TABLE 1. Bacteria Which May Be Seen in Stained Preparations of Cecal Content From Formalinized Rats.

Bacterial type	*Genera*
Gram positive rods	*Lactobacillus,* Clostridium**
Gram positive cocci	*Streptococcus, Peptostreptococcus**
Gram negative rods	*Bacteroides,* Escherichia*
Gram negative cocci	*Veillonella,* Rumenococcus**
Fusiform bacteria (pointed ends)	*Fusobacterium**
Spiral shaped bacteria	*Borrelia,* Treponema,* etc.*

*Strictly anaerobic bacteria, i.e., will only grow in the absence of oxygen.

as an ecosystem is to challenge the students with the following problem which allows them to think about the benefit of gut bacteria to the wellbeing of the host, i.e., an example of symbiosis and to consider the mechanisms of microbial interaction.

Challenge Problem:

The normal bacteria of the gastrointestinal tract are essential to the wellbeing of the animal host. Disturbances to the homeostasis of the ecosystem, e.g., administration of antibiotics, may make the host more susceptible to invasion by intestinal pathogens. Thus, a germfree rat will die if administered 1-10 Salmonella *bacteria. A normal rat needs to be given over 10 million* Salmonella *before it becomes infected. Using your recently acquired knowledge of the microbiology of the rat ecosystem and applying ecological principles, explain the protective effect of the normal gut flora.*

A major feature of any ecosystem is that, over a period of evolution, organisms have adapted to life at particular sites. Thus the gut organisms are likely to be much better equipped to survive in the gut than intestinal pathogens and so do not allow them to colonize in numbers sufficient to cause disease. For example, salmonellae would be excluded from entering intestinal crypts due to competition from the mucin degrading spiral organisms. Another mechanism is bacterial antagonism. The fusiform (pointed) shaped bacteria that are seen to dominate the rat cecum produce volatile fatty acids as a breakdown product. Concentrations of butyric acid are found in the normal cecal content which can be shown to inhibit the growth of salmonellae.

Many potential pathogens, e.g., yeast may be found in low numbers in the large bowel of normal animals. They are kept in check by the gut bacteria. Antibiotics may remove the bacteria, but have no effect on the yeasts which can flourish with possible deleterious consequences. This overgrowth of yeasts or "super infection" following antibiotic therapy may result in the disease "Thrush" in two similar microbial ecosystems in the human body, i.e., the mouth and vagina (oral or vaginal candidiasis is the correct name for this condition as the pathogenic yeast-like organism is called *Candida albicans*).

Conclusion

The formalinized rat provides an opportunity for an interesting study in microbial ecology. Material that has hitherto been discarded can form the basis for a novel but convenient laboratory exercise. The author would be interested in hearing from teachers who try these experiments and can provide further micrographs of the gut ecosystem on request.

A Natural Selection Game

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This game is simple, inexpensive, and effective. It readily reinforces the concept of natural selection by simulating selection pressures on a hominid group. I have found it a vehicle for eliciting good discussion. Beyond that, it is fun and diverting. It can be set up and played in one class period and involves the whole class. Since the class represents the population, the only other materials needed are scrap paper and pencils.

The game is played as follows:

Step 1. The instructor chooses the traits to be used. Any heritable trait may be used (see figure 1). To begin, write the following words on the chalkboard: a.) manual dexterity; b.) posture; c.) skin color;

manual dexterity
posture
skin color
brain size
social behavior
body hair
hair color/texture
resistance to toxic chemicals
resistance to radiation

FIGURE 1. List of heritable traits useful for the Natural Selection Game.

d.) brain size; e.) social behavior.

Step 2. Students write the traits on paper slips. One trait is copied onto one slip of paper. Each student then has five slips of paper, each bearing a different trait.

Step 3. The instructor assigns each student a number. Every player is randomly given a number from one to five. The student writes the number on the slips of paper. If the student was assigned the number 4, next to each trait the student would write 4, e.g. "a.) manual dexterity 4."

Step 4. The paper slips are folded and sorted into an appropriate box. That is, all the slips with the posture trait go in one box, those for skin color in another, etc.

Step 5. The students choose traits. Each student randomly picks one slip from each of the five boxes.

Step 6. The instructor explains the numbering system. Larger numbers indicate better dexterity, more upright posture, darker skin color, larger brain size, good social behavior. A player whose traits included manual dexterity-2, posture-4, skin color-5, brain size-5, social behavior-1 would be an intelligent, dark-skinned individual with upright posture and poor social and dexterity skills.

Step 7. Environment is announced by the instructor. A particular environment places particular stresses on individuals. Let us suppose the environment chosen is the African Savannah. The instructor leads the discussion to see which traits are advantageous. It is assumed that the hominid population is technologically naive.

Step 8. Discussion continues. Now that students recognize which traits would hold an advantage (such as darker skin color—UV light protection; good manual dexterity, intelligence, upright posture—tool making, *et al.*; good social behavior—ability to communicate, share duties, etc.), decisions must be made concerning which combined traits would allow good survivability.

Clearly certain traits would be selected against. Those with skin color ratings of 1 or 2 might succumb to hypervitaminosis D, for example. Those with skin ratings of 3 to 5 would have UV light protection but may not survive if their other traits hold little advantage. Through class discussion it is usually agreed upon that at least three traits must be advantageous to assure survivability.

By asking students about their particular traits, those individuals who possess advantageous traits are found. These individuals are "survivors" and are asked to move to one side of the room. The rest are considered eliminated. In this manner the "new" population is formed.

Step 9. Wrap up and debriefing. The game can be ended at this point. However, if desired, the game may continue by exposing the survivors to a new environment. For example, the instructor may say that the new population has migrated northward. The class must decide which traits now hold an advantage; this is followed by determining the new survivors.

If time permits, the original population may be regrouped and Step 7 repeated, this time using a different environment.

The traits used can obviously be modified, deleted, or added quite easily as long as they are considered heritable ones. The approach outlined above is traditional in that it links dexterity, posture, and brain size. Resistance to radiation/fallout and toxic chemicals are traits that may provide interest in discussions of current trends.

The objectives of the activity include an appreciation of how selection works, an understanding of how abiotic factors are able to influence a population, and how interactions within the population can influence the group. What is more, students can "see" the results of natural selection on a human population. It is also possible to see how neutral and nonadvantageous traits can be carried along. The concept of evolution and, in particular, human evolution, which can sometimes prove to be a stumbling block to good discussion, is never mentioned. Of course, during the post-game debriefing, the concept would, I expect, arise as should some of the limitations of the model.

I have found much student interest in the game. It certainly can provide a stimulating break from the normal routine and is flexible enough to be modified to suit various needs.