Nucleic Acids as Information Molecules

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Too often in our teaching we allow factual details to obscure the central concepts of biology. This problem is especially obvious in genetics and molecular biology, where we can easily overwhelm students with an ever-expanding, specialized vocabulary and with the minutia of the central dogma, while neglecting the key concept that DNA and RNA are information molecules. It makes little sense for students to memorize the structure of DNA if they do not understand that its function is to store, copy and make available the information in biological systems. I recently used the 15-minute activity described below to emphasize this concept for high school students who were taking a full-year elective course in genetic engineering.

Materials

one vinyl record
one cassette tape
one compact disc
one organism, any kind (I used a carnation, borrowed from the desk of a BSCS colleague.)

Procedure

Keep the materials in a bag so the students cannot see them. Organize the students into groups of three. Tell them that you are going to show them four objects and that they will have three minutes to discuss what those objects have in common and to record their responses on paper.

Withdraw the objects from the bag one at a time, in the following order: the vinyl record, the cassette tape, the compact disc, and the organism. Repeat the question, "What do these objects have in common?"

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Allow the groups to discuss the question and record their answers for about three minutes. Then, record the responses on the chalkboard; take one new response per group until you exhaust all responses. You can discuss each response in turn or wait until you compile the complete list and then work through the responses individually, asking for comments from the class.

Among the responses I received were the following:

- They have symmetry. (Yes.)
- They have color. (Yes.)
- They have evolved. (Yes, in the sense that they have changed through time; but only the carnation is the product of organic evolution—and artificial selection.)
- They are made of matter. (Yes.)
- They are all solid. (Yes.)

I had to ask some leading questions to get to the notion of information. The rather awkward question that finally worked was, "What is in each of these objects that we might want to get out, or interpret?" Finally, one student said, "Information." I pursued that response with some additional statements and questions:

Question: "Yes. What does the information in each of these objects have in common?"
Response: There was no response, even after waiting a reasonable amount of time, so I tried another question.
Question: "How is the information stored?"
Response: "It's in a code."
Question: "Yes. Tell me about the codes in the different objects."
Responses: "Records have grooves." "Tapes are magnetic." "CDs have numbers, zeroes and ones." "The flower has DNA; it has As, Gs, Ts and Cs."
Question: "Okay. DNA is a molecule that encodes information. What other molecule encodes information?"
Response: "RNA."
Question: "Yes. Of these four objects, which are the most similar in the way they encode information?"
Response: (after some pondering and questioning): "The CD and the flower; they're both digital."
Question: "How would you describe the information in the record and the tape?"
Response: "It's analog."
Question: "Yes. What are the earliest known organisms in which we find information molecules?"
Response: "Bacteria."
Question: "Yes, and we have evidence that bacteria have been around for about 3½ billion years. Evolution produced a digital information system at least that long ago. What else does an information system need?"
Response: "You need a way to get the information out."
Question: "Yes. Tell me about that."
Response: The discussions at this point compared the working mechanisms of record players, tape players and CD players. This is a good opportunity to invite physics or technology teachers to contribute to the discussions. The intent is to help the students recognize that replication, transcription and translation are biochemical mechanisms that encode and decode biological information. The physical structures in records, tapes, CDs and

DNA allow storage, replication and transcription of the information. Just as records, tapes or CDs are useless without the appropriate mechanisms for transcription and translation of the encoded information, information molecules require cellular mechanisms to turn their information into products that are helpful to the whole organism.

Conclude the activity by emphasizing the following points:

- The information system in living things is virtually universal; this universality provides evidence for the relatedness of all species by descent with modification.
- The information in living things—DNA—replicates with great fidelity. Occasionally, there are mistakes—mutations. These mistakes can cause problems, but they are also one source of the biological variation that is fuel for the fires of natural selection.
- Variations in the sequence of the digitally encoded information in nucleic acids—As, Ts, Cs, Gs—interact with environmental variables (internal and external) to produce all of the intraspecific variation on the planet and, ultimately, all of the interspecific biodiversity.

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