot" stage. These flies, typified by the European flesh-fly, *Wohlfahrtia magnifica*, a related Canadian species, *W. vigil*, and the American screw-worm fly, *Chrysomyia macellaria*, and indirectly by various infestations, including skin nodules or "warbles" in lower animals, may be said to conform to the usual habitus of egg or larval deposition and development in decomposing flesh, with the modification that living sites are occupied. These are represented by portions of the skin surface, open wounds, discharging nasal or auditory surfaces, or even the interior of the digestive tube. The condition is known as **myiasis**, and further as **cutaneous, nasal,** or **intestinal** according to the particular type of localization.

The mosquitoes, Culicidae, include a large number of dipterous insects in which the mouth parts are somewhat differently modified to form a piercing and sucking tube. They live upon plant juices or animal blood; some, such as the species of common mosquitoes, *Culex*, being for the most part significant as temporary parasites, and others, such as the malarial mosquitoes (*Anopheles*) and the yellow fever mosquitoes (*Stegomyia*), important as the carriers of lower parasitic organisms. The life history includes aquatic phases, the eggs, larvae or "wigglers" and the pupae being found in water, a point of importance in controlling the spread of diseases in which they play an accessory part.

The **Hemiptera** include, in addition to a variety of aquatic and leaf-inhabiting forms, the common bed-bug, *Cimex lectularius*. In this form the body is dorsoventrally flattened, the anterior wings reduced to small dimensions, while posterior wings are absent. The species is chiefly remarkable for its nocturnal habits, living in out-of-the-way places, such as the crevices in bed-frames, and attacking human beings at night. The eggs are deposited in similarly concealed situations. The hemipterous type is considered to be that to which the term "bug" is to be specially applied.

The **lice, Anoplura,** are small, soft-bodied, wingless insects having the mouth parts of a suctorial type but unjointed and with the appendages ending in hooks. The human lice belong to a family of the *Pediculidae*. *Pediculus humanus*, the head-louse, lives on the hairy parts of the head, and the eggs or "nits" are deposited upon the hairs. The body or clothing louse, hitherto classified as *P. vestimenti*, has been shown not to be separable as a species from the foregoing one. It lives, however, on the neck and trunk, the eggs being deposited upon the clothing. *Phthirius pubis*, the pubic or crab-louse, lives on the hairy portions of the body, especially in the pubic region. As in the case of other surface parasites attacking the skin the organisms are less significant from their immediate presence than from the secondary effects for which they are accountable; for example, the results of bleeding, or scratching of the skin on the part of the individual affected, eczematous conditions and surface infections by extraneous organisms being not uncommon. They are also the most important, if not the sole agents, in the transmission of the virus of typhus fever.

The **fleas, Siphonaptera,** of which there are many species attacking various animals, are well, though peculiarly, segmented laterally compressed insects in which the mouth parts are suctorial, and in which the limbs, especially the hinder pair, are strongly developed. The thinness of the body enables them to pass through very narrow spaces, while their jumping capabilities are well known. The adults are blood-suckers, and some are important as carriers, notably the rat-flea, *Xenopsylla cheopus*, now recognized as the transmitting organism of bubonic plague. The penetrating flea "jigger" or "chigoe", *Dermatophilus penetrans*, occurs in the West Indies, Central and South America, and elsewhere. The female burrows with the head into the human skin, the body increasing greatly in size and assuming a spherical form. The human flea, *Pulex irritans*, lives in human habitations, usually under unsanitary conditions. It is said to be chiefly European, the dog flea, *Ctenocephalus canis*, which also attacks man, being of more general distribution. The eggs of fleas are deposited in the dirt of cracks in the floor and similar situations.

Lo-2681 (2)
K1-4798 (1)
Ly-6501 (3)
E1-1012 (2)
Miss Wilson