#616

Quick! What's a Quark?

AT THE 1987 COMMENCEMENT CELEBRATION OF HARVARD University, while champagne corks popped among the black robes, a film maker carried his camera into the crowd. Approaching new graduates at random, he posed a simple question: "Why is it hotter in summer than in winter?" The results, starkly displayed in the film "A Private Universe," were that only 2 of the 23 students queried could answer the question correctly. Even allowing for the festive atmosphere of a graduation ceremony, this doesn't give us much faith in the ability of America's most prestigious universities to turn out graduates who are in command of rudimentary facts about the physical world.

In 1988, Jon D. Miller, director of the Public Opinion Laboratory at the Social Science Research Institute of Northern Illinois University, surveyed 2,000 American adults at all educational levels and asked them a dozen and a half questions on scientific concepts. Among them: "The earliest human beings lived at the same time as the dinosaurs. Answer True or False." Only 37 percent answered correctly, false. To the question "Antibiotics kill viruses as well as bacteria," a mere 25.5 percent answered correctly, false. Miller, who conducts this test every two years, concluded that only some 17 percent of American college graduates and only 25 percent of those with graduate degrees have even a rudimentary knowledge of science.

Every university in the country shares this same dirty little secret: They are all turning out students who cannot understand

---

Robert M. Hazen and James Trefil are the authors of "Science Matters: Achieving Scientific Literacy," to be published by Doubleday this month. This article is adapted from the book.

By Robert M. Hazen and James Trefil

Test

Here is a short "pop quiz" that probes aspects of science that are important in everyday life. Each question covers a small detail of the workings of the physical world, but represents an important area of knowledge. For example, we ask about the specific difference between atoms and molecules, but this is a proxy for a more general question like "How is matter constructed?" In sum, we feel, you are scientifically literate if you can place atoms and molecules on a continuum of structures ranging from quarks, the basic building blocks of matter, to quasars, the violent galaxies that are the most distant known objects we can see in the universe. These questions may seem simple to some (who can probably count themselves among the scientifically literate), but they are similar in tone and content to those Jon Miller asks college graduates in his surveys every other year. (Answers on page 26.)

1. Summer is hotter than winter because:
a. Light from the sun travels in a straighter line in summer.
b. The earth is closer to the sun in summer.
c. The earth is tilted on its axis.
d. The moon reflects more sunlight in summer.

2. An atom differs from a molecule because:
a. Molecules are made of atoms.
b. Atoms are made of molecules.
c. Gases made of molecules, but solids are made of atoms.
d. Atoms and molecules are two words for the same thing.

3. Earthquakes occur in California because:
a. Earthquakes always accompany volcanoes.
b. California is sinking into the Pacific Ocean.
c. Giant underground explosions occur every few years.
d. Two blocks of the earth's crust are grinding past each other.

4. A semiconductor is:
a. An essential component of all wire.
b. A material that protects you from electrical shock.

ILLUSTRATION BY ROSS MACDONALD, PHOTOGRAPH BY NASA/PHOTO RESEARCHERS

Your Scientific Literacy

c. A key substance in every piece of microelectronics.
d. An important type of oven insulation.

5. Genetic engineers can create new life forms because:
a. Scientists can build living things atom by atom.
b. All genes are written in the same genetic code.
c. Scientists in Japan and the United States have collaborated.
d. All life is made from the same kind of cell.

6. Galaxies, like our Milky Way, are made of:
a. Hundreds and hundreds of stars.
b. Thousands and thousands of stars.
c. Millions and millions of stars.
d. Billions and billions of stars.

7. Why do physicists want the Superconducting Supercollider, which will be built in Texas at a cost of $35 for every U.S. citizen?
a. To help develop fusion energy sources.
b. To probe the basic structure of matter.
c. To test radiation therapies for cancer.
d. To improve propulsion systems for jet engines.

8. The most abundant gas in our atmosphere is:
a. Oxygen.
b. Carbon dioxide.
c. Nitrogen.
d. Smog.

9. Acid rain is caused by:
a. The decay of dead trees near lakes and streams.
b. Poorly run chemical plants that manufacture acids.
c. Agent Orange.
d. Nitrogen and sulfur compounds released into the air from burning coal.

10. Why is the ozone layer of the earth's atmosphere important?
a. It blocks harmful ultraviolet radiation.
b. It reduces the greenhouse effect.
c. It keeps the planet smelling fresh and clean.
d. It prevents oxygen from leaking into space.

11. Which of the following facts cause scientists to worry about the greenhouse effect?
a. A variety of synthetic gases contribute to the greenhouse effect.
b. The concentration of atmospheric carbon dioxide has increased dramatically during the past century.
c. An inevitable byproduct of burning fossil fuels (our primary energy source) is carbon dioxide.
d. All of the above cause scientists to worry about the greenhouse effect.

12. Which of the following does not travel at 186,000 miles per second (the speed of light)?
a. Microwaves in your microwave oven.
b. Radio waves from your local radio station.
c. The solar wind, streaming from the sun.
d. Light from a fluorescent light bulb.

13. The blueprint for every form of life is contained in:
a. The National Institutes of Health near Washington, D.C.
b. DNA molecules.
c. Proteins and carbohydrates.
d. Viruses.

14. Sexual reproduction is important in evolution because:
a. Having a mother and father increases chances of survival.
b. Sexual reproduction produces more offspring.
c. Sexual reproduction allows offspring to differ from either parent.
d. Sexual reproduction is fun.

the most basic science-related stories in the newspaper on the very day of their graduation. Is it any wonder that Americans rank near the bottom among industrialized nations on standardized mathematics and science tests?

The term scientific literacy implies the grasp of a specific body of knowledge — the knowledge one needs to grapple with public issues, to understand why scientists do what they do, and to recognize that the physical universe displays an underlying order on which we depend in many of our day-to-day activities. We all live in a physical world of matter and energy; understanding how it works is an integral part of any education.

To consider such issues as waste disposal, energy conservation, climate change and genetic engineering requires an eclectic mix of facts, vocabulary, concepts, history and philosophy. This is not the specialized stuff of the experts, nor does it rely on obscure words or complex mathematics. If you can read an article about genetic diseases or the Superconducting Supercollider and put it in a meaningful context — in short, if you can treat news about science the same way you do news about business, politics, entertainment or sports — then you are scientifically literate.

OUR OWN PROPOSAL FOR REFORM OF SCIENCE EDUCATION is centered on a simple, self-evident proposition: If you expect students to know something, you have to tell them what it is.

In contrast to professors of English literature, who can argue endlessly about which play or novel (if any) ought to be read by all students, scientists usually agree on the basic tenets of their field. It would be rare to find a scientist who didn't include among the list of things everyone should know concepts like the conservation of energy, the motion of plates at the earth's surface, and the role of DNA in determining inheritance. Our experience has been that when we sit down and talk about scientific literacy with our colleagues, a general consensus develops fairly quickly, although inevitably there are quibbles about details.

Thus the outline of a science-education curriculum already exists. The problem for universities is that it doesn't correspond very well to the century-old division of the university into conventional departments. Think about what one needs to know to understand the scientific component of the greenhouse debate, for example: an understanding of the role of infrared radiation in the earth's heat balance (physics), the production of carbon dioxide by human activity (chemistry), the way climate can be affected by the greenhouse effect (earth science), the possible effects of climate changes on living things (ecology) — in other words, a little bit of physics, a little bit of chemistry, a little bit of biology and a little bit of earth science, together with a general grounding in the way science works. By training and tradition, however, university scientists want to teach the students a lot about their own particular area of expertise — a lot of physics, a lot of chemistry or a lot of biology.

Scientists must define which parts of their craft are essential for the scientifically literate citizen and then put that knowledge together in a coherent package.

In their present state, American universities are simply incapable of producing scientifically literate graduates. There are two main reasons for this state of affairs. In the first place, in the modern university there is almost no incentive for faculty to pay attention to teaching undergraduates. The publish-or-perish system is still firmly in place, and despite some lip service to teaching, faculty members know their rewards will be based solely on specialized research.

But as far as the sciences are concerned, there is an even stronger impediment. We have found that because of the way they are trained, working scientists are, by and large, scientifically illiterate outside their own areas of expertise. Physicists tend to ignore biology, and biologists return the compliment. How can university scientists impart a vision of the world as a marvelously interconnected system governed by a few overarching principles if they themselves do not possess that vision?

If our hopes are realized, the day will come when if one scientist calls another a "generalist," it won't be meant as an insult. And we may then have graduating classes across the country where students know (among other things) why it's warmer in summer than in winter. ■