Dear Paul
With sincer

NOTES

ON

ANIMAL PARASITES AND PARASITISM

LECTURE OUTLINES OF

A COURSE IN PARASITOLOGY

WITH SPECIAL REFERENCE TO FORMS OF ECONOMIC IMPORTANCE

By WILLIAM A. RILEY

Department of Entomology, Cornell University

1912

HOME USE RULES.

All Books subject to Recall.

All books must be returned at end of college year for inspection and repairs.

Students must return all books before leaving town. Officers should arrange for the return of books wanted during their absence from town.

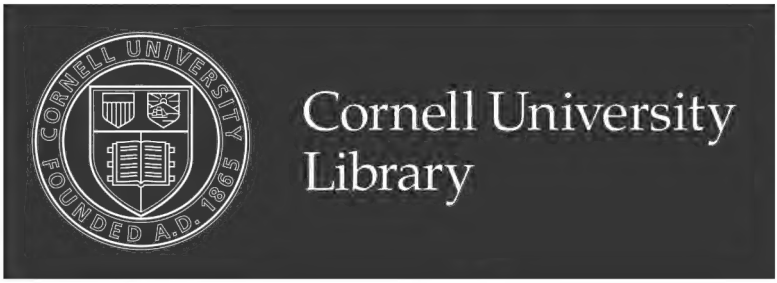
Books needed by more than one person are held on the reserve list.

Volumes of periodicals and of pamphlets are held in the library as much as possible. For special purposes they are given out for a limited time.

Borrowers should not use their library privileges for the benefit of other persons.

Books of special value and gift books, when the giver wishes it, are not allowed to circulate.

Readers are asked to report all cases of books marked or mutilated.



NOTES

ON

Animal Parasites and Parasitism

LECTURE OUTLINES OF

A Course in Parasitology

WITH SPECIAL REFERENCE TO FORMS OF ECONOMIC IMPORTANCE

By WILLIAM A. RILEY

Department of Entomology, Cornell University

1912

PREFACE

This pamphlet is not intended as a text-book on the subject of animal parasites and parasitism. It consists merely of the outlines of an elementary and very brief course on the subject, given primarily from the general zoological viewpoint. They are printed in this form to facilitate the taking of notes and to point out the more important sources of information.

Any such course must be under heavy obligations to the classical works of Leuckart, Cobbald, Neumann, Railliet, Blanchard, and other pioneers in the field, and to the work of Stiles, Ward, Ransom, Law, and their staffs in this country. The little booklet by Franz von Wagner, entitled "Schmarotzer and Schmarotzertum in der Tierwelt," though out of date in some respects, is a most helpful and suggestive discussion of the general subject.

The bibliographies given are far from complete but indicate the more important available discussions. Much of the fundamental work appears in foreign publications and, as in all scientific work, a knowledge of at least French and German is invaluable to the student. It is urged that the opportunity to become acquainted with original papers treating of the subject be improved whenever possible.

INTRODUCTION

Object of the course—Primarily a study of parasitism from a biological viewpoint. Nowhere more striking illustrations of the adaptation of the organism to its mode of life, or more wonderful life histories. Such studies must underlie rational methods of control.

Species of economic importance will be discussed when they serve equally well as others for illustrating the points under consideration. Often a species of no apparent economic importance will be selected because its life history or habits may best aid in an understanding of those of more complicated forms.

The relation of parasites to disease an important phase of the subject which can only be touched upon here. The pathology and therapeutics of parasitism are subjects of other courses and only incidentally discussed here. So also the wide series of plant parasites, including the bacteria, is omitted, though it includes some of the most important forms.

The more important text-books and special articles—These will be listed in the bibliography alphabetically, according to author. In the text, special references will be to author and date of publication and the full reference can be found by turning to the bibliography. Though the list is far from complete, it may be supplemented by the bibliographies in most of the articles included, and by special lists, such as the "Index Catalogue of Medical and Veterinary Zoology" by Stiles and Hassall, and the "Zoological Record."

GENERAL PART

GENERAL REFERENCES

Braun, '06; Küchenmeister, '57; Law, '03; Leuckart, '86; Linstow, '78; Manson, '07; Neumann, '92; Neveu-Lemaire, '08, '12; Perroncito, '01; Railliet, '95; Stiles, '07; Wagner, '02.

Definition of the term "parasite"—Not easily limited. Often defined as "An organism which lives at the expense of another." This definition applicable to a predatory species or, in its broadest sense, to *all* organisms. Parasitism not an isolated phenomenon. For the purpose of this course we may say:

A parasite is an organism which, during the whole or a part of its life, lives on or in the body of another organism, from which it obtains its sustenance.

The infested organism is known as the *host.*

Parasites distinguished from *saprophytes,* which live on decaying organic matter. Impossibility of drawing a sharp line between this method of life and that of true parasites.

Distinguished from *predatory species,* which typically live on organisms smaller than themselves, and which immediately kill their prey. Intergrading.

Parasitism a form of *symbiosis.*

Symbiosis defined—Symbiosis (*syn* = together, *bios* = life) is the living together or two dissimilar organisms. Parasitism contrasted with *mutualism* (typical symbiosis) and with *commensalism.*

Forms of parasitism—In considering the forms of parasitism one may distinguish:

Ectoparasites, those which live on the exterior of their host or, more rarely, in cavities which communicate freely with the surface. Also known as *epizoa.*

Endoparasites, those which live within the internal organs.

Temporary parasites, those which visit the host only at intervals, contrasted with *stationary parasites.* Of the latter we may have *periodic parasites,* such as bot-flies, or ichneumon flies, parasitic in only a stage of the life cycle; and *permanent parasites,* parasitic for life.

Facultative, or *pseudoparasites* are species which are normally free-living, but which are able to exist as parasites when accidentally introduced into the body of another animal. Ex., vinegar-eels, larvae of blow-flies.

Spurious parasites are objects which have been mistaken as parasites and, sometimes, even been given specific names. Ex., plant hairs, bits of gristle, banana cells, etc. Grosser illustrations are cases of frogs and lizards claimed to have lived within the human body.

Structure of the parasite—*Adaptation to environment* nowhere more strikingly shown than in the case of parasites. With all the variety of structure, there are yet certain characteristic modifications which accompany parasitic life.

Adaptations of two general types:

A. *Neoformations*—Organs of attachment, as, modified tarsi of hair-inhabiting lice; suckers of leeches, tapeworms, *et al;* hooks of various intestinal parasites. Adaptations in sexual organs, illustrated by hermaphroditic forms. Adaptations in eggs of parasites.

B. *Degenerations*—Reduction of organs of locomotion, as, loss of wings in parasitic insects; of legs and other appendages of crustacea; fusion of body-segments; loss of cilia.

Correlated changes in the muscular system. Reduction of the nervous system and sensory organs.

Loss of alimentary canal.

While these various changes are usually spoken of as *degenerations*, it must be remembered that they all have for an end the better adaptation of the parasite to its manner of life.

Occurrence of parasites—*Practically all animals subject to attack*—From amoeba with parasites in its nucleus, or in its body-protoplasm, to man. Leuckart, '76, lists 33 species parasitic in man but now (Neveu-Lamaire, '08) over 150 species infecting man are known.

Parasites themselves may be infested by other parasitic species which are then known as *hyperparasites.*

Numbers which may occur in a single host—In the case of protozoan parasites of the higher animals there may be countless myriads of individuals. Of higher forms of parasites a crow examined here had as many as 2,000 nematode worms in a single drop of blood; chicken had over 1,000 tape worms. 3500 hookworms have been expelled

from man; it has been estimated that in a severe case of trichinosis 60,000,000 of the worms may be present.

Concurrent infection by two or more species in the same individual is very common. Krause, cited by von Beneden, found in a single horse over 500 *Ascaris*, 170 *Oxyuris*, "several millions" of *Strongylus*, 214 *Sclerostomum*, 69 *Taenia*, 287 *Filaria*, and 6 *cysticerci!* In men, as many as five species of intestinal parasites at a time, have been reported (Riley, '12).

Location within the host—Larger number of species of parasites occur on the surface of their host or in cavities opening to the surface, such as the alimentary canal, respiratory, and urinogenital passages. Other species occur in the muscles, connective tissue, nervous tissue, the blood, and the lymph. They may live freely within a cavity or inside of cells or even of cell nuclei.

Early views regarding the origin of parasites—*Theory of abiogenesis*, or *spontaneous generation* taught by the earlier zoologists and popularly accepted, even today. Redi's work in 1668. Others supposed parasites inherited.

Theory of biogenesis or *development from pre-existent living forms* extended to internal parasites by beginning of 19th century, but by most authorities it was then believed that such species originated from free-living protozoa or other organisms, the *theory of heterogenesis, or chance development from wholly different species.*

The development of the experimental method of study furnished the key to the problem. Feeding experiments by Küchenmeister, '44, followed by Leuckart, Haubner, Cobbald, and many others.

Life history of the parasite—"If we only know concerning a certain animal that it is a parasite, we know but little; thoroughly to understand its history, we must follow out all the separate stages and conditions of its existence, and especially the circumstances under which it becomes a parasite."—Leuckart, '86, p. 42.

As regards relation to host, parasites may be grouped as:

a *Monoxenous parasites* (*monos*, one; *xenas*, host), such as live only in one genus or species of host.

b *Heteroxenous parasites* (*heteros*, different; *xenas*, host), such as pass different stages of their lives in different hosts, usually belonging to different genera, and often widely distinct.

Intermediate host—Supports asexual or immature form.

Definitive host—Supports the sexually mature form.

Passive transfer—Ex., embryos taken with food or drinking water.

Active transfer—Ex., larval hookworms boring into the skin.

Alternation of generations, one or more asexual generations followed by a sexual generation, very common among parasites.

Simple alternation of generations illustrated by the life history of the malarial parasite, *Plasmodium praecox*. Sexual stage in mosquitoes of the genus *Anopheles;* asexual stage in blood of man.

A complicated type, introducing several generations into the life-cycle, illustrated by the life-history of the liver-fluke of the sheep, *Fasciola hepatica*. Adult in liver of sheep; *ciliated embryo* in water; *sporocyst* in body of snail, giving rise to several generations of *rediae;* development of *cercariae*, which pass into the water, become encysted on herbage, and are taken up by sheep, in which they become sexually mature.

The reproduction of parasites—Complicated life-history a disadvantage in that it enormously lessens the chances of the species perpetuating itself. Compensating advantages. The handicap met by:

Enormous fertility typical—Estimated that the beef tape worm of man produces 150,000,000 eggs per year. Polyembryony of certain parasitic insects, a hundred or more embryos developing from a single egg.

Resistance of eggs and larvæ of many species—Thick-shelled eggs of tapeworms, whipworms. Living embryos have been found in *Ascaris* eggs preserved for months in strong formalin and other chemicals. Trichinæ may live for months after the infested hog is killed.

Hermaphroditism commonly met with in parasites, providing for perpetuation of species by a single individual.

Action of parasites upon their host—Extreme divergence of views as to injuries caused by parasites. The prevailing views among medical men and veterinarians who have not especially studied the question, underestimate possible effects.

Seriousness of direct action largely dependent upon the situation of the parasite—Multiceps cœnurus in the brain causing death of sheep.

Drain on nourishment of the host—Direct, or by taking blood.

Mechanical disturbances by parasites—Filaria causing elephantiasis by stoppage of the lymph passages. Abundance of roundworms in chickens sometimes causes plugging of the alimentary canal.

Production of specific poisons by the parasite—By the hookworm, certain tapeworms, *et al.*

Centers of infection produced—Injury to intestinal mucosa, or to skin.

Dangers from intermittent parasites—Disease carriers.

Economic value of parasites—*From our viewpoint, not all parasites noxious*—Parasites an important factor in the control of injurious species. Fighting insect pests by the introduction of their parasites. Hyperparasites of injurious parasites.

Determination of parasites in the living host—*Ectoparasites*—Diagnosis usually simple, but cases sometimes complicated by secondary infection.

Endoparasites—1. Examination of *feces* for protozoa, eggs and larvæ of intestinal and liver parasites (Hall, '11). 2. Examination of *sputum* for evidence of lung parasites. 3. Examination of *urine* for evidences of kidney, bladder, or certain blood parasites. 4. Examination of *blood*, not only for blood parasites but for pathological conditions indicative of the presence of certain parasites elsewhere in the body. 5. "Harpooning" for trichinæ. 6. Clinical symptoms sometimes sufficient.

Methods of control of parasites—Must be mainly preventive. Such measures must be based on a knowledge of the life-history of the parasite.

Destruction of intermediate hosts, when feasible—Mosquitoes for malaria; stray dogs and coyotes for certain sheep parasites, etc.

Sanitary methods—Cleanliness; sewage disposal; meat inspection in local slaughter houses; thorough cooking of food; inspection of uncooked foods; avoidance of infection through drinking water.

Origin of parasites—*Parasitic habit not a basis of classification*—A tendency to regard parasites as constituting a natural group. Older writers grouped various endoparasites together as "helminths."

Relation to free-living forms—Readily seen in ectoparasites and in certain endoparasites. Clearly shown by the developmental history of others. All evidence shows that,—

Parasitism is an adaptive phenomenon, originating independently in widely different groups.

We shall therefore briefly outline the major groupings of animals, before considering more fully the parasitic forms.

THE ZOOLOGICAL RELATIONS OF PARASITES

INTRODUCTION

Zoological classification—*Necessity for classification*—Great variety of animals. Some estimates place number of species as high as 10,000,000. Popular attempts at classification based on superficial characters.

Bearing of the theory of evolution on zoological classification—Aim of naturalists to work out a natural classification, one that will express *blood relationship.*

Names and sequences of the different kinds of groups—Animal kingdom, phyla or sub-kingdoms, classes, orders, families, genera, species, varieties, individuals.

Characteristics of these groups—*Definition of species*—"In general terms, a species is a collection of individuals which resemble each other as closely as the offsprings of a single parent. As a rule the pairing of sexes of different species will not be fertile."—Comstock.

Zoological Nomenclature—*Necessity for an international code of nomenclature*—(See, Stiles, '05, which should be obtained by students planning to specialize along zoological lines). Same species often named independently by two or more workers. Especially true of parasites, which have been often named by physicians or others with little zoological training. One species of tapeworm has received 110 different names.

The more important rules of zoological nomenclature—

1. The name of a species must consist of two words, and only two, one indicating the genus to which the species belongs and the second used to designate that particular species.

2. The names must be Latin in form.

3. After the name of the species may be the name of the author who first described it.

4. The valid name of a genus or species can be only that name under which it was first designated and defined in some published work, except specific names published before 1758, or changes due to subdivision of groups. This is known as "The Law of Priority."

CLASSIFICATION

See Parker and Haswell's Text-book of Zoology, or their Manual of Zoology.

Phylum PROTOZOA

Animals in which the entire body consists of a single animal cell.

Subphylum Sarcodina—Protozoa in which the motile organs are pseudopodia.

Class Rhizopoda—Sarcodina without axial filaments in the pseudopodia.

Amœba proteus as an example of this class. Habitat of Amœba. Form. *Pseudopodia.* Mode of movement. Substance of which body is composed termed *protoplasm.* Division of the body into *ectosarc* and *endosarc. Nucleus. Contractile vacuole.* Taking of food. Growth. Reproduction by *simple* or *binary fission.* Characteristics of *living* beings. Definition of the term *cell.*

Subphylum Mastigophora—Protozoa with an outer cell-integument and in which the motile organs are flagella.

Subphylum Infusoria—Protozoa with an outer cell-integument and which are always ciliated either through life or in the young condition.

Subphylum Sporozoa—Parasitic Protozoa typically without organs of locomotion, and which reproduce by spore-formation. Group not a natural one.

Phylum PORIFERA

Not discussed in this course.

Phylum CŒLENTERATA

Not discussed in this course.

Phylum PLATYHELMINTHES

The Platodes or Flat-worms

The flat-worms are bilaterally symmetrical animals, which are devoid of true metameric segmentation, and which have no body cavity between the alimentary canal and the integument. There is no blood-vascular system; but there is an excretory (water-vascular) system. The alimentary canal when present has only a single opening, and is much branched.

Class Trematoda—Parasitic flat-worms, without a covering of cilia in the adult state, with a well-developed digestive apparatus, and with the mouth at the cephalic end of the body. The liver-fluke is an example of this class.

Class Turbellaria—Non-parasitic flat-worms, with a ciliated epidermis. Not discussed.

Class Cestoda—Endo-parasitic flat-worms, without cilia, and without a digestive cavity; usually becoming segmented by budding. This class includes the tapeworms.

Phylum NEMATHELMINTHES

The Thread Worms

The body is cylindrical, spindle-shaped, or threadlike, unsegmented, and covered with a thick cuticle; the body cavity is usually spacious.

Class Nematoda—Possess a complete alimentary canal. To this class belong most of the thread worms. The most familiar examples are *Ascaris*, *Oxyuris*, and *Trichina*.

Class Acanthocephala—Lack alimentary canal; possess a protrusible *proboscis* which is covered with many rows of recurved hooks.

Phylum ECHINODERMATA

Not discussed in this course.

Phylum MOLLUSCOIDA

Not discussed in this course.

Phylum ANNULATA

The Segmented Worms

Bilaterally symmetrical animals with the body composed of similar segments or metameres, without jointed legs, and with an alimentary canal furnished with two openings. Only one of the classes discussed in this course.

Class Hirudinea—Segments of body marked externally by secondary rings. Each end of the body is furnished with a sucker. The medicinal leech is an example of this class.

Phylum ARTHROPODA

See Comstock's "Manual for the Study of Insects" and "The Spider Book."

Bilaterally symmetrical animals in which the body is segmented and bears a pair of jointed appendages on each or on some of the segments.

Class Crustacea—The members of this class are aquatic Arthropoda, which breathe by true gills. They have two pairs of antennæ and at least five pairs of legs.

Class Arachnida—The members of this class are air-breathing Arthropods, in which the head and thorax are grown together, forming a cephalothorax; which have four pairs of legs fitted for walking, and which have no feeler-like antennæ. To this class belong the spiders, ticks, mites, and others.

Order Acarina—This order includes the mites; these differ from other Arachnida in that the abdomen is fused with the cephalothorax, giving the entire body a more or less saclike appearance.

Class Myriapoda—This class includes the centipedes and the millipedes, air-breathing Arthropoda in which the thorax and abdomen form a continuous region, with from six to two hundred segments, each bearing a pair of legs.

Class Hexapoda—Air-breathing Arthropoda, with a distinct head, thorax, and abdomen. They have one pair of antennæ, three pairs of legs, and usually one or two pairs of wings in the adult state. This class is composed of the different orders of insects; among these are the following:

Order Mallophaga—This order includes the bird-lice; these are wingless parasitic insects, with biting mouth-parts; their metamorphosis is incomplete.

Order Hemiptera—This order includes the bugs, lice and others. The winged members have four wings, but the lice and some others are wingless; the mouth parts are formed for sucking; the metamorphosis is incomplete.

Order Diptera—This order includes the flies, among which are the mosquitoes, bot-flies, the sheeptick, and many others. The winged members have only two wings; the mouth-parts are formed for sucking; the metamorphosis is complete.

Order Siphonaptera—This order includes the fleas; the members of it are practically wingless, the wings being represented only by minute early plates; the mouth-parts are formed for sucking; the metamorphosis is complete.

Phylum MOLLUSCA

Not discussed in this course.

Phylum CHORDATA OR VERTEBRATA

Not discussed in this course.

SPECIAL PART

I. REPRESENTATIVE PARASITIC PROTOZOA

IMPORTANT GENERAL REFERENCES

Calkins, '09; Castellani and Chalmers, '10; Crawley, '12; Doflein, '09; Lankester, '03; Manson, '07; Ward, '08.

INTRODUCTION

Parasitic Protozoa—Importance for years overlooked. Pasteur's, '58, study of the protozoa causing silkworm disease had great influence on development of germ theory of disease. In 1880, Laveran discovered the malarial parasite, but it was not until the beginning of the present century that much attention was devoted to parasitic Protozoa.

Groups of Protozoa concerned—Parasitic forms now known in all groups except Radiolaria and Foraminifera.

Habitat—Organ, tissue, and cell parasites,—even nuclear parasites known.

Adaptations—Comparable to those seen in other parasitic groups.

Sub-Phylum SARCODINA

Entamœba dysenteriæ—*Amœba coli* Lösch; *Entamœba hystolytica* Schaudinn). Supposed cause of a type of tropical dysentery. Since Lambl, 1859, amœba known to occur in human intestine but pathogenic nature disputed. Since work of Schaudinn, '03, known that there are two species; one, at least, pathogenic. *See*, Strong, '07.

Habitat—Human colon, intercellular; occasionally lower part of small intestine and even liver. Walls of intestine greatly thickened and, in serious cases, ulcerated.

Structure—Essentially that of Amœba (see p. 11); one or two pseudopods; endosarc granules, frequently containing red blood corpuscles; nucleus eccentric, with sparse chromatin.

Reproduction—Two types: 1st, simple division, or budding; 2d, by encystment and spore formation. Autogamy. Method of dissemination of the parasite.

Prophylaxis—Heat sterilization of food and drinks.

Neuroryctes hydrophobiæ—(*Negri bodies*). Diagnosis of rabies a slow process until Negri's discovery, in 1903, of peculiar bodies found in nerve cells of animals affected. Most numerous in cells of hippocampus major. Size up to 25μ. Believed by good authorities to be protozoon in nature because evidence of typical nucleus, growth, reproduction by simple division and budding. Sarcodina?

Sub-Phylum MASTIGOPHORA

Trypanosoma brucei—The cause of the tsetse-fly disease or "nagana" of domestic animals in South Africa. Duration of diseases few days or weeks to many months but always fatal in horse and donkey, very few cattle recover. Supposed to be due to bite of tsetse-fly. Parasite discovered by Bruce, 1874, free in blood plasma. See Bruce, '07, and Laveran and Mesnil.

Structure—Spindle-shaped body, with a more or less spiral twist and with one edge provided with delicate, undulating membrane. Flagellum arising near posterior end at a highly refractile granule known as the "blepheroplast" and continuing as the thickened edge of the undulating membrane, to project at anterior end. A micro- and a macro-nucleus present.

Movements—Exceedingly rapid. When parasites are abundant, they may be detected under moderate power by motion of blood corpuscles. Usually present in small numbers and blood must be centrifuged to find them. Euglenoid movement.

Reproduction—Longitudinal division. Sexual reproduction in dispute.

Artificial culture—One of the few forms of protozoa which has been artificially grown with marked success. First grown by McNeal and Novy, '03, on nutrient agar and defibrinated rabbit's blood. Influence of this work on study of parasitic protozoans important.

Method of transferral—Solely by tsetse-fly, as shown by Bruce's experiments, 1894. Infective for 48 hours after feeding on sick animals. Evidence that there is then a latent period after which the flies again become infective.

Prophylaxis—Protection of cattle from bites of the fly. Destruction of big game.

Related species—Group a large one, over sixty species being known, some apparently harmless but among them some of the most dangerous parasites.

Tryanosoma gambiense cause of "sleeping sickness" of man; *T. evansi* causes "surra" a fatal disease affecting especially horses and mules in the Philippines, India; *T. equiperdum* produces "maladie du coit," or "dourine," a venereal disease of horses, of which there have been serious outbreaks in this country. *T. lewisii* is apparently harmless parasite of rats, the world over.

Spirochæta recurrentis Lebert, 1874. (*S. obermeiri* Cohn 1875). The cause of European relapsing fever of man. The organism as seen in the blood is a slender, flexible spiral, pointed at the ends, with an undulating membrane, but without cilia. Transferred by bite of the bed-bug. Long classed with bacteria but differ in possession of undulating membrane, reproduction by longitudinal division and in biological characters. See Nuttall, '08.

Related species—A number of species infesting man and animals are known. Disease known collectively as "spirochætoses." In cases best known the parasites are transferred by ticks.

Trichomonas—Several species of this genus live in alimentary canal of mammals, birds, snakes, batrachians and lizards. Usually small, pear shaped; with three or four cilia arising from the anterior end and an undulating membrane which runs spirally around the body.

Lamblia intestinalis—Parasite of man and various animals, and in some cases supposed to cause dysentery. Anterior end of parasite hollowed out to form a saucer-like depression, which fits over the epithelial cells. About this depression six flagella and posteriorly, two others. Cysts containing two individuals to be found in feces.

Sub Phylum INFUSORIA

Balantidium coli In rectum of man and swine. Usually associated with intestinal diseases when found in man, but causative action disputed.

Form and structure—Large, 200μ long by 50μ wide, resembling somewhat a *Paramœcium*. Body covered with cilia which are longer and coarser about the peristome or "mouth." Ectosarc and endosarc distinct, body with longitudinal striæ or "myonemes." Two contractile vacuoles. Nucleus bean- or kidney-shaped.

Reproduction—By simple cross-division. Conjugation occurs. Encysted forms to be found in feces.

Balantidium entozoon—This species is commonly found in the rectum of frogs and will be studied in the practicum. Possesses four contractile vacuoles.

Various other species of *Balantidium* also infest frogs and certain ones have been found in the body cavity of annelid worms.

Nyctotherus cordiformis is a form found in the large intestine of the frog and sometimes mistaken for *Balantidium entozoon*. Differs in being larger, having *one* contractile vacuole, more prominent persistome, and less strongly curved nucleus.

Opalina ranarum—Rectum of frog.

Form and structure—Large enough to be seen as minute, whitish, actively moving spots, 600–800μ in size. Body flat, disk-like, or oval; divided into ectosarc and endosarc. Cilia uniform in size. Multinucleate. Mouth, gullet, and contractile vacuole lacking, food being directly absorbed.

Reproduction—Ordinary cross or oblique division. Also, repeated binary fission, the minute forms so produced encysting and passing out with feces of the frog, at the breeding season. Taken up by tadpoles, cyst dissolves, liberating a lanceolate, uninucleate form, which develops into the adult, multinucleate Opalina.

Sub Phylum SPOROZOA

Order Gregarinida

Cœlom-inhabiting sporozoa, reproducing usually by spore-formation alone, and after the fertilizing union of but slightly different *gametes*. Following Lankester, '03, take as a type:

Monocystis agilis—Found in the seminal vesicles of the common earthworm. The majority of individuals of this worm are infested.

Trophozoite, earliest known stage, minute, nucleated, amœboid. Lives in one of the sperm morulæ floating in the sperm sac, and grows at the expense of the developing sperm cells. Ectosarc and endosarc present. Motility due to longitudinal myonemes. Adult trophozoite known as

Gametocyte, which is ready for reproduction. Two gametocytes associate and form a cyst, but do not fuse. Independently within each gametocyte there is a formation of a segmentation nucleus which divides repeatedly and with their surrounding protoplasm constitute the *gametes*. These fuse in pairs to form

Zygotes, or definitive *sporoblasts*, which by the secretion of tough membranes, or sporocysts, become *spores*. Within the spores

Sporozoites are formed by the nucleus of the spore dividing into two, four, and, finally, into eight nuclei, around each of which some of the protoplasm of the spore becomes aggregated.

Dissemination of the parasite—By analogy from known forms, spores pass to exterior, are scattered and then swallowed accidentally by an earthworm with its food, sporocysts dissolved by digestive juices, and liberated sporozoites bore through tissues.

Occurrence of Gregarinidæ—Invertebrate hosts, mainly insects, but generalized life cycle makes them important objects of study. Disseminated passively, infection of host being by way of the alimentary canal. Majority of species probably harmless to their hosts.

Order COCCIDIIDIA

Cell-infesting sporozoa which usually reproduce intracellularly by asexual spore formation (*schizogony*), as well as by true *sporogony*, thus giving a life-cycle with an alternation of asexual and sexual generations. After fertilization the *oosphere* forms sporoblasts which may or may not be covered by a sporocyst membrane, and which may each become transformed into one or several sporozoites. Take as a type

Coccidium schubergi—(See Leuckart-Chun's Chart 103, and Schaudinn's explanation thereto. For detailed account see Schaudinn, '00). Intestinal parasite of a myriapod, *Lithobius forficatus*. Infection by encysted sporozoites taken up with food. Alternation of generations.

Sporozoites released from cyst by action of digestive juices of host, fig. 1. Penetration of epithelium, fig. 2. Mature sporozoite known as a

Schizont, (fig. 4), Nuclear division. *Schizogony*, giving rise to numerous

Merozoites, (fig. 5), as the asexual elements are called, in contradistinction to the *sexually produced* sporozoites. Repeated schizogony. From certain merozoites develop

Gametes—Macrogametes, (fig. 6). *Microgametoblasts*, (fig. 6a). Maturation of the macrogametes. Formation of the *microgametes*

from the microgametoblast, (figs. 7a and 7b). Fertilization of the macrogamete and formation of an

Oocyst—Segmentation nucleus. *Sporogony*, (figs. 10–13), the breaking up of the oocyst content to form

Sporoblasts, (fig. 11), which by further division give rise to

Sporozoites—Migration of the sporozoites.

Eimeria stiedæ—(Better known as *Coccidium oviforme*). Causes common and very serious disease of rabbits, occurs rarely in man.

Description—Infests epithelium of bile ducts, as egg-shaped bodies varying considerably in size (the smaller 26–35μ long by 14–20μ wide; larger ones 40–49μ long by 22–28μ wide); with smooth, thick shells having a micropylar-like depression at one pole. Granular contents sometimes distributed uniformly or sometimes collected into a spherical mass. Resemble very greatly eggs of certain parasitic flukes and have been so described. In this stage they pass from the liver and intestines to the exterior where, in presence of moisture, their contents segregate into four oval spores which become surrounded by a tough sporocyst. Within each sporocyst are formed two sporozoites. (*Note that the excellent account of Leuckart, '86, erroneously refers to these spores as developing into a single sporozoite.*) Sporocysts taken up with food by rabbits and the released sporozoites by amœboid motion pass into the tissues. Useless to treat diseased animals. Avoid crowding, isolate diseased rabbits, and keep runs dry and clean.

Order HEMOSPORIDIA

Blood dwelling sporozoa, intracorpuscular or free in the blood-plasma; with or without alternation of hosts. A somewhat heterogeneous group, of which we shall consider two representatives.

Plasmodium praecox—The genus Plasmodium contains the organisms of malarial fever. Three species generally recognized. True alternation of generations, combined with a change of host. The asexual reproduction, or *schizogony* occurs in the blood of man; the sexual *sporogony* in the alimentary canal of a mosquito. Following Schaudinn, we shall describe the life cycle best worked out, that of *P praecox*, the cause of pernicious malaria. See Leuckart-Chun's Chart, 102, and Schaudinn's explanation thereto. Compare the life cycle of Coccidium schubergii, as given above.

Schizogony. (Figs. 1–6). *Sporozoite* penetrating a red blood corpuscle and developing into a *schizont.* Nuclear multiplication. Schizogony, producing *merozoites.*

Gamete-development. Under certain conditions there appear sexual forms whose further development can take place *only in the body of a mosquito.* (Figs. 7–11). *Macrogamete* corresponding to the egg. Maturation. *Microgametoblast* from which develops the *microgametes.* Fertilization. Migratory ookinete penetrates the epithelium of the mosquito's stomach, (cf. the encysted *oocyst* of *Coccidium*).

Sporogony—Oocyst in submucosa of mosquito intestine. Formation of sporoblasts. *Sporozoites.* Escape of sporozoites into body cavity and collecting in salivary glands.

Dissemmination of disease. Solely through mosquitoes of the genus *Anopheles.* Methods of control considered more fully in discussing mosquitoes.

Babesia bovis—(*Pyrosoma bigeminum* Smith and Kilborne; *Piroplasma bigeminum* Patton.) The "Texas fever" organism, discovered by Smith and Kilborne, 1893.

Form and habitat of asexual phase—Lives within the red blood corpuscles and in fresh preparations appear as minute homogeneous pale pear-shaped spots, usually two in a corpuscle. From 2–4μ in length and 1.5–2μ at widest portion. The common appearance of two associated parasites is due to dividing forms. Live at expense of red corpuscles, as many as 50 per cent of which may be infested. Bloody urine, characteristic of disease, due to breaking down of corpuscles.

Life cycle—Transferred from animal to animal solely by cattle ticks (*Boophilus annulatus*) of the second generation. By analogy, a sexual cycle in the tick, but it has not been satisfactorily worked out. Note that we have here a case of true hereditary transmission of a disease, the adult ticks passing it on to the second generation which, in turn, infects cattle.

Methods of control—Primarily a problem in economic entomology, —the protection of cattle from the tick and the extermination of the tick.

Related species—*Babesia parvum,* in African cattle; *B. canis,* in dogs; *B. ovis,* in sheep; and various others, causing similar

diseases of the type known as *piroplasmosis*. *Babesia hominis* cause of "spotted fever" of man in Montana and Idaho.

Order SARCOSPORIDIA

Sporozoa found in or between the muscle-cells of vertebrates, appearing as whitish, elongate-ovoid bodies. Great sac-like spore cases, with double membranes, are formed. Take as a type.

Sarcocystis miescheriana—Trophozoites occur commonly and in great abundance in the muscles of hogs. Large, .6 or even 2–3mm. in length, and sometimes visible to naked eye as greyish points. Wall of a thick cuticle, transversely striated. Content, even in very early stages granular from presence of great numbers of rounded "*pansporoblasts.*" The content of pansporoblasts divides to form finely granular, pale sporoblasts, in each of which develops a spore. Method of transfer from host to host unknown. Effect on host disputed but where they occur so abundantly they must cause injury. Evidence that there is an active poison secreted by the parasite itself. Laveran and Mesnil claim to have isolated such a toxin, which they call *sarcocystin*, from *Sarcocystis tenella*, of the sheep.

Order MYXOSPORIDIA

Parasites of cold blooded animals, especially known as causing serious epidemics among fish and in silk worms. Often called *psorosperms*. Characterized by facts that the trophozoite is amoeboid; spore formation commences at an early stage and proceeds continuously during the growth of the trophozoite; spores are produced within the protoplasm of the trophozoite, and each spore always possesses one or more very distinctive structures known as "polar capsules"—Lankester, '03.

Nosema bombycis—The cause of "pebrine" or silkworm disease which, until the work of Balbiani and of Pasteur, threatened to wipe out the silk industry of France.

Form—In tissues of host as a microscopic corpuscle enclosing numbers of spherical sporoblasts from which develop many sporozoites. Spores oval, 3μ long by 1.5μ wide, characterized by the peculiar "polar-capsule" and by a polar filament which is rendered visible by the action of reagents.

Development—Two methods of spread of the disease. 1st, spores scattered on leaves are swallowed by young caterpillars, the polar filament is expulsed, the capsule splits and an amoeboid trophozoite emerges which bores into the tissues of the caterpillar. 2d, the parasites reach the ovaries and infest the eggs of the host. From these infested eggs are hatched weak, diseased caterpillars which, though they soon die, contaminate the food.

II. REPRESENTATIVE PLATHYELMINTHES

Class TREMATODA

IMPORTANT REFERENCES

In addition to the general works of Braun, Leuckart, Neumann, Railliet, *et al.*, see, Benham, '03; Braun, '89; Gamble, '96; Loos, '94; Stiles, '04; Ward, '04.

Order MONOGENEA

Almost exclusively ectoparasites. With more than two suckers and often with hooks. Development direct and without change of host. Take as an example:

Polystomum integerrimum—Lives in bladder of frogs.

Description—Mature fluke .5cm. long by .15cm. wide, flattened, with four eye spots on anterior end. Alimentary canal bifurcate, the two branches connected by many cross-canals. Six suckers at posterior end and between them attachment hooks.

Life history—Eggs laid in water by protrusion of body of the parent through urinary aperature of the frog. About 1000 eggs in ten days. After about six weeks free swimming ciliated larva hatches, but perishes if it does not meet a tadpole within twenty-four hours. If fortunate, attaches to gills of the tadpole, loses cilia, and remains eight to ten weeks, forming suckers from behind forwards. When tadpole transforms the *Polystomum* enters oesophagus, passes down intestine and enters bladder of the frog. Said to require three years to reach sexual maturity.

Diplozoon paradoxum—Well named, for one of the most puzzling of animal forms. Adult X-shaped organism made up of two fused individuals. Eggs on gills of various small fish give rise to ciliated larvæ which, if they succeed in attaching to a minnow develop into a larval form long known independently under generic name *Diporpa*. These *Diporpa* develop and mature sexual organs only by conjugation in pairs. Fuse at point of contact and within each complete sets of genitalia develop.

Order DIGENEA

Exclusively endoparasites. Not more than two suckers, and without hooks. Development with heterogony and with change of host; the sexual generation in vertebrates, the asexual in invertebrates. Take as an illustration

Fascolia hepatica—(*Distomum hepaticum*)—The liver-fluke of the sheep and other ruminants. Adult in liver, causing "rot." Though not common in the United States, it is one of the most dangerous parasites of sheep, sometimes causing enormous loss in Europe. Youatt estimated that in Europe alone more than 1,000,000 sheep die annually from its attacks.

Structure—Adult flat, unsegmented, oval, enlarged in front, about 3.4 cm. (1.5 inch) in length. Two suckers near anterior end, cuticle covered with minute backwardly directed spines. Digestive system branched, ramifying all over the body. Excretory system much branched, main duct opening to exterior caudal end. Reproductive system hermaphroditic, with very prominent yolk glands.

Life history—Adult in liver of a sheep; discharges of eggs *via* the bile ducts of the sheep; development of eggs only in water to form the ciliated embryo; entrance of embryo into the body of a snail; change to a *sporocyst*; development of *rediæ* in sporocyst; second generation of *rediæ*; development of *cercariæ*; passage of the cercariæ into the water; *encysted cercariæ*; passage of young fluke to the liver of a sheep; development into an adult fluke.

Methods of control—Medical treatment of little avail and preventive measures very important. Drain pastures to destroy snails; keep sheep away from damp pastures. Carp, frogs and toads may play an important role by feeding on snails. Destroy bodies of diseased animals and spread manure from such animals only on dry ground.

Related species—Stiles, '94, lists twelve species of liver-flukes found in man and the higher animals. Of these the following are especially deserving of mention:

Fasciola magna—Widely distributed in the United States, especially Southern, being apparently much more common in sheep and cattle in this country than *T. hepatica.*

Opisthorchis pseudofelineus Ward 1901, found in gall ducts of the domestic cat. Closely related species *O. felineus* in Europe occasional parasite of man.

Paragonimus westermanni—The lung-fluke of hogs, cats, dogs; causes a very serious lung disease of man. Symptoms sometimes mistaken for those of tuberculosis. Asiatic disease but the species has in recent years been found in United States (see Ward, '95). Readily diagnosed by presence of eggs in sputum, as many as 12,000 daily discharged in one case studied.

Schistosoma haematobium, the "blood-fluke" of man. The worms occur in pairs in portal vein and in veins of intestine and bladder wall. Eggs, provided with a stout terminal spine work through tissues into the lumen of the intestine and bladder, often causing serious malady. In Porto Rico and South America occurs a form with *lateral* spined eggs, *Schistosoma mansoni*.

Class CESTODA

IMPORTANT REFERENCES

Braun, '94–'00; Cobbald, '79; Davaine, '77; Hall, '12; Stiles, '98 and '06; Ward, '01.

The greatest confusion still exists in the classification of the Cestoda. This is due to the facts that the same species has been independently described and named from different hosts, or that different stages have been known under different names, and more to the fact that the life histories of many common species are unknown. We shall discuss a few representative forms, using as a type:

Taenia solium—The pork tape-worm of man. About ninety synonyms. Adult in small intestine of man. Immature stage primarily in hogs but occasionally in man, and reported for dog, cat, black rat, and various other animals.

Form and structure—Body ribbon-like, forming a chain of many segments; total length usually 2–4 meters. Head, or *scolex*, minute (1 mm.) globular, with apical *rostellum* provided with a double row of hooks, and with four suckers. Head followed by a short unsegmented *neck*, following which is a series of segments or *proglottids*, 800–1000 in number. *Alimentary canal*, *circulatory*, and *respiratory* apparatus entirely lacking. *Nervous system* of two longitudinal cords connected in the head and extending throughout the body. *Excretory system* of two longitudinal canals communicating by cross branches in each proglottis. Near middle of one side of each proglottis a *genital papilla*, or *pore*. *Reproductive organs* occupy almost entire segment, hermaphroditic, male organs developing

before the female. Male organs: *testes, efferent ducts, vas deferens, cirrus,* or *penis, penis sac.* Female organs: *ovaries, oviduct, yolk gland, shell gland, uterus, receptaculum seminis.* Ripe proglottids have sex organs, except enormously enlarged uterus, atrophied; are little more than sacs of eggs, of which it is estimated that there may be as many as 50,000 in each. Terminal proglottids break off and pass out with feces.

Life history—Independent life of the free proglottid; scattering of the eggs; the *six hooked embryo* taken up with food by hog or man; migration of the embryo from the alimentary canal of its host (swine or man) to the muscles or other organs; formation of cysts, "measles" each containing the invaginated head of the future tapeworm, (the *Cysticerus* stage). Development of the adult from the cystic state. Possibility of *autoinfection* renders T. solium a dangerous species.

Interpretation of structure and life history—Two views; 1st, that there is a true alternation of generations, the tape-worm representing a linear *colony* of which the proglottids are the *sexual individuals,* produced by budding from an asexual scolex. 2d, that it is to be regarded as a segmented *individual,* comparable to an Annelid. Anatomical facts opposed to "colony" theory. According to second theory, the formation of proglottids a process of accelerated regeneration.

Frequency of occurrence in man—Relation to food habits. Very uncommon in U. S. Confusion with *T. saginata.*

Prevention—Avoiding imperfectly cooked pork; meat infection.

Other species infesting man in this country—*T. saginata,* the beef tape-worm; *Hymenolepis nana*; *Echinococcus granulosus,* adult in dogs; *Dipylidium caninum,* normal host, dogs; *Dibothriocephalus latus,* larva in fish.

Dipylidium caninum—(*Taenia cucumerina*). Commonest parasite of pet cats and dogs. Occasionally in children. Size small, 15–30 cm. Structure, head with retractile rostellum, 4 rows of hooks; proglottids resemble cucumber seeds in shape; two genital pores and double sets of sexual organs.

Life history—Eggs in capsules. Larva a *cysticercoid,* parasitic in dog louse or dog flea. Transfer by dog biting infested fleas. Infection of humans by accidental ingestion of an infested flea, (see Blanchard, '07).

Echinococcus granulosus—The hydatid tape-worm. According to Styles, there are 110 synonyms. Often known as *Taenia echinococcus. Adult* in dog, .20 inch or less in length. 3 segments and head. *Larva* in a great variety of hosts, man, cattle, sheep, hogs, *et al.*

Life history—Cystic stage may attain size of an orange, or even of a child's head. Within this cyst there develop by budding a great number of broad capsules, each containing from 1–120 heads capable of developing into tapeworms. For detailed account of life history, see Leuchart, '86.

Multiceps coenurus—(*Taenia coenurus, Coenurus cerebralis*). The tapeworm whose larva in the brain or spinal cord of sheep produces the fatal disease known as "gid". Adult in small intestine of dog, eggs scattered with feces over herbage and taken up by sheep. Embryos migrating to brain develop into cysts which may reach size of a hen's egg. On the interior of these cysts are to be found many invaginated heads of the future worm. May be as high as 500 to a cyst.

Prophylaxis—Burn infested heads of sheep to prevent infection of dogs; by direct treatment keep dogs free from the tapeworms, and avoid possible contamination of pastures. The parasite has not yet gotten established in this country and law requires quarantine and examination of feces of all imported collies. (See Ransom, '05).

III. REPRESENTATIVE NEMATHELMINTHES

REFERENCES

In addition to the general texts already cited see, especially, Hall, '12; Neveu-Lemaire, '12; Ransom, '11; Stiles, '07; Ward '03; and the special articles cited in discussing various species.

Class NEMATODA

The great majority of the Nematoda, or "thread-worms," are internal parasites of animals in the whole or part of their life but some infest plants and many live free either in water or damp earth. The classification of this group is in a very unsatisfactory condition, but we shall follow Neveu-Lemaire in arranging the families and shall discuss a representative of each. This grouping does not differ essentially from that used by Ransom, '11.

FAMILIES OF NEMATODA

(As defined by Neveu-Lemaire, '12)

Ascaridae—Body relatively thick; mouth usually surrounded by three lips, which are often supplied with papillae. One lip dorsal, the two others touching on the median line of the ventral surface. Oesophagus long, muscular, swollen posteriorly and at times followed by an oesophageal bulb. Males provided with *one* (*Oxyuris*) or usually, two spicules. Females with a double ovary; oviparous. Development direct. *Ascaris, Heterakis, Oxyuris, et al.*

Strongylidæ—Body elongate, cylindrical, rarely filiform. Mouth in some cases terminal, in others inclined towards the dorsal or ventral surface. Oesophagus more or less swollen posteriorly but never with a posterior bulb. Males with a caudal bell-shaped bursa supported by thickened rays, the so-called hooks, and with two equal or subequal spicules. Vulva may be in front of the middle of the body but is usually behind the middle. Many species formerly included under the genus *Strongylus* are included in this family under various generic names; includes also the hookworms, gapeworm, *et al.*

Trichotrachelidae—Body very long, anterior end produced into a long and slender portion; posterior more or less swollen, containing the genital organs. Mouth round and devoid of papillae; oesophagus very long and traverses a peculiar strand of cells; no oesophagus bulb. Anus terminal. Males with single or no spicule. Only one ovary; vulva at the origin of the swollen part of body. Representative genera *Trichuris* and *Trichinella.*

Eustrongylidae—Caudal bursa without thickened rays and with a single spicule. *Eustrongylus, Hystrichis.*

Spiruridae—Caudal bursa closed and vesiculate, entirely embracing the posterior extremity of the body. The two spicules unequal. *Physaloptera.*

Filaridae—Body long and filiform; mouth, of variable form, with papillæ, or with two lips. Oesophagus slender; no oesophageal bulb. Males with coiled tail and with a single spicule or two unequal spicules. Females with two ovaries; vulva at the anterior part of the body. Representative genera *Filaria, Spiroptera, Dispharagus.*

Gnathostomidae—Body cylindrical, covered for all its length or merely anteriorly by chitinous lamellae, most of which have the posterior border spinulate. Anterior extremity often swollen into a globular head clothed with simple spines. Mouth with two lips, a dorsal and ventral. Males with a spirally-coiled tail, whose ventral face is provided with papallae, and with two spicules. Ovary double, vulva back of middle of body. Oviparous.

Anguilluidae—Small size, filiform; mouth followed by a small cavity, the *vestibule,* containing a chitinous spine, or teeth. Oesophagus swollen into a fusiform bulb, often followed by a second bulb, with or without a dental armiture; posterior third of the oesophagus may be simply thickened. Males with two equal spicules; at times with a caudal cuticular expansion. Ovary double; vulva posterior of middle. Oviparious. Most of this group are free-living. *Anguillula.*

Angiostomidae—Heterogenos forms, that is, having two types of sexual generations. Genus *Strongyloides.*

Family ASCARIDAE

Ascaris lumbricoides—Intestinal parasite of man and of hog. That of the hog has been regarded by some writers as a distinct species, *Ascaris suilla.*

Form and structure—Body milky-white, long (males 15–17 cm.; females 20–25 cm.); elastic and pointed at the extremities. Resembles a large earthworm. Head with three lips,—a dorsal and two ventro-lateral,—bearing papillae. Male has caudal end curved towards the ventral side and bearing two spicules. Female with caudal end conical and straight; vulva about the anterior third of the body.

Development—The ellipsoidal egg 60–75μ long covered by a transparent mammillated sheath which gives it a very characteristic appearance. Scattered with feces, are capable of direct development, without any intermediate host, when ingested by man or hogs.

Heterakis vesicularis—A roundworm of chickens. Lives in caecum and sometimes present in such numbers as to cause death by mere mechanical obstruction. Males 7–13 mm. long, spicules unequal; female 10–15 mm. long. Adults and eggs pass out with droppings of the fowls and, developing in presence of moisture, without intermediate host, give rise to adults when swallowed by chickens. Best controlled by cleanliness in yards, shifting to uncontaminated soil, soil sterilization or even by deep ploughing or spading.

Family STRONGYLIDAE

Bunostomum phlebatomum—(*Monodontus phlebatomus*). A "hookworm" of cattle, occurring in the small intestine. See, Conradi and Barnett, Bull. 137, South Carolina Exper. Sta. Male 10–12. mm, female 16–19 mm. Mouth cavity enlarged to form a buccal capsule, with strong dorsal tooth projecting forward into its cavity and with two ventral buccal teeth and two subventral buccal teeth or lancets.

Necator americanus—(*Uncinaria americana, Ankylostoma americana*). The American hookworm. The cause of uncinariasis, one of the most important and most common diseases of the South, Porto Rico, Cuba and other parts of tropical America. Characterized by great anemia, weakness, colicky pains, perverted appetite, such as "dirt eating", inertia. Victims often underdeveloped

mentally. Disease sometimes fatal. See Ashford and Igaravidez, '11; Stiles, '03, and the publications of the Rockefeller Sanitary Commission.

Description—Adults 7–11 mm. long, possesses a dorsal and a ventral pair of lips, a prominent dorsomedian tooth and four lancets. As in other Strongylidae, the bell-shaped caudal bursa of the male is supported by ray-like thickenings which form the so-called "hooks". Females contain segmenting eggs; vulva in the anterior half of the body.

Development—The thin-shelled eggs, 64–72μ long by 36–40μ broad are deposited in early segmentation stage, reaching the open with feces. In warm weather larva 210μ long will escape before end of first day, or at any rate soon after. In a few days larva grow to 560–600μ and molt; soon a second molt occurs but old larval skin is not cast off. In this condition many live for four or five months. Enters man either through the skin (causing the well-known "ground itch" or, occasionally, with water or food.

Prophylaxis—Avoidance of soil pollution; use of sanitary privies, wearing of shoes. Medical treatment simple but should be under control of a physician.

Related species—*Agchylostoma duodenale*, the Old World hookworm of man long known as cause of "tunnel disease", "miners anaemia", etc. *Agchylostoma caninum* cause of a pernicious anaemia of dogs.

Syngamus trachealis—The gapeworm of birds. Lives in the trachea and large bronchi of many species of birds. Causes enormous loss of young chicks and pheasants. See Theobald, '96; Megnin, '06.

Description—Body cylindrical, red, head broad and truncated. Mouth large, circular depression, supported by a circular capsule; at the base of this capsule are six horny, pointed processes around the opening of the oesophagus. Male from 2–6 mm. long, the female varies from 10–20 mm. (Theobald). Mature male permanently attached to the female, the two forming a V-shaped compound.

Development—Eggs not laid but escape by the rupture of the parents body, being coughed up by the birds. Develop in water or damp ground in 7 to 40 days, according to temperature, and when taken up by birds reach the air passages and develop into adults. No intermediate host necessary, though embryos may remain alive

in alimentary canal of earth worms and thus be transferred to chickens.

Symptoms of the disease—Chief symptom the "yawning" or "gaping" with widely opened beak and straining forward of the neck. Wheezing cough and frothy saliva sometimes to be noted.

Prophylaxis—Remove all fowls known to be infected; bury *deeply* or, better, burn heads and necks of all dying from the disease. Disinfect houses and runs with one per cent solution of sulphuric acid or by heat. Frequent change of yards, and care to have yards in dry clean places will do much to lessen disease. Mechanical removal of parasites from trachea unsatisfactory.

Family TRICHOTRACHELIDAE

Trichinella spiralis—(*Trichina spiralis*). The cause of trichinosis, a serious disease of man caused by eating pork infested with the larvae of this worm. See Leuckart, '66; Ransom, '07; Stiles and Hassall, '01.

Description—Adults inhabit the small intestine of man, hogs, rats, and various other mammals for a short period after ingestion of infested meat. Very small, barely visible to the naked eye. Males 1.4–1.6 mm. in length, no spicules, but with two conical caudal appendages, behind which are four papillae. Females 3–4 mm. in length, viviparous, possess but one ovary; vulva ventral in anterior fifth of body.

Life history—Female is fertilized while in the intestine of host and soon begins to produce young,—1,500 or more, each—which both by active migration and by transfer by the lymph or blood are distributed throughout the entire body. Begin to reach the striated muscles about the tenth day after infection, and up to the eighth week enter fibers and there encyst. Lemon shaped cysts, formed by modified tissues of host, each containing a coiled sexual larva. An ounce of badly infested meat may contain 4,000 cysts. Cysts may become calcified and larvæ remain alive in them for many years. When the infested flesh is eaten the larvæ are released and obtain sexual maturity in two days.

Symptoms of trichinosis in man—Severity of symptoms depends on number of larvæ ingested. While in the intestine, may cause gastro-intestinal irritation, nausea, abdominal pains, diarrhoea and fever. From the seventh to the tenth day and later, the migrating

larvæ cause more or less fever, muscles tense, swollen, and painful on movement or pressure. Trichinosis often mistaken for typhoid, and muscular pains sometimes mistaken for rheumatism.

Diagnosis—Examine suspected port for cysts. During first two weeks after suspected infection examine feces for adult worms. Marked eosinophilia accompanying "muscular rheumatism" may be indicative of trichinosis and in such cases excision of a minute piece of patient's muscle, and microscopic examination may reveal cysts.

Prophylaxis—Avoidance of imperfectly cooked pork in any form. Microscopic inspection not trustworthy. Destruction of rats, which seem to be the normal host of this worm.

Family EUSTRONGYLIDAE

Eustrongylus visceralis*—The giant strongyle, or kidney-worm of the dog is the largest of nematode worms. Males may attain length of 40 cm., females even 1 meter, blood red in color. Eggs pass out with urine and embryo develops in presence of moisture. Further development not known; has been thought to occur in fish but experiments have failed to justify this view.

Family SPIRURIDAE

Unimportant and not discussed in this course.

Family FILARIIDAE

Filaria immitis—Adults found in the right half of the heart of dogs, usually causing death. Larval forms in enormous numbers in blood of host. For good, up-to-date summary see Neveu-Lemaire, '12; or Manson's, '07, discussion of F. bancrofti.

Description—Adults have the general family characteristics of Filariidae. *Males* 12–18 cm. long, tail tapering, spiral, and with two lateral wings. Two unequal spicules. *Females* 25–30 cm. long, tail short and obtuse.

Life history—Female viviparous, larvae 290μ long, escape into blood of host whence they are taken by a mosquito. In the body

*According to the rules of zoological nomenclature this name must be replaced by *Dioctophyme renale* (Goeze 1782) but in order to avoid confusion we have followed Neveu-Lemaire's in the generic as well as the family name.

of the mosquito they enter the Malpighian tubes, undergo a metamorphosis, develop rudimentary sexual organs, and finally, about the twelfth day, destroy the tubes of the mosquito and come to lie in the proboscis. When such an infected mosquito bites a dog the larvæ pass to the heart of the dog and there develop into the adult stage.

Related species—*Filaria bancrofti* a very common parasite of man in the tropics, being one of the causes of elephantiasis. It was in this species that the agency of the mosquito as an intermediate host was first worked out. *F. medinensis*, or guinea-worms undergo one stage in crustaceans Cyclops. Another species of Filaria is very common in the blood of crows, almost 50 per cent of those about Ithaca being infested. Its life cycle has not been satisfactorily worked out.

Dispharagus hamulosus—A representative of the family Filariidae which infests the gizzard of chickens, being imbedded in the muscles. It has been reported a few times from widely remote regions (Brazil, Italy), but seems to be not uncommon in New York State. Life history not known but it has been thought that the sow-bugs or pill bugs (*Oniscus*) serve as intermediate hosts. The ravages of this parasite seem to be serious and the writer would be glad to receive specimens or any data to aid in a study of life history.

Family GNATHOSTOMIDAE

Gnathostomum hispidum—Found in the stomach of hogs. Not discussed in this course.

Family ANGUILLULIDAE

Anguillula aceti—The vinegar eel. This nematode which normally lives free and is very commonly found in vinegar, has been reported several times as occurring in the human bladder. See Stiles and Frankland, '02.

Other species of this family, normally living on vegetables, have been occasionally reported as parasites of man.

Family STRONGYLOIDES

Strongyloides stercoralis—The Cochin China diarrhoea worm. Occurs primarily in the tropics but cases are occasionally imported.

Description—Like others of the family Strongyloides this species occurs under two forms, a *parasitic generation* and a *free-living generation*. The *parasitic adults* are females only, reproducing parthenogenetically. They measure 2.2 mm. in length, four lips, oesophagus one-fourth as long as body. Anus opens shortly in front of the pointed end of the body; genital opening in the posterior third of the body. *Free-living adults* are of both sexes. Males .7 mm. long, posterior end rolled up to form a hook; the two spicules small and much curved. Females 1 mm. long or a little more; tail end straight and pointed.

Life history—The parasitic forms bore into the intestinal mucosa and deposit their segmenting eggs, 50–59 x 30–34μ in size. These hatch out into the so-called rhabditiform embryos about .2 mm. in length which grow to double or three times that size in the lumen of the intestine end and are passed out with the feces. Under favorable conditions they molt and become mature in a day or so, copulate, and females deposit thirty to forty eggs from which there develop a generation of free-living rhabditiform young. These molt and transform into larvæ which resemble the adults found in the intestine. It is these "Strongyloid" larvæ which infect man, either by being taken in with water or food or by boring into the skin as do the hook worms.

Diagnosis—Examination of feces for the rhabditiform larvæ.

IV. REPRESENTATIVE ARTHROPODA*

IMPORTANT REFERENCES †

In addition to the general references and to special papers cited in the text, see Comstock, '95, '12; Huber, '99–03; Megnin, '80, '06; Nuttall, '99; Osborn, '96.

Class ARACHNIDA

Order ACARINA

For characteristics of this order, see p. 13 of this outline and for general discussion of the group see, especially, Banks, '04, Ewing, '12.

Superfamily TROMBIDOIDEA

Harvest mites—Last part of palpus forms a thumb to the preceding, which ends in a claw.

Trombidium holosericeum—"*Leptus irritans*", the "red bug", or so-called "jigger" or "chigger". Minute, exceedingly annoying parasite of man and some animals in our central and southern states, England, South of France, Germany, and tropics, burrowing into the skin and causing intense itching, redness and swelling. Distinct from the true "chigoe", or jigger, which is a flea.

Description—Red, almost microscopic. 230μ longest diameter, *larva of a free living mite.* Six legs, with prominent claws on the tips, and with a powerful hypostome which they drive through the skin.

Habits and life history—Only the larvæ parasitic and they on man abnormally so, for they die after entering the skin. Common species on the housefly in autumn and on grasshoppers. Adults predaceous, one species commonly feeds on grasshopper eggs. Adults hibernate and deposit eggs in or on the ground.

---

*The question of the relation of Arthropods to disease is the subject of a special course, and hence this important phase will be but incidentally considered here. For special bibliography see Riley, '12a.

†In addition, the publication of the Bureau of Entomology and the Bureau of Animal Industry should be consulted, whether specifically cited or not. The bulletins of the Public Health and Marine Hospital Service also contain much of importance along this line.

Relief from attacks—Flowers of sulphur or powdered naphthalene in stockings and underclothing, or rubbing in vaseline or bland oil protects. As *palliatives*, warm, salt baths, ammonia, or sulphur ointment. Destruction of mites on lawns, etc., by close cropping sometimes feasible.

Superfamily IXODOIDEA

Ticks—Large, breathing pore on each side of the body, above 3d or 4th coxa; "tongue" large and roughened with sharp teeth. Not only many serious parasites, but various species are now known to play important roles in the transmission of diseases of man and animals. See Banks, '08; Nuttall, '08–'12; Salmon & Stiles, '02, and many valuable reports of the Bureau of Entomology and the Bureau of Animal Industry, on life history, habits and classification. Two families.

A—**Argasidae**—Lack *scutum* (firm, chitinized dorsal shield); no marked differences in general appearance between sexes. Palpi composed of long, cylindrical joints which enable them to move in a leglike manner. Nymphs and adults moderate and rapid feeders, engorging and then leaving host and hiding in cracks and rubbish. As an illustration:

Argas persicus, a chicken tick. (See Hassall, '00). Cosmopolitan in distribution, occurring among other regions in southern United States, South America, Persia, Egypt, Australia, et. al., though it has often been renamed, as a new species. In some regions transmits a serious disease (*spirochaetosis*) of fowls.

Description—Body usually flat and thin, much like a bedbug, one-fourth inches long, outline oval, deep reddish brown. Tegument roughened by wrinkles and folds and marked by circular pits. Head or *capitulum* ventral.

Life history and habits—Eggs laid in hiding places of the adults, in cracks, crevices, etc., in batches of 20–100 more or less. Hatch in about three weeks into six legged larvae or "seed ticks" which after several days feeding drop from host and molting in about eight more days into the *first nymphal form*, feeding intermittently and rapidly for about two weeks when they again molt and the *second nymphal form* is assumed. After some weeks these molt to form the adult. Adults feed about once a month in hot weather, at longer intervals

when it is cool. Lounsbury found that entire life cycle from egg to egg required 10 months in one case studied. Great longevity; we have kept specimens unfed and in a dry tin box alive for nearly two years. Instances on record of survival for three years. (See, Nuttall, '08).

Economic importance—Bite often causes serious injury to man. Aside from importance in some regions as transmitters of poultry disease, they are directly responsible for the death of many fowls and for much loss due to depleted condition.

Means of control—Cleanliness of poultry houses and yards, white-washing (filling all cracks), removal of rubbish under which ticks can hide. Use of dips to kill the ticks on fowls.

B—**Ixodidae**—Dorsal shield or *scutum* present; sexes very distinct in appearance; palpi relatively short and rigid. Nymphs and adults remain attached to host for days or months, increasing enormously in size when gorged. Not so long-lived as typical Argasidae.

Boophilus annulatus—"*Margaropus annulatus*", the Southern cattle tick. Causes enormous direct loss, but it is as a carrier of Texas fever of cattle that it becomes one of the most important pests of the South. Conservative estimates place losses to the South due to it as $40,000,000 annually.

Life history—Mate on host, female drops to the ground and deposits many eggs. After twenty to twenty-five days in summer, or months in the fall, "seed ticks" or larvæ emerge, crawl to top of grasses and bushes, where they await their host. After six or seven days on the host molt and form *nymphs* with eight legs. During nymphal stage sexual organs develop. In from five to eleven days the nymphs molt and appear as adults. In summer, female feeds six to twenty days after copulation before dropping from the host to lay her eggs.

Relation to Texas fever—Since the discovery of the causative organism of Texas fever by Smith in 1889, it has been clearly demonstrated that the disease is not transmitted by saliva, urine, or manure of diseased animals but solely by the cattle ticks, hatching from eggs laid by individuals which had fed on diseased cattle or on apparently healthy Southern cattle which carried the parasite in their blood. Not only the clearest of circumstantial evidence, but proved experimentally very many times.

Methods of control—Establishment of a quarantine line limiting area infested by the tick and prohibiting removal of cattle, except for immediate slaughter, during the period when the tick could live and develop in the North. Cattle going to market during the closed season must be shipped in special cars or boats and, when unloaded for feeding, watering, or sale, are placed in special pens. Cars and boats must be disinfected before other stock can be carried. Cattle may be freed of ticks by hand-picking, greasing, dipping, or spraying. The most important measures are those which, by taking advantage of a minute study of the biology of the tick, render it possible to free infested pastures. Essentially, exclude from the pasture from June until late fall all cattle or horses and mules which might carry ticks. In the meantime, cattle from the infested field are freed from ticks by placing in a tick-free feed lot for three weeks by which time many ticks would drop off, but seed ticks would not have hatched. Then place in a second tick-free lot for twenty days, and finally, for certainty that ticks had all dropped off, place in a third lot. By this time the tick-free cattle should be placed in a forage field until mid-November, by which time all the ticks in the original pasture will have died. By essentially this method large areas of the quarantined region are being freed from ticks and hopes are entertained that the tick may be exterminated. For details see Farmers' Bulletin 378, "Methods of Exterminating the Texas Fever Tick" and various publications of the Bureau of Animal Industry and of the Bureau of Entomology.

Superfamily GAMASOIDEA

Abdomen not annulate; "tongue" small, without teeth, venter without furrows, body often with coriaceous shields, posterior margin never crenulate; no eyes. This family includes many species free-living or attached to insects, but one group is parasitic on birds, bats, rodents, etc. One species of very great economic importance is:

Dermanyssus gallinae, the red chicken mite. Incorrectly called "chicken tick". Most destructive external parasite of fowls.

Description—"Body ovopyriform, posterior end largest, slightly flattened from above to below; abdomen margined by short, well-separated bristles; color varying from yellowish-white to dark red, according as the insect is fasting or more or less replete; the intestinal

tube, gorged with blood, can be seen as a variously shaped figure. The ovigerous female is .70 mm. long and .40 mm. broad; the male, .60 mm., and .32 mm. broad."—Neumann.

Life history and habits—Eggs laid in cracks and crevices or in rubbish, singly, about one a day. Hatch in three or four days and after two or more molts become mature in about ten days under favorable conditions. Intermittent feeders, most active at night, and hiding during the day. May attack man and domestic animals. Very long-lived, specimens having been kept in a pill box without food for at least three months. Dispersal by shipping crates, show crates, etc.

Methods of control—Cleanliness and sunlight, removal of manure, litter, superfluous boxes, boards, and all trash. Whitewashing, with addition of four ounces of carbolic acid to each gallon of whitewash. Spraying with kerosene emulsion; must be thorough, and repeated in three or four days to kill mites which have hatched from eggs.

Superfamily SARCOPTOIDEA

Itch mites, hair and feather mites—Small, palpi small, 3-jointed; no eyes; no spiracles; tarsi often end in suckers. The itch mites belong to the family Sarcoptidae, illustrated by:

Sarcoptes scabei, parasitic within the skin of man and other mammals, causing a diseased condition known as the "itch", scabies, or mange.

Description—Body oval or nearly circular, 200–235μ x 145–190μ in the male, 330–450μ x 250–350μ in the female. Whitish, marked by transverse folds partly interrupted on the back. Chitinous hairs at the base of the legs and the first two pairs of legs are provided with pedunculated suckers in both sexes; the third and fourth pair in the female terminate in long bristles, while the fourth pair in the male has a pedunculated sucker.

Life history and habits—Lives in tunnels that it excavates in the epidermis, the female at the bottom, the male near the opening. The tunnels contain excrement and the minute eggs from which hatch the hexapod larvæ. Enormous rapidity of increase. Disease spread by contact, or, rarely by clothing or bedding of those infested; may be contracted from horses and other animals infested.

Diagnosis and treatment—In man, the diagnosis of a simple case is readily made by finding the galleries with the female at the end, but there is often secondary infection, due to scratching. Treatment consists in preparatory warm bath, or for cleaning off scales, incrustations, etc., and softening of the skin and then in applying a sulphur ointment.

Psoroptes communis ovis, mite of common sheep scab, the most prevalent and most injurious malady of sheep. May begin attacks in almost any part of body but usually in parts covered by wool; wool falls out, scabs are formed, and finally the skin becomes more or less bare, parchment like, greatly thickened, furrowed and bleeding in the cracks.

Description—One of the larger mites, males 500–600μ x 340–370μ, female 670–740μ x 450–460μ, quite easily seen with naked eye. Rostrum or beak elongated, conical. Ambulatory suckers on long, 3-jointed pedicle, on first three pairs of legs in the male, and on first, second, and fourth legs of the female. Male with copulatory suckers and abdominal prolongations.

Life history—Female lays 15–24 eggs on the skin, or fastened to the wool near the skin. In three or four days the six-legged larva hatches and three or four days later molt to form nymphs which pair, molt twice more and begin to lay eggs. Gerlach estimates fifteen days as an average for a generation and that under ideal conditions a single pair of mites may produce 1,500,000 individuals in three months.

Methods of control—Preventive and curative. Exceedingly contagious and penalties for shipment of diseased sheep are heavy. Contagion may be direct, by contact of sheep with one another or indirect, from fences, posts, etc. or from places where infested sheep have been "bedded" down. Hence, if pastures, corrals, or sheds become infested leave them vacant for at least four weeks before using for clean sheep. *Curative treatment,* some external application which will kill the parasites. Various dips used. For details see Bureau of Animal Industry Bul. 21 "Sheep Scab, its Nature and Treatment", or more recent publications of the Bureau.

Superfamily DEMODECOIDEA

The hair-follicle mites—Very small, abdomen annulate, elongated.

Demodex folliculorum, very common in the sebaceous glands and hair follicles of man, usually with no ill results. A variety of the same species on dogs gives rise to a very serious disease, *demodecic scabies.*

Description—Very small, 300–380μ x 45μ, elongate, veriform, with eight short 3-jointed legs and in front a short, median, sucking rostrum. Abdomen tapering transversely striated and rounded at the tip.

Life history and habits—Deposit fusiform eggs, 70–90μ x 25μ. Multiplies very slowly; hexapod larva, two nymphal stages. Mites migrate over the skin to enter new glands.

Class HEXAPODA

(True Insects)

Review the characteristics of the four orders discussed, as given on page 14.

Order MALLOPHAGA

Includes all *biting* lice infesting birds and mammals. Illustrated by:

Menopon pallidum, the common *hen louse.* Responsible for much loss to poultrymen, through reduced vitality and even death of birds, and failure to incubate eggs properly.

Description—Elongate oval, very flat, pale yellow body 1–1.5 mm. long. Head triangular, semilunate, antennae 4–jointed, mouth parts fitted for biting.

Life history and habits—Eggs laid at base of feathers, especially around the vent, hatching in six to ten days. Nymphs molt five or six times. Lice very active; unlike the chicken mite, they remain on the host and die soon after its death. Accounts of their occurrence on horses confused with cases of the mite or of other species of biting lice. The lice spread from bird to bird by infested mother hen, cock-birds and to a less extent, by infested nests, etc.

Methods of combatting—Roomy, dry, and sunny *dust baths.* Various dusting machines for treating individual birds are on the

market. Dipping fowls in 1¼ ounces of pure carbolic acid to a gallon of warm water. Proprietary remedies.

Related species—Various species of the genus *Trichodectus* parasitic on domestic mammals. Biting mouth parts, antennae 3-jointed.

Order HEMIPTERA

Includes the true bugs and the *sucking* lice. Take as illustrations:

Cimex lectularia, the *bed-bug.* World-wide in distribution.

Description—Reddish-brown, broad and very greatly flattened. Head short, broad, two prominent eyes, but no ocelli; mouth parts for sucking. Peculiar "buggy" odor due to secretion of sac-like glands at the base of the abdomen.

Life history and habits—Eggs laid intermittently for a long period, in cracks, under wall-paper, etc. Hatch in 7–10 days. Nymphal stages five, total period to development of adult varying from 40–150 days or more. May live for months without food. In cases of deserted houses, may feed on mice or other mammals. Invasion of a house not necessarily due to neglect as the bugs may migrate, be brought in with baggage, laundry, furniture, or otherwise.

Methods of combatting—Use of iron bedsteads and reduction of hiding places. Gasoline or alcohol squirted into cracks and crevices. In more general infestations, fumigation with sulphur, 2 pounds to 1,000 cubic feet. Under proper precautions, fumigation with hydrocyanic acid gas (See U. S. Bureau of Entomology Circ. 46 "Hydrocyanic acid gas against household insects").

Haematopinus eurysternus, the *short-nosed sucking louse of cattle.* Found especially on ears, back of head, mid back and places where hair is long and they cannot be readily reached by the animal.

Description—Bluish-gray, males 2½ mm., females 3 mm. in length. Mouth parts and unjointed beak capable of great extension, with a chaplet of barbs at base, for attachment. Wings lacking, legs highly specialized for clasping.

Life history—Remain on the host. Eggs, or so-called "nits" pyriform and attached to the hairs by an adhesive substance. Hatch very soon and young escape through a caplike covering at top of egg.

Methods of combatting—Cleanliness, keeping infested animals apart from others if possible. Washes of kerosene emulsion or

tobacco infusion plus kerosene, or carbolic acid. Fumigation with sulphur or tobacco for 20-30 minutes in a tight box stall with an opening for the head of the animal.

Pediculidae of man—Three species of sucking lice infest man, *Pediculus humanus*, or head louse (usually referrred to in medical works as *P. capitis*), *P. corporis*, or body louse, and *Phthirius inguinalis*, pubic louse.

Order DIPTERA

True flies. Two suborders: NEMATOCERA, *mosquitoes, gnats, et. al.*, have long antennae, consisting of at least six segments. BRACHYCERA, *bot-flies, house flies, sheep "ticks", et. al.*, have short, 3-segmented antennae.

Suborder NEMATOCERA

Family **Culicidae,** mosquitoes. Small, 2-winged, wings narrow, and with their veins covered with scales; antennae plumose in males, simple in females. Females only, suck blood. Immature stages aquatic, larvæ commonly known as wrigglers; pupæ active. See the important general discussion of Howard, '01, Smith, '04, Mitchell, '07.

We shall consider here the general characters of the genus *Culex*, as compared with those of Anopheles, the malaria bearing mosquito:

Culex.	Anopheles.
Adult—Wings clear Palpi short Resting position with body and wings parallel to wall.	*Adult*—Wings spotted Palpi long as beak. Resting position with body at an angle to wall.
Eggs—Laid in raft-shaped masses on end.	*Eggs*—Laid singly, always lying on their sides.
Larvæ—Hang in water at a great angle to the surface.	*Larvæ*—Lie in water with body parallel to surface.
Pupæ—Rest almost perpendicular to the surface. Breathing siphons narrow.	*Pupæ*—Rest at a much smaller angle to the surface. Breathing siphons broad.

Economic importance and relation to disease—Direct injuries not only annoying to man and animals but may be serious. Occur in enormous numbers in some regions, rendering them uninhabitable. Deprecation of real estate, retarding development of many localities. As disease carriers, they are the sole agents in transmission of malaria, yellow fever, filariasis and are suspected of directly transferring some other diseases.

Methods of combatting—Efforts should be directed against the larvæ. Destruction of breeding places; drainage; oiling; introduction of minnows and other small fish. Screening against adults, necessity of screening patients with mosquito-born diseases.

Family **SIMULIIDAE,** the *black flies.* Illustrated by:

Simulium pecuarum, the *buffalo gnat.* Causes enormous losses of horses, mules, and other domestic animals in the Mississippi Valley. See Osborn, '96,

Description—Size minute, about 6 mm. long, body short and stout, color black, but body covered with grayish-brown, short and silken hairs. Antennae 10-jointed, scarcely longer than head; wings without scales.

Life history—Early stages aquatic. Eggs laid in patches on rocks, submerged stumps, brush, etc., in rapidly moving water. Larvæ slender, cylindrical, closely crowded so as to appear like dark patches of agal growth on the objects to which they are attached (see patches on the brinks of falls or in rapids of any of our local streams). Pupal case conical, grayish or brownish, and has its upper half cut squarely off, more or less raggedly. Time of appearance of adults varies with the earliness or lateness of the spring, and consequently much earlier in the southern parts of the Mississippi Valley.

Habits of adults and economic importance—Blood-sucking exceedingly active, appear in enormous swarms, attacking domestic animals and not infrequently causing death. No evidence that losses are due to a specific disease transmitted by the fly but rather to loss of blood and terrible irritation caused by the myriads of poisonous bites. Area infested, in the worst years, all of Mississippi Valley from the mouth of the Red River, in Louisiana, to St. Louis, Mo., and land adjacent to the tributaries of the Mississippi River in these regions.

Methods of combatting—Destruction of larvae not feasible. As preventives, smudges in fields and yards or even in pails suspended

from the necks of animals which have to be on the roads. Application of grease, or of oil of tar to animals.

Related species—*Simulium meridionale*, the turkey gnat; *Simulium molestum*, the Adirondack black-fly. It has been suggested by Sambon that species of Simulium transmit *pellagra* of man; but evidence is by no means conclusive.

Suborder BRACHYCERA

Family **TABANIDAE,** the horse fly, deer flies, *et. al.* Medium to large size, body broad and slightly flattened; head large and depressed from before to behind; eyes contiguous in the males; last segment of the antennae annulate and without stylet. Females provided with powerful piercing mouth-parts. Life history illustrated by:

Tabanus atratus, the *black horse-fly.* Largest native species, bite one of the most severe, attacks cattle more commonly than horses. Eggs laid in large black masses on marsh plants. Larvae live in mud or water; large, twelve jointed, cylindrical, tapering at each end. Winter passed in larval stage. Pupal stage lasts but a few days. Adults are not only pests, but may directly transmit disease.

Family **OESTRIDAE,** the *bot-flies*—Large, or medium size, with rudimentary mouth-parts; most of the species resemble bees in general appearance. Adults live comparatively short time; females lay their eggs on the bodies of mammals; larvæ are parasitic and their development requires several months. We shall consider three species:

Gastrophilus intestinalis, (G. equi), the *horse bot-fly.* Adults about 12–15 mm. in length, wings transparent with dark spots; body very hairy, head brown, with three rows of blackish spots. Eggs light yellow in color, attached to hairs of the horse, more commonly on the fore legs and shoulders. Eggs hatch in two weeks or more, escape of larva being aided by licking by the horse. Taken up in this way or with food they reach the stomach and attach to its walls. Winter in host as larvæ and following summer pass out with feces; pupate in the ground and after thirty to forty days emerge as adults. Bots may be so numerous in stomach as to cause marked pathological changes and digestive disturbance.

Hypoderma lineata, the *ox-warble*—Larvae form more or less conspicuous lumps under the skin of the backs of cattle during the latter part of winter or early spring. Adult fly about 12 mm. long, very hairy, and somewhat resembles a small black bee in appearance. Though unable to bite, cattle have a great fear of them. Deposit eggs, throughout the summer, on the hairs of cattle and young larvæ are taken up by licking and penetrating the walls of the oesophagus, migrate through the tissues to reach the subcutaneous tissue of the back of the host. In spring or early summer the grub emerges, pupates in the ground and adults emerge in about a month. Studies of Carpenter, '07, indicate that larvae may possibly enter skin directly, but this is not normal method. Estimated that loss by injury to hides, decrease in milk and beef, and lessened vitality reaches over $90,000,000 annually in this country. *Preventive measures*, such as protection of cattle from attacks of the fly, hardly feasible. Much may be accomplished by removal of the grubs, by pressure, during late winter and spring.

Oestrus ovis, the *sheep bot-fly* or *head maggot*—Adults somewhat resembling "an overgrown house-fly" appear in June and July and deposit living larvæ, or eggs ready to hatch, in nostrils of sheep. Larvæ pass into frontal sinus and horns, causing disease known as "staggers". Mature in about ten months and are expelled by sneezing of the host, pupate in the ground, and adults emerge in forty to fifty days. *Preventive measures*, such as smearing noses of sheep with oil or tar not of demonstrated value. Substances to make the sheep sneeze and thus expel the larvæ no more efficient than the irritation caused by the larvæ itself. Removal of immature grubs by surgical treatment worth while in case of valuable animals.

Family **MUSCIDAE,** including the *flesh flies*, *house-flies*, *horn-flies*, and many others—By some writers considered a superfamily, with many families.

Musca domestica, the *common house-fly*—90 per cent of the flies found in houses being of this species. Detailed description unnecessary, but it should be emphasized that the mouth-parts are adapted solely for sucking and lapping. Breeds primarily in horse manure, but also in decaying vegetation, garbage, and human feces. 120+ eggs in a batch and may deposit as many as four batches. Larvæ known as maggots. Entire life cycle in hot weather may be undergone in ten days. Always a pest, the house-fly is now known to be

an important factor in the spread of typhoid, and various intestinal diseases, and to a less extent tuberculosis, and possibly other diseases. Methods of control by screening and trapping, destruction of breeding places, trapping out of doors during preoviposition stage. Danger as a disease carrier lessened by proper sewage disposal, and by disinfection of typhoid discharge. For detailed discussion, see Howard "The house-fly-disease carrier".

Haematobia serrata, the *horn-fly*—Now found nearly everywhere in the United States, though introduced from Europe about 1885. About half the size of a house-fly and very much like it in shape and color, these flies get their name from their habit of clustering about the base of the horn. When feeding, puncture skin and suck blood. Remain on animal day and night and by irritation and annoyance cause much loss through reduced vitality, lack of growth, or loss of milk. Eggs laid in freshly dropped cow manure, hatch in twenty-four hours; larvæ transform in four or five days into pupæ which remain in the ground for ten days. *Preventive measures,* spraying cattle by means of a hand spray pump with a mixture of fish oil 100 parts, oil of tar 50 parts, crude carbolic acid 1 part.

Family **HIPPOBOSCIDAE,** the *louse flies*—Abnormal flies which, as adults live parasitically, like lice, upon the bodies of birds and mammals. Some species winged, some wingless, others winged for a time and then lose their wings. The most common representative is:

Melophagus ovinus, the so-called "*sheep tick*"—Reddish, wingless, flattened, louse-like body, prominent proboscis, and strongly developed legs, with very prominent claws. Viviparous, each female producing a half-dozen, more or less, full grown larvæ which, attached to the wool, quickly transform into seed-like brown puparia. When abundant may cause death of lambs, and cause considerable damage to old sheep. May be readily controlled by dipping sheep each year after shearing, in any of the standard dips for lice and scab.

Order SIPHONOPTERA

True Fleas

Ctenocephalus canis, the *dog flea*—The most common house flea in this country. Closely related, if not the same species, occurs on cats.

Description—Reddish-brown, compressed, strongly chitinized body; ocelli present, a comb of blunt black spines—seven to nine—on lower border of each side of the head and of posterior border of the thorax; no wings; legs long and stout, coxae being remarkably developed, fitted for leaping. Mouth parts in the form of a rostrum or beak enclosing the serrated mandibles fitted for puncturing, maxillae, and labium.

Life history—Eggs scattered in dust, in cracks and in sleeping places of the host. Veriform footless larvae, with sparse covering of hairs, feeds on dead organic matter. In 10–12 days spins a silken cocoon, pupates, and adult emerges in 10–12 days more. Under optimum conditions entire life cycle may be completed in two weeks.

Control—As a household pest, controlled largely by cleanliness and exclusion of dogs and cats. May be necessary to spray carpets and floors with benzine. Fumigation with hydrocyanic acid gas has been practiced with success.

Sarcopsylla gallinacea, the *chicken flea*,—Widely distributed in warmer climates; is a serious pest in some of the southern states. Unlike ordinary fleas, the chicken flea attaches itself firmly to its host but it does not burrow under the skin as does the chigoe or true "chigger". Both male and female parasitic to the same extent; attach themselves to the head, around the eyes, and neck of young chickens in great numbers causing knots, lumps, and sores.

BIBLIOGRAPHY

Ashford, Bailey K. and **Igaravidez, P. G. 1911.** Uncinariasis (hookworm disease) in Porto Rico. A medical and economic problem, U. S. Senate Document vol. 59 no. 808. 335 pp. 8. Wash.

Banks, Nathan. 1904. A treatise on the Acarina, or mites. Proc. U. S. National Mus., vol. xxviii. 114 pp. — figs.

——— **1908.** A revision of the Ixodoidea, or ticks, of the United States' Tech. Bull. 15 Bureau Entomology, U. S. Dept. Agric. Wash. 61 pp.

Benham, William B. 1901. Platyhelmia, mesozoa, and nemartini. E. Ray Lankester, Treatise on Zoology, pt. 4. 212 pp. 8°. London.

Blanchard, Raphael. '89–90. Traité de zoologie médicale. 2 vols. 808+ 883 pp. 8° Paris.

——— **1907.** Parasitisme du Dipylidium caninum dans l'espece humaine à propos d'un cas nouveau. Arch. parasit. Paris. xl p. 439–471.

Braun, Max. 1889. Article, Trematoda. Bronns Klassen u. Ordnungen des Thier-Reichs. v. 4 pp. 303–925. (Contains a very extended bibliography).

——— **1894–1900.** Article, Cestoda. Bronns Klassen und Ordnungen des Thier-Reichs. vol. 4, pp. 927–1731, pls. xxxv–lix.

——— **1906.** The animal parasites of man. A handbook for students and medical men. Transl. from the German by Pauline Falcke. Brought up to date by Louis W. Sambon and Fred V. Theobald. xix+ 453 pp. 290 figs. 4. London.

Braun, Max and **Luhe, M. 1910.** A handbook of practical parasitology. Eng. transl. by Linda Forster. vii+208 pp. 100 figs. 4°. London.

Bruce, David. 1907. Article, Trypanosomiasis. Osler's Modern Medicine, vol. i pp. 460–487.

Calkins, Gary N. 1909. Protozoology. ix+349 pp., 4 col. pl. and 125 text figs. 8°. New York.

Comstock, John Henry. 1912. The Spider Book. A manual for the study of spiders and their near relatives, the scorpions, pseudoscorpions, whip-scorpions, harvestmen, and other members of the class Arachnida, found in America north of Mexico, with analytical keys for their classification and popular accounts of their habits. xv + 721 pp., 770 figs. 4°. Doubleday, Page & Co., New York.

Comstock, John Henry and **Anna B. 1895.** A manual for the study of insects. x + 701 figs., 6 pls. and 797 text gigs. 8°. Ithaca, N. Y.

Crawley, Howard. 1912. The protozoon parasites of domesticated animals. Circ. 194 Bur. Animal Indust., U. S. Dept. Agr., Wash. 33 pp. (Reprint from Rept. of Bureau for 1910.)

Davaine, Casimir-Joseph. 1887. Traité des entozoares et des maladies vermineuses de l'homme et des animaux domestiques. 2 éd., cxxxii 1004 pp., 72+ 38 figs. 8°. Paris.

Doane, Rennie W. 1910. Insects and disease. xiv + 227 pp. — figs. 8° New York.

Doflein, Franz. 1909. Lehrbuch der Protozenkunde. Eine Dorstellung der Naturgeschichte der Protozoan mit besonderer Berücksichtigung der parasitischen und pathogenen Formen. x + 914 pp., 825 figs. 8°. Jena.

Gamble, F. W. 1896. Platyhelminthes and Mesozoa. Cambridge Nat. Hist., London, v 2. pp. 1–96.

Hall, Maurice C. 1912. Our present knowledge of the distribution and importance of some parasitic diseases of sheep and cattle in the United States. Circ. 193 Bur. Animal Indust. U. S. Dept. Agric. Wash. 44 pp. (Reprint from Rept. of Bureau for 1910).

Hassall, Albert. 1900. Note on the chicken tick (Argas americanus). 16th Ann. Rept. Bu. Animal Ind. U. S. Dept. Agric. pp. 25–28.

Howard, Leland O. 1901. Mosquitoes, how they live, how they carry disease, how they are classified, and how they may be destroyed. xv + 241 pp. 8°. New York.

Huber, Joh. C. '99–'03. Bibliographie der klinischen Entomologie 4 pts. 8°. Jena.

Küchenmeister, Friedrich. 1857. On animal and vegetable parasites of the human body, a manual of their natural history, diagnosis, and treatment. Transl. from 2d German edition by Edwin Lankester. 2 vols. xix + 452 pp., 8 pls. and xvi + 287 pp., 9 pls. 8°. London.

Lankester, E. Ray. '03–'09. A treatise on zoology. vol. i. Introduction and Protozoa; vol. iv. Platyhelmia, Mesozoa, and Nemertine. 8°. London.

Law, James. 1903. Text-book of veterinary medicine. Vol. 5, Parasites, parasitisms, etc. 532 pp. 8° Ithaca.

Leuckart, Rudolph. 1866. Untersuchungen über Trichina spiralis. Zugleich ein Beitrag zur Kentniss der Wurmkrankheiten. 2 Aufl. pp. iv + 120. 7 figs., 2 pls. 4°. Leipzig.

——— **1886.** The parasites of man and the diseases which proceed from them. A text-book for students and practitioners. Natural history of parasites in general. Systematic account of the parasites infesting man. Protozoa-Cestoda. Transl. from German key by William E. Hoyle. xxvi + 271 pp. 404 figs. 8°. Edinburgh.

von Linstow, Otto. 1879–89. Compendium der Helminthologie. Ein Verzeichniss der bekannten Helminthen, die frei oder in thierischen Körpern leben, geordnet nach ihren Wohnthieren, unter Angabe der Organe in denen sie gefunden sind und mit Beifugüng der Litteraturquellen. xxii + 382 pp. and xvi + 151 pp. 8. Hannover.

Loos, Arthur. 1894. Die Distomen unserer Fische und Frösche. 296 pp., 9 pls., 192 figs. 4°. Stuttgart.

McNeal, Ward J. and **Novy, Frederick G. 1903.** On the cultivation of Trypanosoma Lewisi. Contrib. Med. Research, Ann Arbor, Mich. June 1903, pp. 549–577.

Manson, Patrick. 1907. Tropical diseases. A manual of the diseases of warm climates. 4 ed. xx + 876 pp. 7 cols. pls., and 241 figs. in text. 12°. London and New York.

Megnin, Pierre. 1880. Les parasites et les maladies parasitaires chez l'homme, les animaux domestiques et les animaux sauvages avec lequeuls ils peuvent etre en contact. 478 pp., 63 figs., atlas, 26 pl. 8°. Paris.

——— **1906.a** Médecine des oiseaux. Causes, nature et traitement de leurs maladies. 4 ed. 334 pp., 52 figs. 8. Vincennes.

——— **1906b.** Les insectes buveurs de sang et colporteurs de virus. 150 pp., 53 figs. 12 mo. Paris.

Mitchell, Evelyn G. 1907. Mosquito life. xxii + 281 pp. 8°. New York.

Neumann, Louis Georges. 1892. A treatise on the parasites and parasitic diseases of the domesticated animals. Transl. and edited by George Fleming. xxiii + 800 pp., 364 figs. 8° London.

——— **1909.** Parasites et maladies parasitaires des oiseaux domestiques. viii + 230 pp., 89 figs. 12°. Paris.

Neveu-Lemaire, Maurice. 1908. Précis de parasitologie humaine Maladies parasitaires dues à des végètaux et à des animaux. 4 ed. v + 712 pp., 391 figs. 12 mo. Paris.

——— **1912.** Parasitologie des animaux domestiques. Maladies parasitaires non bactériennes. ii + 1257 pp., 770 figs. 12 mo. Paris.

Nuttall, George H. T. 1899. On the role of insects, Arachnids and Myriapods as carriers in the spread of bacterial and parasitic diseases of man and animals. A critical and historical study. Johns Hopkins Hosp. Rept. viii + 154 pp., 2 pls.

Nuttall, George H. T. 1908–1912. Ticks. A monograph of the Ixodoidea. Part I Argasidae Oct. 1908. xx + 104 pp. + 35 pp. Part II Ixodidae (in part) May 1911. ix + pp. 105–348.

——— **1908.** Spirochoetosis in man and animals. Jr. R. Inst. Pub. Health Aug. 1908.

Osborn, Herbert. 1896. Insects affecting domestic animals: an account of the species of importance in North America with mention of related forms occurring on other animals. Bull. 5 n. s. Division of Entomology, U. S. Dept. Agric. Wash., 302 pp., 170 figs.

Perroncito, Eduarodo. 1901. I parassiti dell 'uomo et degli animali utili e le piu' communi malattie da essi prodotte. Profilassi e cura relativa. 2 ed. xv + 632 pp., 25 pls., 276 figs. in text. 8. Milan.

Railliet, Alcide. 1895. Traité de zoologia médicale et agricole. 2 éd. xv + 1303 pp., 892 figs. 8. Paris.

Ransom, Brayton H. 1905. The gid parasite (Coenurus cerebralis) in American sheep. Bull. 66. Bur. Animal Indust., U. S. Dept. Agric., Wash., 23 pp., 12 figs.

Ransom, B. H. 1907. Trichinosis: A danger in the use of raw pork for food. Circ. 108, Bu. Animal Ind., U. S. Dept. Agric., Wash., pp. 1–6. 5 figs.

Ransom, Brayton H. 1911. The Nematodes parasitic in the alimentary tract of cattle, sheep and other ruminants. Bull. 127 Bur. Animal Indust., U. S. Dept., Agric., Wash. 132 pp. 152 figs.

Riley, William A. 1912a. Notes on the relation of insects to disease. Lectures outline of Course 23 in Entomology. 51 pp., 8°. Ithaca.

Schaudinn, F. 1900. Untersuchungen über den Generationswechsel bei Coccidien Zool. Jahrb. Anat., xiii, pp. 197–292, pls., 13–16.

——— **1903.** Untersuchungen über die Fortpflanzung einiger Rhizopoden. Arb. kais. Gesundheitsamte. xix pp. 347–576.

Smith, John B. 1904. Report upon the Mosquitoes occurring within the State, their habits, life history, etc., N. J. State Agric. Exper. Sta., 1904, v + 428 pp., 136 figs.

Stiles, Ch. Wardell. '98. The flukes and tapeworms of cattle, sheep, and swine with special reference to the inspection of meats. Bull. 19 Bur. Animal Indust., U. S. Dept., Agric. Wash., Feb. 8, pp. 11–136, figs. 1–124.

——— **1904.** Illustrated key to the Trematoda parasites of man. Bull. 17, Hyg. Lab., U. S. Pub. Health and Mar.-Hosp. Serv., Wash., pp. 66.

——— **1906.** Illustrated key to the Cestode parasites of man. Bull. No. 25, Hyg. Lab. U. S. Pub. Health and Mar. Hosp. Serv., Wash., 104 pp., 166 figs.

——— **1907.** Diseases caused by animal parasites. Osler's Modern Medicine, vol. I, pp. 525–638.

Stiles, Ch. Wardell & Frankland, W. A. A case of vinegar eel (Anguillula aceti) infection in the human bladder. Bull. 35 Bur. Animal Ind., U. S. Dept. Agric., Wash., pp. 35–40.

Stiles, Wh. and **Hassall, Albert. 1901.** Trichinosis in Germany. Bull. 30 Bu. Animal Ind., U. S. Dept. Agric. Wash. 211 pp.

Strong, Richard P. 1907. Amoebic dysentary. Osler's Modern Medicine, vol. I, pp. 488–524.

Theobald, Fred V. 1896. The parasitic diseases of poultry. 120 pp. 23 figs. 12°. London.

Wagner, Franz von. 1902. Schmarotzer und Schmarotzertum in der Tierwelt. Eine erste Einführung in die tierische Schmarotzerkunde. 151 pp., 67 figs. 16 mo. Leipzig.

Ward, Henry B. 1895a. The Asiatic lung distome in the United States. Medical News. March 2, 1895.

——— **1895b.** The parasitic worms of man and the domestic animals. Rept. Nebraska State Board of Agric. for 1904, pp. 225–348. 82 figs.

——— **1901.** Article, Cestoda, Ref. Handbook Med. Sci. vol. ii, pp. 779–794.

——— **1903.** Article, Nematoda. Ibed. vol. vi pp. 205–225.

——— **1904.** Article, Trematoda. Ibed., vol. vii, pp. 860–873.

——— **1907.** The influence of parasitism on the host. Science xxv, 201–218.

——— **1908.** Article, Protozoa. In Reference Handbook of the Medical Sciences, revised appendix. p. 634–660. 4°. New York.

Zurn, F. A. 1882. Die thierischen Parasiten auf und in dem Korper unserer Haurraügethiere, sowie die durch erstere veranlassten Krankheiten, deren Behandlung und Verhütüng. 2 Aufl. 8°. Weimar.