THE ALIMENTARY CANAL OF CALASOMA SYCOPHANTA LINNEAUS

HENRY A. BESS,[1]
Ohio State University

In the following discussion are presented the results of investigations made upon the general morphology and histology of the digestive tract of the carabid beetle *Calasoma sycophanta* Linnaeus. These studies were made principally upon hibernating beetles.

This beautiful green metallic beetle is a native of Europe but has become abundant in New England since its introduction in 1906 to aid in the control of the gipsy moth (*Porthetria dispar* L.).

METHODS

The material was collected at various points in New England during the early summer of 1932 and 1933. The bulk of the material was kept alive in moist sphagnum moss until ready to make the dissections for laboratory study.

Beetles were taken from the hibernation container and dissected in normal saline solution for general anatomical studies. Where the tract was to be used for histological studies the specimen was first killed in a cyanide bottle and then dissected in Kahle's solution. The alcohols and Cedar Oil were used for dehydration and clearing. Difficulties were encountered in staining the sections. One stain might be fairly good for one region of the tract while it would not take at all in another region. Delafield's Haematoxylin and Eosin, as well as Heidenhain's Iron-Haematoxylin, gave only fair results in the posterior portion of the tract.

In making drawings, either a Camera Lucida or a projection machine was used for making the outlines and putting in as many of the cell walls and nuclei as stood out vividly. The minute details were put in free hand by the aid of a planescopic

[1]The writer is indebted to Dr. C. H. Kennedy for his helpful suggestions and criticisms of this work, also to Mr. C. W. Collins, and his entomological assistants at the Gipsy Moth Laboratory, for assistance in obtaining material for these studies.

microscope. All drawings might be classed as diagramatic but care was taken to present the material as much like the actual sections as possible.

GROSS ANATOMY OF THE DIGESTIVE TRACT

GENERAL ANATOMY

The alimentary canal in this carnivorous species is only slightly greater in length than the insect's body. The three primary divisions of the canal, based on embryonic origin, are distinct and their limits are well marked. The relation of these primary divisions (stomodaeum, mesenteron, and proctodaeum) to each other, and their component parts, is shown in Fig. 1, Plate I.

FORE-INTESTINE

The fore-intestine (stomodaeum) is little more than an elongated thin-walled sac, except for the gizzard which lies just anterior to the oesophageal valve. The fore-gut extends caudad into the mesothorax, comprising slightly less than one-third of the total length of the entire canal.

The pharynx is the slightly dilated portion of the fore-gut just posterior to the mouth, which connects the mouth with the oesophagus.

The oesophagus is nothing more than a simple tube of variable length connecting the pharynx with the crop. It lies in the posterior portion of the head and the anterior one-third of the prothorax. The only essential difference between this region and the two it connects is size, the oesophagus being the smallest. Apparently the pharynx and oesophagus have no function other than that of conduction.

The crop is present as a dilation of the tract immediately posterior to the oesophagus. It is a rather capacious thin-walled sac lying in the posterior two-thirds of the prothorax and the anterior portion of the mesothorax. In all the freshly killed specimens dissected the crop contained enough air to keep the walls distended although little food was present in the digestive tract of these hibernating individuals.

The gizzard is a thick-walled oval region lying just posterior to the crop and bounded posteriorly by the oesophageal valve. This portion of the tract lies within the mesothoracic segment. It is generally referred to as a grinding organ.

The oesophageal valve shows up externally as a distinct constriction of the tract immediately posterior to the gizzard, marking the division between the fore- and mid-intestines. This structure is located near the junction between the mesothoracic and metathoracic segments. It possibly functions in preventing regurgitation.

MID-INTESTINE

The mid-intestine (mesenteron) or stomach forms a conspicuous part of the alimentary canal, although comprising only about one-third the total length of the tract. It is bounded anteriorly by the oesophageal valve, located near the anterior part of the metathorax, and posteriorly by the pyloric valve and Malpighian tubules, located in the fourth

abdominal segment. There is a gradual reduction in the diameter of the mid-intestine from about the middle toward the posterior end at the pyloric valve. The stomach is a slightly tortuous tube, invested with numerous closely packed small villus-like enteric coeca, but the latter are much reduced on the posterior third. The coeca vary in size and shape as to whether beetles are in a hibernating or active condition. In the hibernating forms the crypts are small and finger-like in shape, while the crypts of actively feeding individuals are larger and bulbous at their bases. It is in the region of the stomach that most of the secretion (and absorption?) takes place.

HIND-INTESTINE

The hind-intestine (proctodaeum) comprises slightly more than one-third the total length of the tract and is differentiated into three regions.

The pyloric valve is located at the union of the mid-gut with the hind-gut, where the Malpighian tubules arise. This valve supposedly serves to close the posterior end of the stomach.

The Malpighian tubules are attached in the region of the pyloric valve and are four in number. All arise separately and at about equal distances apart around the tract. The bulk of the excretory tubules lies within the general region of the pyloric valve, but they extend as far anteriorly as the metathorax, and as far posteriorly as the sixth abdominal segment. The total length of the four tubules is approximately sixty centimeters. Many beetles were dissected and in no case were there loose ends of Malpighian tubules found. Evidently they unite distally but the four do not always make a common union, if ever. The diagram in Fig. 7, Plate II, shows a fusion of tubules found in one dissection, but no duplication of this in other individuals was found. Frequently two tubules are found which are superficially fused, but by careful dissection they can be separated.

The ileum, frequently called the small intestine, is not easily differentiated from the colon in gross dissection. It follows a rather irregular course but lies almost wholly within the fourth abdominal segment. Its function is obscure.

The colon links the distal end of the ileum with the proximal end of the rectum. It is a rather tortuous tube confined almost entirely to the fifth abdominal segment. At the posterior end, where it unites with the rectum, it is considerably reduced in size. Functionally the colon is a conduction tube.

The rectum is quite large and lies within the fifth and sixth abdominal segments. Six rectal pads are visible along the anterior portion of the rectum. The rectum connects the colon with the anus.

HISTOLOGY OF THE ALIMENTARY CANAL

FORE-INTESTINE

The histological structure of the fore-gut is quite uniform throughout its parts with the exception of the gizzard. An examination of the sections of the wall of the fore-gut shows the following tissues from

within outwards: (1) Intima of cuticula or chitin, (2) Epithelium of hypodermal cells, (3) Longitudinal muscles, (4) Circular muscles, and (5) "Peritoneal membrane" of connective tissue cells. In the gizzard there are, in addition to the above, spines which arise from the intima and project into the lumen.

The fore-intestine is lined throughout with a rather heavy layer of non-cellular cuticula or intima. It projects into the lumen of this portion of the tract in irregular wave-like folds. In the gizzard this layer is much heavier and thickened in such a manner that in cross-section it appears to be heavy teeth projecting into the lumen. There are large chitinous plumose spines which arise in the intima of the gizzard and project more or less caudad into the lumen. These ridges of heavy intima probably function in grinding up particles of food while the spines possibly tend to prevent the food from being forced anteriorly during the grinding process.

The epithelium which is composed of flattened irregular hypodermal cells forms the tissue just outside the intima in the oesophagus and crop. In the gizzard the epithelium is composed of rather regular cells.

In the oesophagus and crop there lies immediately outside the epithelium a series of bundles of longitudinal muscle tissue. There are usually six such bundles located at fairly regular intervals around the tract. There are associated with these bundles of longitudinal muscles small ducts which are probably trachae. In the region of the gizzard the longitudinal muscles form four large bundles, alternating with the chitinous projections of the intima, which are an important part of the crushing or grinding apparatus.

Surrounding the longitudinal muscle layer in the oesophagus and crop is a rather uniform layer, one or two strands in thickness, of circular muscle tissue. In the gizzard this layer of circular muscles is much thicker, being composed of several strands.

MIS-INTESTINE

The mid-intestine or stomach is markedly different from the fore- and hind-intestines in that there is no intima and the relative positions of the circular and longitudinal muscles are reversed.

Through histological study the following sequence in the positions of the tissues is found in the stomach from within outward: (1) Digestive epithelium of endoderm cells supported by a basement membrane, (2) Circular muscles, (3) Longitudinal muscles, and (4) Connective tissue, known as "peritoneal membrane."

There is no evidence of a peritrophic membrane.

The cells of the digestive epithelium are slightly columnar in structure but vary in size and shape. Many sections showed evidence of a striated border. The location of the regenerative tissue, or nidi cells, was not cleared up to the satisfaction of the writer. From the study of hibernating individuals it appears that probably the regenerative tissue is located within the crypts. In Fig. 5, Plate I, a diagram of a longitudinal section of a crypt is shown which has many very small cells near the tip. Rungius (12) has illustrated the structure of the

digestive epithelium of the crypts of *Dytiscus marginalis* L. It is similar to that of *Calasoma sycophanta* L. However, these digestive epithelial cells in the crypts are frequently arranged so that their apical ends point more toward the opening of the crypt into the stomach than those shown in Fig. 5, Plate I.

Whether the very delicate basement membrane is located next to the digestive layer just described, or whether it lies just outside the layer designated X in Figs. 4 and 5, Plate I, has not been determined. The structure of this X-layer has not been adequately investigated, but it stands out very vividly in sections stained with Iron-Haematoxylin. There are nuclei (labeled Y) in this layer which may be regenerative tissue, or possibly the whole layer X is regenerative in function.

The outer layer of the crypts is composed of rather large distinct cells. This Z-layer is liberally supplied with trachae. That would indicate that the X-layer may have a large component of tracheoles.

Surrounding the X-layer in the main part of the mid-gut there are two to three layers of circular muscles. This muscle tissue is rendered less conspicuous by the numerous crypts which protrude through the wall of the stomach.

Surrounding the circular muscles are isolated strands of longitudinal muscles.

HIND-INTESTINE

Histologically the hind-intestine presents from within outwards the following tissues: (1) Intima, (2) Epithelium of hypodermal cells resting on a basement membrane, (3) Circular muscles, (4) Longitudinal muscles, and (5) Connective tissue, or "peritoneum."

The Malpighian tubules are external structures of the hind-gut which arise in the region of the pyloric valve. These tubules are made up of numerous cells with large ovate nuclei. The cells have a striated border on their inner margin. Surrounding these cells is a thin layer of connective tissue.

The pyloric valve is marked externally by the origin of the Malpighian tubules. Histologically it is a folding over of the epithelium of the hind-gut into the lumen of the mid-gut. The length of the lips of the valve varies in different individuals. The hypodermal cells of the epithelium are columnar in structure as is true of the epithelial cells of the oesophageal valve. The valve is lined with an intima of chitin which extends as far forward as the point of union between the mid- and hind-intestines. There are numerous circular muscles just outside the epithelial layer, a slight distance posterior to the union, which may function in closing the valve.

The intima of the ileum, or anterior portion of the hind-gut, is quite heavy. The intima in this region has spines which may be easily overlooked due to the digestive products which accumulate around them. The epithelial layer in this region is also quite thick and makes six large folds which project into the lumen. Just outside the epithelium within these folds are strands of longitudinal muscles. The circular muscle layer is several strands in thickness just posterior to the valve.

Strands of the outer layer of longitudinal muscles appear as six bundles immediately outside the circular muscle layer. Connective tissue is evident in some sections of the ileum.

The colon has much the same histological structure as the ileum, but differs in that the intima and epithelial layer are thinner. The size of the colon is much reduced near the point of union with the rectum.

The rectum is much larger and has a much thinner wall than the other divisions of the hind-gut. There are six rectal pads located on the inner surface of the wall of the rectum near the anterior end which may be plainly distinguished due to the thickness of the rectal wall. These pads are composed of very large cells with ovoid nuclei. The pads lie between the intima and the very delicate epithelial layer. The layer of circular muscles which lies immediately outside the epithelial layer is but one to two muscle strands in thickness. The longitudinal muscles appear outside the circular muscles as six irregular bundles.

CONCLUSIONS

The alimentary canal of *Calasoma sycophanta* L. is slightly longer than the insect's body, a length which corresponds to its carnivorous habits. The three primary regions of the canal known as the stomodaeum, mesenteron, and proctodaeum are well defined, and show the following specializations:

Stomodaeum, or Fore-intestine.—Pharynx, oesophagus, crop, gizzard and oesophageal valve. It is ectodermal in origin and thus lined throughout with chitin.

Mesenteron, or Mid-intestine.—The whole region is known as stomach and is endodermal in origin, having no intima. There are evaginations of the digestive epithelium in the form of villus-like projections, termed crypts. These increase the area of the digestive epithelium enormously, and it is this layer which has to do with the secretion and absorption connected with digestion.

Proctodaeum, or Hind-intestine.—Pyloric valve, four Malpighian tubules, ileum, colon and rectum. There are six oval rectal pads on the anterior end of the rectum. The hind-gut is lined throughout with chitin, being ectodermal in origin.

The present study of the crypts has been far from sufficient enough to clear up their histology thoroughly. It is hoped that a more complete study of these structures will be possible.

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EXPLANATION OF PLATES

PLATE I

Fig. 1. A dorsal view of the alimentary canal.
Fig. 2. Cross-section through oesophagus.
Fig. 3. Cross-section through gizzard.
Fig. 4. Cross-section through crypt.
Fig. 5. Longitudinal section through crypt.

PLATE II

Fig. 6. Longitudinal section through oesophageal valve.
Fig. 7. Diagram of fusion of Malpighian tubules. (See text.)
Fig. 8. Longitudinal section through pyloric valve.
Fig. 9. Cross-section through anterior portion of mid-intestine.

PLATE III

Fig. 10. Sketch of crypts of a hibernating beetle.
Fig. 11. Sketch of crypts of a beetle in the active feeding condition. Drawn to same scale as Fig. 10.
Fig. 12. Cross-section of anterior ileum.
Fig. 13. Highly magnified portion of a cross-section of posterior rectum. (Muscle striations are much closer together than shown in any of these figures. There should be three muscle bands in a space the length of a muscle nucleus.)
Fig. 14. A portion of a cross-section through the region of the pyloric valve, showing entrance of Malpighian tubule.
Fig. 15. Cross-section of colon.
Fig. 16. Cross-section through a rectal pad.
Fig. 17. Cross-section of Malpighian tubule near origin.
Fig. 18. Cross-section through anterior rectum, showing rectal pads.

KEY TO ABBREVIATIONS

An. Gl.—Anal gland.
An. Gl. Res.—Anal gland reservoir.
C. Mus.—Circular muscle.
Co.—Colon.
Cr.—Crypt.
D. Epi.—Digestive epithelium.
Epi.—Epithelium.
Giz.—Gizzard.
Il.—Ileum.
Int.—Intima.
L. Mus.—Longitudinal muscle.
Lu.—Lumen.
M. T.—Malpighian tubule.
M. I.—Mid-intestine.
Oes.—Oesophagus.
Oes. V.—Oesophageal valve.
Ph.—Pharynx.
Rec.—Rectum.
Rec. Pad—Rectal pad.
Sp.—Spine.
Tr.—Trachea.
X—Layer which stains very dark with iron-haematoxylin.
Y—Possibly nucleus associated with regenerative tissue.
Z—Layer of rather large cells with distinct nuclei. Not fat cells.

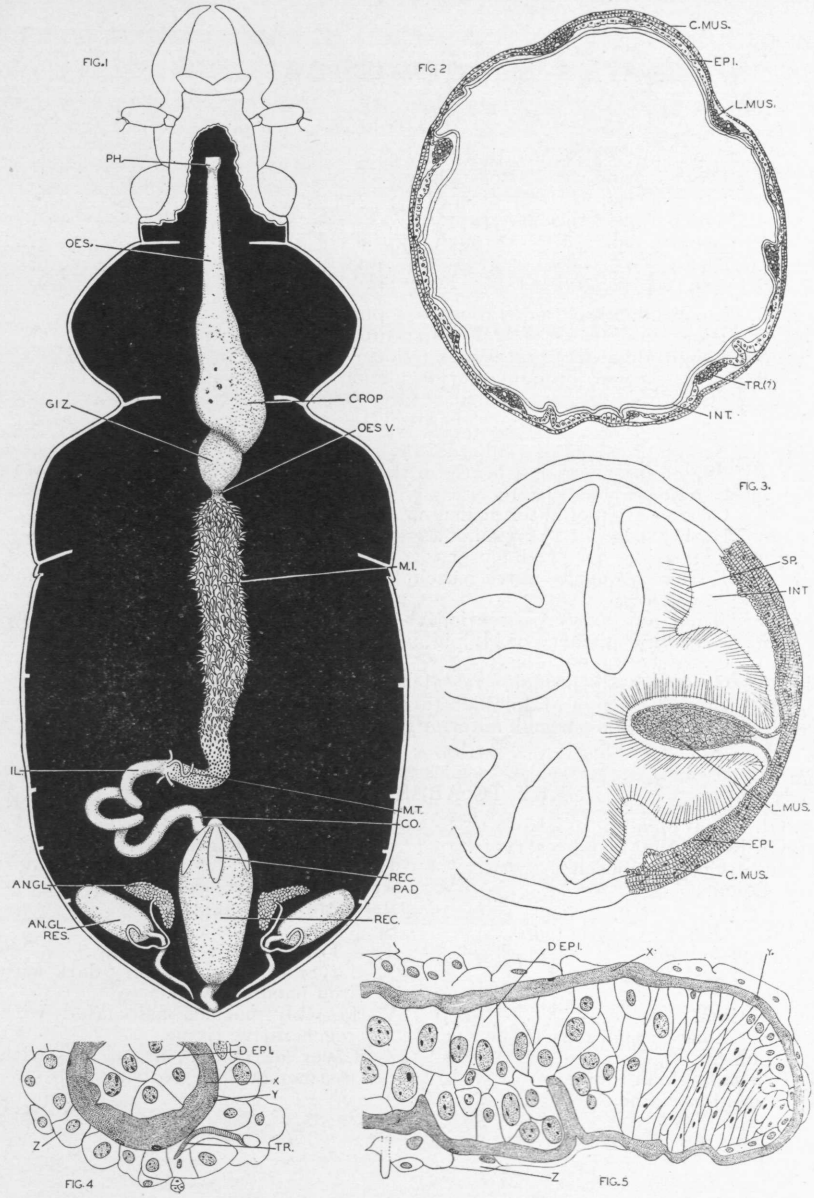


FIG.1
PH.
OES.
GIZ.
CROP
OES V.
M.I.
IL.
M.T.
CO.
REC. PAD
REC.
ANGL.
ANGL. RES.
FIG 2
C.MUS.
EPI.
L.MUS.
TR.(?)
INT.
FIG. 3.
SP.
INT
L.MUS.
EPI.
C. MUS.
D EPI.
X
Y
Z
TR.
FIG.4
D EPI.
X
Y
Z
FIG.5

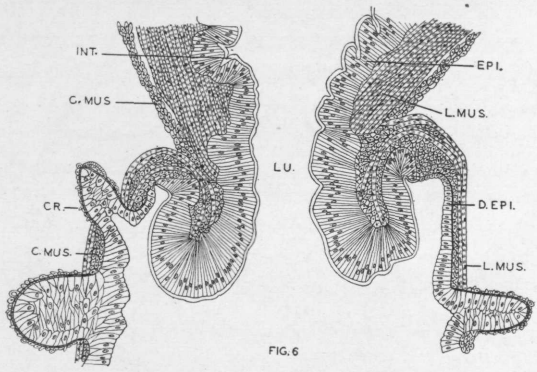


FIG. 6

FIG. 7

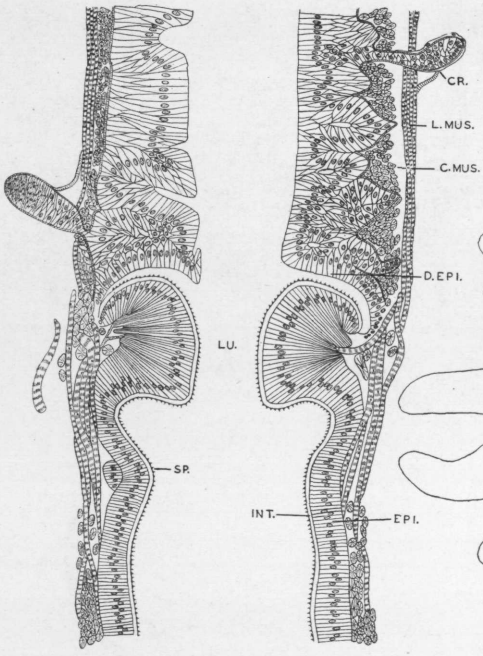


FIG. 8

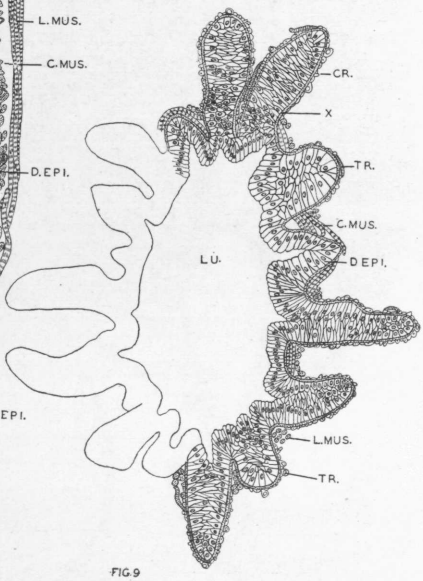
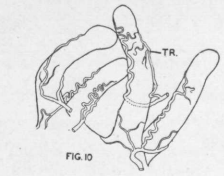


FIG. 9



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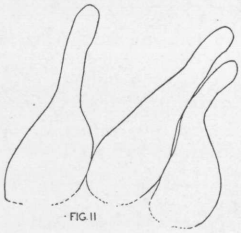
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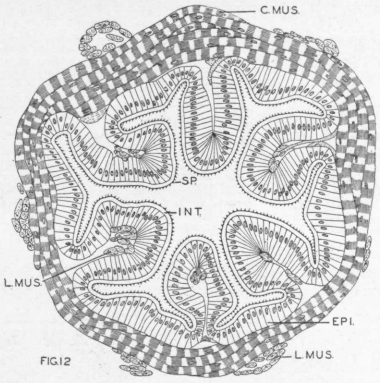

FIG. 12

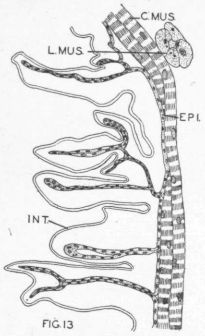

FIG. 13

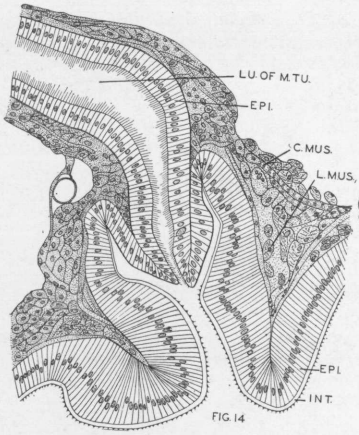

FIG. 14

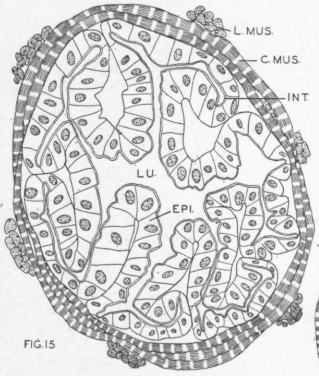

FIG. 15

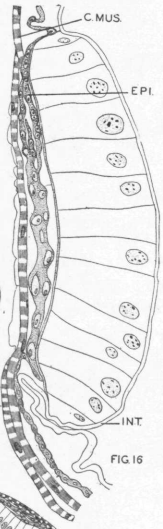

FIG. 16

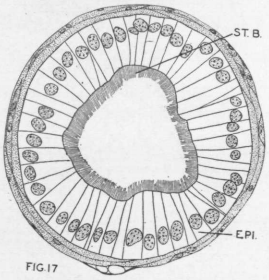

FIG. 17

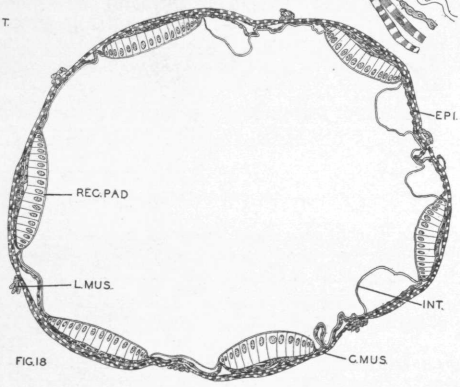

FIG. 18

BOOK NOTICES

Man and His Biological World.

This is the second part of a two-volume introductory science course, the first part of which was reviewed in the September 1934 number of this journal. The book is written in easy conversational style, and brings out in a very interesting way the basic facts of biology. The attempt to make the book interesting has, however, been somewhat overdone, resulting in a lowering of the level of prospective students. As it stands, the book should be excellent for courses in high school biology, but probably not for college students, who should by college level be ready for more advanced material than is presented in this text.—L. H. S.

Introductory Course for Science in Colleges, II, Man and the Nature of his Biological World, by F. C. Jean, E. C. Harrah, F. L. Herman and S. R. Powers. x + 589 pp. Boston, Ginn & Co., 1934.

Health and Disease

This monumental volume is written to give to medical students, clinicians and practicing physicians a fundamental understanding of the principles of physiology which underlie the workings of the human body in health and disease. It is an inclusive and all-embracing volume, covering in its nearly 1,200 pages the methods of physiology, the principles involved, and a wealth of detailed information, with appropriate citations to the literature. Inevitably some subjects are sketchily handled, but on the whole the work is a real contribution to medical physiology.—L. H. S.

Physiology in Health and Disease, by C. J. Wiggers, M. D. xxvii+1156 pp. Philadelphia, Lea and Febiger, 1934.

A Co-operative Discussion of Psychological Thought

A group of specialists have brought together, under the editorship of Dr. F. A. Moss, a fine discussion of modern comparative psychology. Beginning with the historical background of the subject, the chapters proceed through "instinctive" functions, incentives and drives, effects of hormones, functions of receptors, the problems of discrimination and learning, the measurement and implications of individual differences, social concepts, and special abilities. The authors have done a fine piece of team-work, and have largely overcome the usual objections to a co-operative venture in writing.—L. H. S.

Comparative Psychology, by twelve psychologists, edited by F. A. Moss. xiii+529 pp. New York, Prentice-Hall, 1934.

What is Truth?

This is one of the most stimulating books it has been the good fortune of this reviewer to read in a long time. Pilate's age-old question is subjected to a searching analysis, resulting, of course, in the conclusion that the question itself is really devoid of meaning. The steps in the process of reaching this conclusion are, however, beautifully laid out. The book is replete with sentences and paragraphs that the reader could wish to frame and keep ever before him. Many of them will remain engraved on his memory for all time to come. To all searchers after truth this book is recommended as a bright light on a dim road.—L. H. S.

The search for Truth, by Eric Temple Bell. x+279 pp. Baltimore, The Williams and Wilkins Co., 1934.

Is the World a Soulless Mechanism?

"The Great Design" presents a brilliant symposium of all the sciences written by fourteen eminent scientists who have been asked "to state in outline how the world seems to them, first as scientists and then as men." Every subject, from stars to the green leaf, has been carefully and painstakingly developed and the result is a broad survey of science which is understandable to the layman and acceptable to the most exacting of scientists.

The only fault one can find with the book is the "purpose" for which it was written. Sir J. Arthur Thomson expresses it thus: ". . . we are writing primarily for those who have not this assurance (that 'God's in His heaven, all's right with the world'), yet may be helped toward it by thinking quietly over the world which Science discovered, and by enjoying it, too."

Many of the writers are extremely scientific in the analyses of their particular fields, ignoring the whole matter of design in nature. Then they awaken to the fact (in the last paragraph of their chapter) that they must "present evidence that might seem to point to Mind or Intelligence behind nature," and they fulfill their "purpose" by quoting a poem, or an excerpt from the Bible.

The book gives intellectual satisfaction to those who are interested only in the philosophical implications of science, and scientific satisfaction to those who accept only the facts and accuracies of science and not metaphysics. Driesch, Metcalf, MacBride and the others seem to have combined the scientific and philosophical fields to their own satisfaction, but—is it Science?—H. S. HYMAN.

The Great Design, edited by Frances Mason. 324 pp. New York, The Macmillan Company, 1934.

Bibliography of Nature Study

For the use of teachers and others interested in nature study Professor Vinal has collected a bibliography of nearly two thousand titles together with their sizes, pages, publishers and prices. A loose attempt at classification of the titles has been attempted and some are indicated as especially suited for children. The list is composed entirely of titles in book form such as would appear in publishers catalogues and omits journal or magazine articles. In other words it is a book list. It might be of particular use in establishing a nature study library.

—D. F. M.

Nature Education—A Selected Bibliography, by W. G. Vinal. School of Education, Western Reserve University, Cleveland, No. 39; 82 pp. 1935. Unbound, mimeographed. Price, 75 cents.

Minerals

This handy book is divided into three parts; first, "About Minerals in General," in which in 126 pages are given the general phenomena and the various ways of handling them. The second part confines itself to the "Description of Minerals," where, in 124 pages, are described some 180 fairly common or important minerals. The third, "Description of Rocks," devotes 11 pages to handling some two dozen common rock types. Appendix I has tables for identification of minerals (33 pages). Appendix II is a Pronouncing Vocabulary, six pages with a good index at the end. For the numerous amateur mineral-collectors this is a good beginning handbook. For those who desire to know the more abundant minerals it should prove a great boon. It is not technical as are the orthodox books on minerals. On the other hand, it is not a great departure from the classic texts. For the casual student of minerals, it should prove very useful. Mr. English has produced a book which eloquently speaks for itself and which should find many users.—WILLARD BERRY.

Getting Acquainted with Minerals, by George L. English. xi+324 pp., 258 illustrations. Rochester, N. Y., Mineralogical Publishing Co., 1934.