Chapter 9

Applying the Learning-Cycle Approach to Digestive Systems and the Principles of Structure-Function and Unity with Diversity

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Introduction

Origin of this Exercise at the University of Missouri-St. Louis

This biology laboratory exercise was developed to help students functioning at the concrete cognitive level to progress into the formal operations required for conceptual and critical thinking in science. In the exercise, students develop the concept of the interrelation of structure and function in digestive systems and the concept of unity with diversity among organisms. This laboratory was developed as part of a total restructuring of a majors entry-level course that was funded by a grant from the Fund for Post-Secondary Education (FIPSE).

Introductory biology for majors is a one-semester course at the University of Missouri-St. Louis. It is designed as an introduction to the basic principles of biology for students who are planning biology majors and entering health-related fields or allied sciences. In addition, an important goal is to introduce students to experimental design, data analysis, and the nature of science. It is a prerequisite for all sophomore and higher-level courses. The course consists of three teaching components, a 3.5-hour laboratory per week, three 50-minute lecture periods, and 1-hour discussion period.

The students in the course come from very diverse academic backgrounds. An increasing number of the students were not completing this prerequisite course satisfactorily and, therefore, could not pursue biological careers at our university. It appeared to the staff of the course that students who were not surviving lacked the ability to solve problems using logical systematic paradigms, and had great difficulty forming and manipulating the conceptual ideas that provide the framework of biology and an understanding of scientific inquiry.

Our Approach: The Learning Cycle

With the help of the FIPSE grant, the course was redesigned. The restructuring of the course incorporated the learning cycle concept formulated by Atkins and Karplus (1962) from the cognitive development theories of Jean Piaget, as explained by Wadsworth (1984). The portion of the Piagetian learning theory that applies at the early college level is the recognition that before individuals can use formal reasoning skills, such as those required in science, they benefit from a period of manipulation or direct interaction with phenomena. This provides the concrete basis for forming and processing the more abstract ideas.

The learning cycle consists of three phases: (1) exploration, (2) concept introduction, and (3) concept application. The laboratory setting particularly lends itself to the exploration type of activity. So, in the restructuring process, the laboratory was designed to precede the lecture presentation and initiate concept introduction — a unique order. After development of these concepts in lecture, the discussion component provides opportunities for students to apply these concepts to additional situations and work out answers to their questions.

Each 3.5-hour laboratory exercise utilizes the three phases of the learning cycle. The students begin by exploring biological materials, aided by suggestions and leading questions in the text of their manual. The students are then guided by questions in the laboratory outline to develop concepts from their observations and manipulations. Finally, students apply the concept to new material and situations, thus providing an opportunity for the "seating in" of the concept.

Success of Teaching Strategy

This teaching strategy lets students begin with the material at whatever level they have previously attained and expand their understanding. Our "better" students enjoy the learning cycle lab format and are not bored. Students with less advanced thinking skills earn approximately one letter grade higher than the traditional style of verifying information presented previously in lecture or text. All students are not completing the course satisfactorily, but more of our entering non-formal thinkers are progressing further than with the traditional approaches.

Notes for the Instructor

Duration

Though designed for a 3.5-hour period, this laboratory exercise can be adjusted to different time periods. If two 2-hour periods are used, the exploration of *Necturus* and earthworm can be completed in the first 2 hours, and the remaining activities can be finished in a second 2-hour period. On eliminating Part IV, the laboratory can be finished in one 3-hour period. If the instructor requires the optional section on gut/body ratios in carnivores and herbivores and encourages maximum exploration and curiosity of the students, then this laboratory can easily expand to two 3-hour periods.

Use of Specimens

If fresh organisms are preferred to preserved ones, freshly killed mice or rats can be substituted for the preserved fetal pigs, and adult frogs for *Necturus*. Carolina Biological Supply Co. (2700 York Rd., Burlington, NC 27215) and Nasco Science (P.O. Box 901, 901 Janesville Ave., Fort Atkinson, WI 53538-0901) are sources of live *Necturus* and adult frogs. Preserved specimen are about $1.00 more than living organisms. However, preserved pigs and *Necturus* can be used for additional laboratories on other organ systems and, therefore, are very cost effective.

Laboratory Safety

If preserved specimens are used, it is recommended that the preserved materials be washed with a stream of running water for 1 hour, and again washed after opening the specimen. As with any preservative, the laboratory space should be adequately ventilated. Supplying disposable gloves for students is recommended.

Use of a Video Demonstration

The video demonstration of movement of water as it relates to surface area can be presented as a live demonstration if taping equipment is not available, if this is the teaching preference, or if strategy warrants it. However, the students can use the taped demonstration at any time during the lab, and it is not necessary to interrupt students in the middle of other explorations for a live demonstration. The live demonstration can be performed by two students utilizing very simple laboratory equipment (Figure 9.1.): two rings and ring stands, two funnels with blunt ends, two coarse filter papers, two paper towels, and two 5-ml pipets.

Figure 9.1. One of two equipment set-ups for demonstrating relation of surface area to passage of materials.

Set each funnel in a ring stand with the blunt end of the funnel tube resting on a paper towel. Place a large piece of slightly damp filter paper into one funnel. In the other funnel, place another piece of equally damp filter paper that has been reduced in area by trimming the diameter to about one-half of the size of the filter paper in the first funnel.

Simultaneously, two student demonstrators add 5 ml of water to the entire surface areas of the filter papers in the funnels. Releasing the water during the count of 10 helps to standardize the release rate. Measuring the rate of expansion of the two water puddles on the paper towels below the funnels gives an estimate of relative water movement through the filter paper surfaces.

Substitution of Materials

Compound light micrographs and electron micrographs of the intestinal tract can be substituted for the histology film strip (which accompanies Leeson and Leeson, 1970). These are readily available in histology and cytology texts or atlases. This activity can be eliminated to make more time available for other activities.

Diagrams, wall charts, photographs, models, and labelled fresh or preserved specimens can be substituted for biomounts. Three-dimensional specimens or models are highly recommended over two-dimensional diagrams and photos for explorations by students still in the concrete stages of cognitive development.

Materials

Materials for each pair of students:
Fetal pig, preserved (1)
Necturus, preserved (1)
Blunt metal probes (2)
Wooden dissecting needles (2)
Fine-pointed scissors (1)
Forceps (1)
Metric ruler (1)
Dissecting tray (1)
Plastic bag, zip-lock type for pig and *Necturus* storage (1)
Label for identification of plastic bag (1)

Materials shared by the class (20–24 students):

Heavy scissors, to cut *Necturus* and pig jaws (4)
Storage pans for pigs
Opened earthworms in dissecting trays (4)
Open each worm by cutting through the dorsal wall to display the intact digestive system. Use scissors with points kept parallel to worm. Use pin or needle to release septa. Use straight pins to hold down the sides of earthworm. These worms may need to be replaced after several sections have used them.
Meter sticks (2)
Fetal pig dissection manuals, optional (5)
Necturus dissection manuals, optional (5)

Classroom demonstrations: (See Appendix A: Preparing Solutions)

Set-up for protein digestion:

Sign reading “PROTEIN DIGESTION” + “DO NOT SHAKE TUBES” (posted on ring stand)
Ring-stands with test tube clamps (4)
Large test tube with cap (1; labelled “Protein + Water”) which contains:
3–5 cubes of hard-boiled eggwhite
50 ml water
Large test tube with cap (1; “Protein + Oral Juice”) which contains:

3–5 cubes of hard-boiled eggwhite (same size and number as above)
45 ml water
5 ml amylase solution
Large test tube with cap (1; "Protein + Stomach Juice") which contains:
3–5 cubes of hard-boiled eggwhite (same size and number as above)
45 ml water
5 ml pepsin solution
Large test tube with cap (1; "Protein + Pancreatic Juice") which contains:
3–5 cubes of hard-boiled eggwhite (same size and number as above)
45 ml water
5 ml pancreatin solution
Allow at least 24 hours at 35°C or 48 hours at room temperature for protein digestion to occur in these four tubes. These tubes may need to be replaced every second or third day because of bacterial action.

Set-up for starch digestion:

Sign reading "STARCH DIGESTION" (posted on ring stand next to bottles)
Dropper bottle (1; labelled "Starch Solution + Water") which contains:
45 ml starch solution (see Appendix A)
5 ml water
Dropper bottle (1; "Starch Solution + Oral Cavity Juice") which contains:
45 ml starch solution
5 ml amylase solution
Dropper bottle (1; "Starch Solution + Stomach Juice") which contains:
45 ml starch solution
5 ml pepsin solution
Dropper bottle (1; "Starch Solution + Pancreatic Juice") which contains:
45 ml starch solution
5 ml pancreatin solution
Dropper bottle of iodine potassium iodide (labelled). This can be kept for a number of semesters.
Spot plate (1)

Set-up for fat emulsification:

Sign reading "FAT DIGESTION" (posted on ring stand)
Large test tube with cap (1; labelled "Oil + Water") which contains:
3 ml vegetable oil
15 ml water
Large test tube with cap (1; "Oil + Bile Duct Juices") which contains:
3 ml vegetable oil
15 ml water
pea-sized pinch of bile salts (or substitute a non-sudsing detergent)
Test tube rack (1)

Note: If the oil sticks to the sides of the tubes, try heparinizing the two test tubes to prevent the sticking, or try de-mineralized water, or try soft animal fat. The tube with bile salts should stay emulsified much longer than the one without bile salts.

Microscopes and prepared slides:

Compound light microscopes (2)
Cross-section of mammalian duodenum (1) (Use scanning objective; put pointer on a longitudinal section of a villus.)
Cross-section of earthworm intestine (1) (Use scanning objective; put pointer on edge of typhlosole.) Label each microscope with appropriate signs

Audiovisual aids:

VCR, monitor, and video tape of "Demonstration of surface size and water absorption" (Produced in-house from description in Notes for the Instructor.)
Film strip projector and screen
The film strip which accompanies Chapters 12–20 of the textbook, *Histology II*, by Leeson and Leeson (1970).
Note: See substitutions listed in Notes for the Instructor.

Biomounts, models, and specimens:

Biomounts are produced by Carolina Biological Supplies Co. and Ward's Natural Science (Rochester, NY 14692-9012):
Earthworm biomount
Chicken biomount
Human digestive sections biomount or use tissue from fetal pig
Human torso model
Preserved, sectioned sea anemone; put in a dissecting pan and cover with plastic wrap.
Index card labels for each of the above models and biomounts.
Note: See substitutions listed in Notes for the Instructor.

Student Outline:

Structure-Function and Unity with Diversity

Part I: Exploration of Digestive Tracts and Principle of Structure-Function

Advertising blitzes of rival hamburger palaces extol the virtues of their products in the communication media. But, in all likelihood, whether you eat a "Whopper" or "Big Mac" is inconsequential to your digestive system when it comes to the digestion of the beef, pickles, onions, ketchup, and bun. What does matter is whether or not your tract has the necessary equipment to carry out the digestive activity on the proteins, fats, and carbohydrates found in meat, the bun, and condiments. In this laboratory session, you will explore the digestive equipment in several organisms to determine how it is structured and how it functions.

A: The Digestive System of a Carnivorous Amphibian: *Necturus*

A1. The mudpuppy, *Necturus maculosus,* (phylum: Chordata; class: Amphibia) has no opportunity to amble down to the local hamburger palace but will eat meat or a choice insect or two if these can be found in their habitat at the bottom of the rivers and streams in the central and eastern United States.

Necturus is an amphibian that keeps its larval form throughout its adult life. Other amphibians, such as frogs, metamorphose from a tadpole larval stage to a different adult form suitable for surviving in a terrestrial environment. Like adult frogs, the mudpuppy does prey upon animals that it finds in its muddy bottom home. Therefore, it is a carnivore.

A2. Dissection: Open a preserved specimen of *Necturus* by cutting the abdominal and chest walls as illustrated in Figure 9.2. Locate a long tube-like structure that is anchored at both the head (cephalic) and tail (caudal) ends. Help with anatomical terms can be found in Table 9.1 and Figures 9.3 and 9.4

Explore this tube, the digestive tract. Feel it. Note the type of material, thicknesses of its parts, expanded areas, constricted areas, and texture of the surfaces. Thoroughly explore openings into the tube visually, and then with your finger and/or a blunt probe. Open the tract by making a cut down its entire length. Thoroughly inspect the inner surfaces and all openings into the tract. Double check any judgments that you made about thicknesses of the unopened tract. Check for any other structures and accessory organs that are connected to the digestive tract by small tubes.

A Note About the Technique of Dissection and Some of its Tools

Dissection and butchering do not use the same technique. The goal in dissection is to separate the structures of the organism from each other so they can be carefully examined, not to cut the organism into eatable chunks. This means that the cutting tools of scissors, scalpel, or razor blade are rarely used. These tools are useful for the initial opening of organisms or opening large internal structures. The major separation tool for macroscopic structures is the blunt metal probe. For smaller structures, the dissecting needle or glass needle can be used. Many organs are anchored by a thin membrane-like tissue that is easily removed by gently moving the separation tool around the structures.

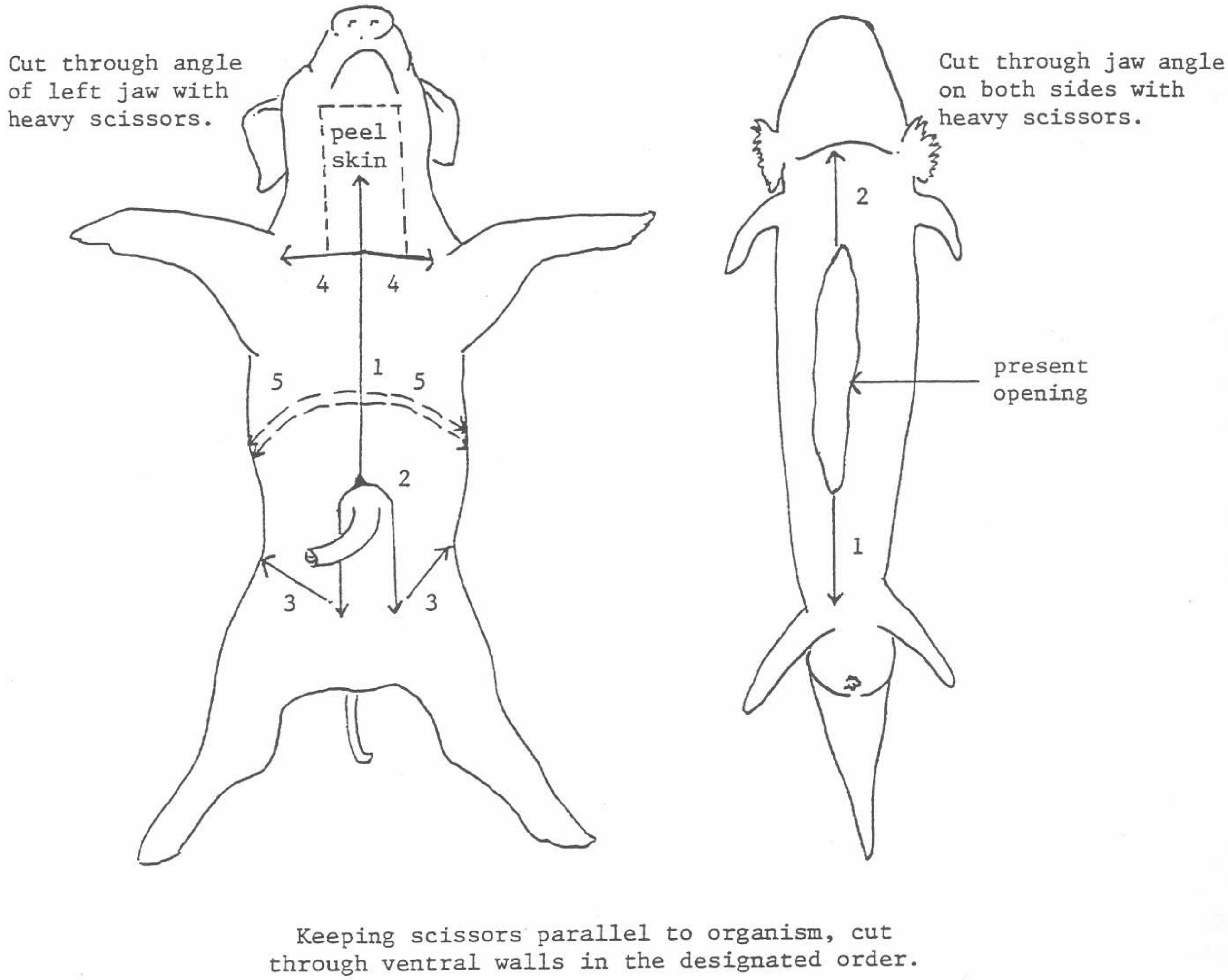

Figure 9.2. Opening the abdominal and chest walls of fetal pig and *Necturus*.

Table 9.1. Anatomical vocabulary.

Term	Definition
right or left	the organism's right or left
anterior	toward the head (biped, front)
cephalic	toward the head
posterior	toward the tail (biped, back)
caudal	toward the tail
dorsal	toward the back
ventral	toward the belly
lateral	toward the side (right or left)
medial	toward the middle or center
proximal	near a specified point of reference
distal	away from a specified point of reference
pectoral	referring to the shoulder region
pelvic	referring to the hip region
superior	biped, toward the head
inferior	biped, toward the foot

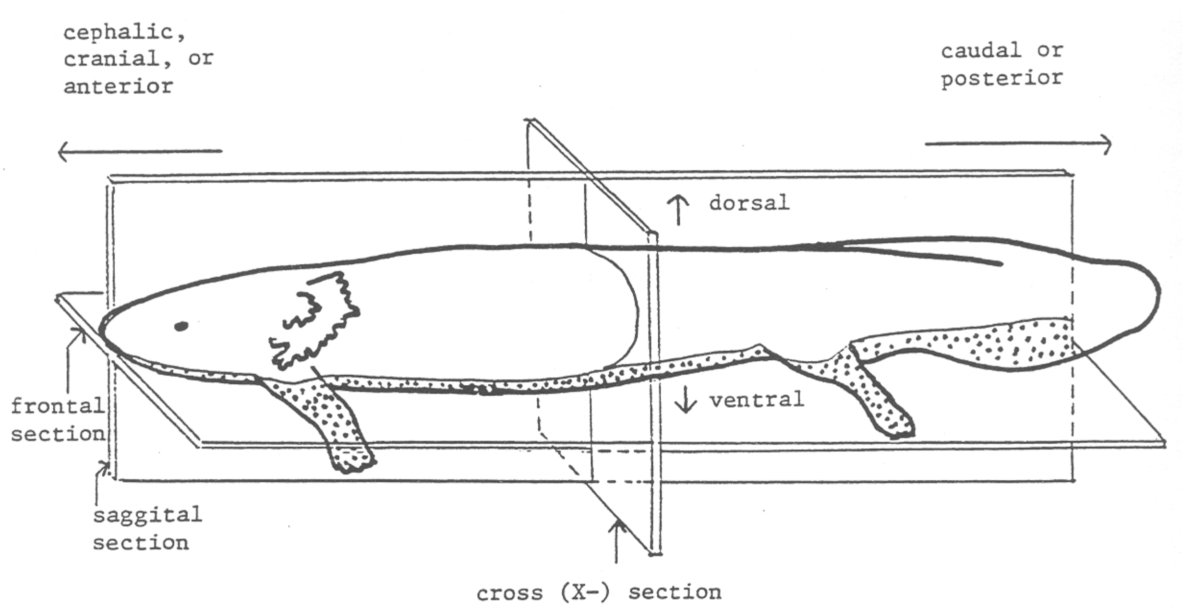

Figure 9.3. Anatomical terms associated with dissection of quadruped

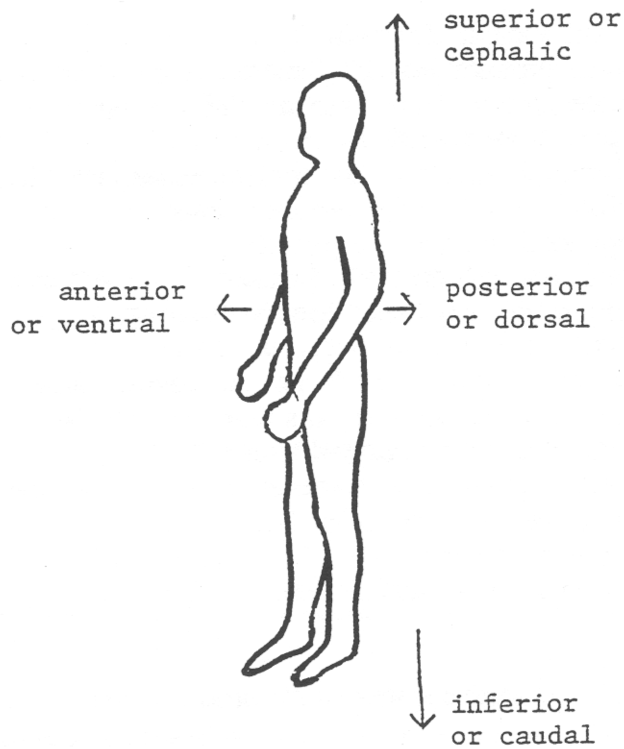

Figure 9.4. Anatomical terms associated with dissection of biped.

A3. Review the differences in structure along the digestive tract. Record your findings in columns A and B of Table 9.2 by describing the different sections in their order from the cephalic end. Examples are given in Table 9.2. To help identify which part of the digestive tract is being described, record the length (in mm) of the different sections along the tract. To measure the length of curved structures lay a string along the structure then measure the length of the string. Do not bother with names for these parts now. You can add names to these structures later as an optional activity.

A4. Recall your previous knowledge of the digestive processes. (You probably have more accumulated knowledge than you realize.) In Column C of Table 9.2, try to assign digestive activities to the structures. Use the following list of functions to supplement your present knowledge of digestive processes. If you have difficulty pairing all of these functions with a part or parts of the tract, do not despair. Pair what you can at this time and return to this task after you have completed some of the other laboratory activities that are designed to increase your working knowledge of digestive processes.

Functions of digestive tract segments in mammals:

(a) Holds food for subsequent digestion.
(b) Chemically breaks proteins into smaller units such as amino acids.
(c) Chemically breaks carbohydrates into smaller units such as sugars.
(d) Separates fats into smaller particles of fat.
(e) Absorbs small units of digested food molecules into the blood transport system.
(f) Stores unused food particles for later elimination.
(g) Physically chops food into smaller particles.
(h) Churns food particles with digestive juices.
(i) Houses microorganisms that break down cellulose, a tough complex carbohydrate found in plant material.
(j) An accessory organ: produces starch, protein, and fat breaking enzymes.
(k) An accessory organ: produces bile salts that emulsify fats.
(l) An accessory organ: concentrates and stores bile.
(m) An accessory organ: produces enzymes that break down starch.
(n) Moves food from one structure to another.
(o) Moves food within a structure.
(p) Absorbs water into the transport system.

Table 9.2.* Digestive system of *Necturus maculosus,* the mudpuppy.

A Distance along the digestive tract (mm)	B Specific description of structure and location	C Description of possible function	D Possible name of structure
2–10 mm from anterior end; in oral cavity	Sharp, hard, lateral and anterior ridges with many backward-pointed conical bumps; on dorsal and ventral jaws	Separation of food into small particles by compression of lower ridge against upper ridge; hold active prey	Teeth
6–12 mm; in oral cavity	Muscle covered bony projection from mid-ventral surface	Limited movement of material in cavity; masher	Tongue

* The table provided for students has additional blank rows and fills one entire page.

B: The Digestive System of a Detritivore: Earthworm

B1. About the organism: Well known as fish bait and as food for birds, earthworms also facilitate the growth of plant roots by turning over soil. This turnover makes soil more porous, allowing air to penetrate and water to drain. In their burrowing activity, worms swallow soil particles, grind them to small pieces, absorb some of the organic matter as food, and discharge the residue back into the soil. A 10-year deposition of soil processed by earthworms was estimated by Charles Darwin to be equal in volume to a 5-cm layer over the entire land surface of the earth!

B2. Digestive system of the earthworm, *Lumbricus terrestris* (phylum: Annelida; class: Oligochaeta): Obtain a dorsally-opened earthworm from the preparation table. You will find many cross-partitions, septae, which separate the worm into segments. Find and explore the digestive tract of the worm as you did for *Necturus*. Record your information in Table 9.3.

Table 9.3.* The digestive system of *Lumbricus terrestris*, an earthworm.

A Distance along the digestive tract (mm)	B Specific description of structure and location	C Description of possible function	D Possible name of structure

Another type of complex food molecule is oil or fat. Observe what happens to oil when shaken with juice from the bile duct which connects the liver and gall bladder to the small intestine (see C4).

C2. **Starch and digestive juices:**

Starch, water and iodine solution (I_2-KI): Transfer a few drops of starch solution from the bottle labelled "starch and water" to one of the shallow depressions in the white "spot plate." Add 1 drop of iodine solution to the starch solution in the depression. Record the results in Table 9.4, located at the end of this section. Your observed results occurred as the large starch molecules and iodine interacted. Obtaining these results on the addition of I_2-KI solution to a possible starch-containing material indicates that starch is present. This procedure is a test for starch.

Starch and oral cavity juice: To a second depression, add the starch solution which was previously combined with oral cavity juice. Again add 1 drop of I_2-KI solution. Record the results in Table 9.4. Compare the result of this test to the result obtained with solution of starch and water. Is there any starch in the solution to which oral cavity juice was added? What evidence was used to determine your answer?

Stomach and stomach juice: Repeat the activity, but use starch solution combined with stomach juice. Record your results.

Starch and pancreatic juice: Repeat the starch test using the starch solution with pancreatic juice.

Please clean, rinse and dry the spot plate, preparing it for the next student.

C3. **Protein and digestive juices:** Observe each tube that initially contained hard-boiled eggwhite cubes of equal size. One type of fluid was added to each tube, as follows:

Tube A: Water
Tube B: Oral cavity juice
Tube C: Stomach juice
Tube D: Pancreatic juice.

In Table 9.4, describe the condition of the eggwhite cubes in each tube. If you can, explain why Tube A was prepared.

C4. **Oils and bile duct material:** Inspect two tubes that contain 3 ml of oil. Tube A has only water and oil. Tube B has juice from the bile duct in addition to water and oil. While holding the stopper with your finger, shake each tube with the same amount of vigor. What happens to the contents of each tube 10 seconds after completing the shaking action? After 1 minute? After 5 minutes? Record your data in Table 9.4. Does each tube appear to contain the same amount of oil after 5 minutes? If it is a fact that the quantity of oil has not been diminished by digestion in either tube, what other possible actions of bile explain your observations? What hypothesis do you propose for the effects of bile in the digestive processes?

C5. Utilizing the results from this exploration of digestive activity, return to Tables 9.2 and 9.3 and complete Column C.

Table 9.4. Digestive activity.

Food type	Container	Fluid with food	Description of results	What digestive activity is occurring?
Starch	A	water		
	B	oral juice		
	C	stomach juice		
	D	pancreatic juice		
Protein	A	water		
	B	oral juice		
	C	stomach juice		
	D	pancreatic juice		
Oil	A	water	0 seconds	
			10 seconds	
			1 minutes	
			5 minutes	
	B	water, bile, salts	0 seconds	
			10 seconds	
			1 minutes	
			5 minutes	

D: Naming Organs (Optional)

The names usually used for these specialized sections of the digestive tract and the accessory organs can be found by consulting references and labelled specimens available in the laboratory. These names may be added to Column D of Tables 9.2 and 9.3. Some of the names you might want to consider are:

anus
appendix
caecum
crop
epiglottis
esophagus
gall bladder
gastrovascular cavity
gizzard
glottis
ileocolic valve
intestine, small
intestines, large
liver
lysosome
oral cavity
palate, hard and soft
pancreas
pharynx
pyloric valve
rectum
salivary glands
smooth muscle in wall of tract
stomach
teeth
tongue
tonsils
ulvula

E: Synthesizing Observations and Forming a Principle

E1. If you have not already begun, it is time to think in a general way about your experiences with digestive systems. Take a moment to synthesize your separate, discrete, observations into an explanatory concept that links a large number of digestive phenomena.

Review Columns B and C of Tables 9.2 and 9.3. Have you been able to find relationships between the structure of the different sections of the digestive tract and digestive activities such as those recorded in Table 9.4?

Support your answer by pointing out several specific examples from your explorations of the structures of *Necturus* and earthworm digestive tracts. Then, take an important step in your education by thinking about your thinking process; explain your thinking process as you linked digestive functions and digestive structures.

E2. Do you understand the principle? Ask your instructor to check your tables to see if you have the information that will allow you to understand the basic principle that "*The ability of an organism to function in a given way is dependent on having the appropriate structure.*"

Part II: Application of the Structure-Function Relationship and Thinking About Thinking

A: Digestive System of the Fetal Pig

Obtain a specimen of a fetal pig. This pig may have already been opened, if not, follow the diagram in Figure 9.2 to open the pig. Explore the digestive tube of this mammal, *Sus scrofa* (phylum: Chordata; sub-phylum: Vertebrata; class: Mammalia). Carefully observe differences in the tube, and associate the digestive functions with a particular structure as you did for *Necturus* and the earthworm. Record your information in Table 9.5.

B: Refining Structure-Function Relationships: Size of Absorptive Surface

B1. View the video tape at the audio-visual table demonstrating the effects of surface area size on the movement of water through filter paper. Describe the effects of the size of the surface area on water movement.

B2. In their thinking patterns, humans frequently form general statements, or concepts, from specific observations. This mental process is given the name *inductive reasoning*. From your observations of the demonstration, can you generalize that the rate (amount of substance per unit of time) at which a substance crosses a surface will increase as the area of the surface increases?

For example, from the general concept that rate of passage increases as surface area increases, you can predict that a particular organism that has a structural modification increasing the absorptive surface will have a higher passage rate than another organism with less surface area.

Table 9.5.* The digestive system of a fetal pig, *Sus scrofa*.

A Distance along the digestive tract (mm)	B Specific description of structure and location	C Description of possible function	D Possible name of structure

* The table provided for students has additional blank rows and fills one entire page.

B3. Return to the inner surface of the small intestine in the fetal pig. Examine the portion that is 2–10 cm from the stomach. If you like, examine it with a dissecting scope.

A cross-section of a mammalian small intestine is displayed on a microscope at the demonstration table. Use this slide to observe the detailed structure of the small intestine.

Considering the structure of small intestine's surface, what is your prediction of the rate with which small molecules cross this surface? What thinking processes led to your prediction?

B4. Observe the sections from a human digestive tube available on the demonstration table; or, you may remove small sections of esophagus, stomach and large intestine from the fetal pig for examination with a dissecting scope.

Try linking your observations of internal surface structure and the *in vitro* observations recorded in Table 9.4. You can infer the location of the breakdown of the big complex food molecules from digestive information in Table 9.4. Associate this information with the surface structure of different portions of the digestive tract. What is your prediction about where the digested food moves from the digestive tract into the blood vessels of the transport system?

B5. You have just used a form of thinking frequently utilized by scientists and informally by non-scientists, *hypothetical-deductive reasoning*. It involves predicting an unobserved phenomenon from some things known or assumed. Again, take a moment to think about your thinking process. How did you arrive at your prediction? Explain what specific pieces of information you used and how you linked them together. Give an example of hypothetical-deductive reasoning in a non-science area.

B6. Look again at the intestinal tract of the earthworm and view the cross-section of the earthworm's intestinal region on the microscope at the demonstration table. Describe or diagram the structure that provides additional surface area in this intestine.

Part III: Induction of the Unity with Diversity Principle from Differences among Organisms

A: Intestinal Modifications

A1. *Intestine:* Do both pig and earthworm have the same intestinal surface modifications? Which one of these organisms would you predict is the most efficient in moving digested molecules into the transport system? Give the specific structural observations and your reasoning processes that led to your answer.

A2. *Stomach:* Take another look at the *Necturus* stomach and review its functions. Do you predict that the stomachless earthworm carries on the activities of holding food for later digestive activity and breaking down protein food particles? If you predicted that the earthworm does carry on these activities, how do these occur without a stomach — or are these exceptions to the structure-function principle? If you predicted that it does not have these functions, what characteristics of this organism's food and habitat negate the need for them?

A3. *Teeth:* Basing your thought process on structural observations, infer and compare the functions of the teeth in *Necturus* to those in humans. Do earthworms have teeth? How can a worm break the soil particles that it consumes?

A4. Check the model or diagrams of earthworm anatomy. Return to your earthworm and re-observe the crop and gizzard. Think about possible relationships between these structures in the earthworm and the stomach and teeth in *Necturus*.

A5. Examine the chicken digestive tract on the demonstration table. What does it use for temporary storage of food? To pulverize food? To mix food with digestive fluids?

Chickens have no teeth and, therefore, have to swallow their food whole. Chicken farmers often provide gravel for the chickens to eat. Propose an explanation for this practice.

B: Similarities Among Organisms

In this last section, you focused on differences among some organisms. Before you lose awareness that all of these examined organisms have similarities, list three general ways in which the earthworm, *Necturus*, and pig digestive tracts are similar.

C: Synthesizing Observations and Forming Another Principle

Would you agree or disagree with the complex statement: “Animals may have different structures that work in slightly different ways to accomplish similar functions“? Give several specific pieces of evidence from your explorations that support your answer.

A much shorter statement of this principle is “unity with diversity.” In the chicken, earthworm, pig, and *Necturus*, each has digestive tract structures that store and grind food. In this way they are alike, or “in unity.” At the same time, these organisms exhibit diversity in the structures performing these functions. In the pig and *Necturus*, the spacious stomach holds food, and the teeth anchored in jawbones and moved by muscles that grind. In the chicken and earthworm, it is the crop, and gizzard with its gravel that perform these respective functions. The structures that store food are similar in having an expandable space, but they are dissimilar in the details of the walls that define the space. The structures that grind food are similar in using strong muscles to move food and to move hard surfaces against each other, but they are different in the structural details and function.

D: Unity-Diversity of an Amphibian and Mammal

D1. In what specific ways are the digestive system of the fetal pig and *Necturus* similar (i.e., unity)?

D2. In what specific ways are the digestive system of these two organisms dissimilar (i.e., diversity)?

Part IV: Additional Explorations and Mental Gymnastics (Optional)

A: Carnivores and Herbivores

A1. What is the length of the digestive tract in the fetal pig? In *Necturus*?

Measure body length of each animal from tip of nose to base of tail. Determine the ratio, in decimal form, of the length of the digestive tract to the length of the animal (relative gut length). What is the relative gut length in the pig? In *Necturus*?

Which digestive tract is longer when compared to the length of the organism?

A2. Animals can be grouped by the type of food they consume. An animal that eats plants is called a herbivore; animals that eat both plants and animals are called omnivores. Pigs are primarily plant eaters but on occasion they may eat other animals. As indicated earlier, the animal-eating *Necturus* is a carnivore.

There is a lot of undigestible material (cellulose) in plants. Animal tissue can be almost completely digested. Does a relationship appear to exist between the relative gut length and the diet of *Necturus* and organisms like the pig? What is this relationship? Describe the observations that led to your answer.

A3. Explain how the relative gut length can be related to the two principles explored in this laboratory.
Unity with diversity:
Structure-function:

B: Gut Ratios and Diets

Listed in Table 9.6 are ratios of gut length to body length found in several organisms. With this information, predict which organisms are primarily carnivores and which ones are herbivores.

Table 9.6. Relative gut length.

Organism	Gut/body ratio	Type of consumer
snail	6.5/1	
guinea pig	5.0/1	
raccoon	1.8/1	
mole	2.2/1	
tapir	4.7/1	
sea lion	1.4/1	

C: Caecum

Neither carnivores or herbivores produce the necessary juices for digesting cellulose. However, in the digestive tracts of some organisms one can find microorganisms, such as bacteria and protistans, that do produce the digestive juices for cellulose breakdown. Some of these organisms have special structures for housing these microorganisms. Is the specialized structure that houses cellulose-digesting microorganisms found in both *Necturus* and pig? What might be a possible link between the diet of these two organisms and the size of the caecum or its absence?

D: A Puzzle

Look at the preserved sea anemone on the demonstration table. With its tentacles, the sea anemone captures small organisms that swim near it and ingests them. Does the anemone need to digest these food organisms? If yes, what observed structures might it use? If no, how can the anemone circumvent the need for something like a digestive tract?

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APPENDIX A
Preparing Solutions

Amylase solution, 0.5% (125 ml):
0.63 g of amylase
Add enough distilled water to make 125 ml solution.
Adjust pH to approximately 7.0 with either 1 N HCl or 1 N NaOH.

Pepsin solution, 4% (125 ml):
5 g of pepsin
Add enough distilled water to make 125 ml solution.
Adjust pH to approximately 2.0 with 1 N HCl.

Pancreatin solution, 2% (125 ml):
5 g of pancreatin
Add enough distilled water to make 125 ml solution.
Adjust pH to approximately 8.0 with either 1 N HCl or 1 N NaOH.

Starch solution, 9.5% (250 ml):
1.25 g of starch
Add 25 ml cold distilled water to the starch and stir. Pour this mixture into 125 ml boiling distilled water, stirring constantly. Allow mixture to cool; adjust final volume to 250 ml.

Note: These four solutions should be refrigerated until used.

Iodine potassium iodide (300 ml):

4 g potassium iodide
Dissolve KI in a small amount of water. Grind iodine and stir into the KI solution. Add water to make 300 ml. Store in brown dropper bottle. This solution can be used for several semesters.