# Research Notes

## Virus Assembly Line

A group of investigators under William B. Wood, professor of biology, is gaining new understanding of the role of certain protein molecules in the formation of a virus known as T4. Wood hopes that the study of molecular architecture at the level of viruses will shed light on the structuring of more complex forms of life.

T4 is a living hypodermic needle only one hundred-thousandth of an inch long. Like all viruses, it is a parasite. It keeps its family line going by squirting its DNA, the carrier of its genetic pattern, into one particular kind of cell—*Escherichia coli (E. coli)*, a common bacterium found in the intestine. This act destroys the cell's own genetic material, converting the bacterium into a factory that makes 100 or so T4 viruses—using T4's DNA blueprint—in about half an hour. The cell then bursts, freeing the new viruses, and dies.

T4 consists of about 40 different kinds of protein molecules that are assembled independently into three major components—head, tail, and tail fibers—that are then combined to complete the virus. Even the hair-like tail fibers are manufactured in two separate parts and then connected at a knee-like joint. Subsequently, the completed tail fiber is attached to the base of the tail. Wood and his group are currently concentrating on learning about the composition of the tail fibers and how they become attached to the virus's tail.

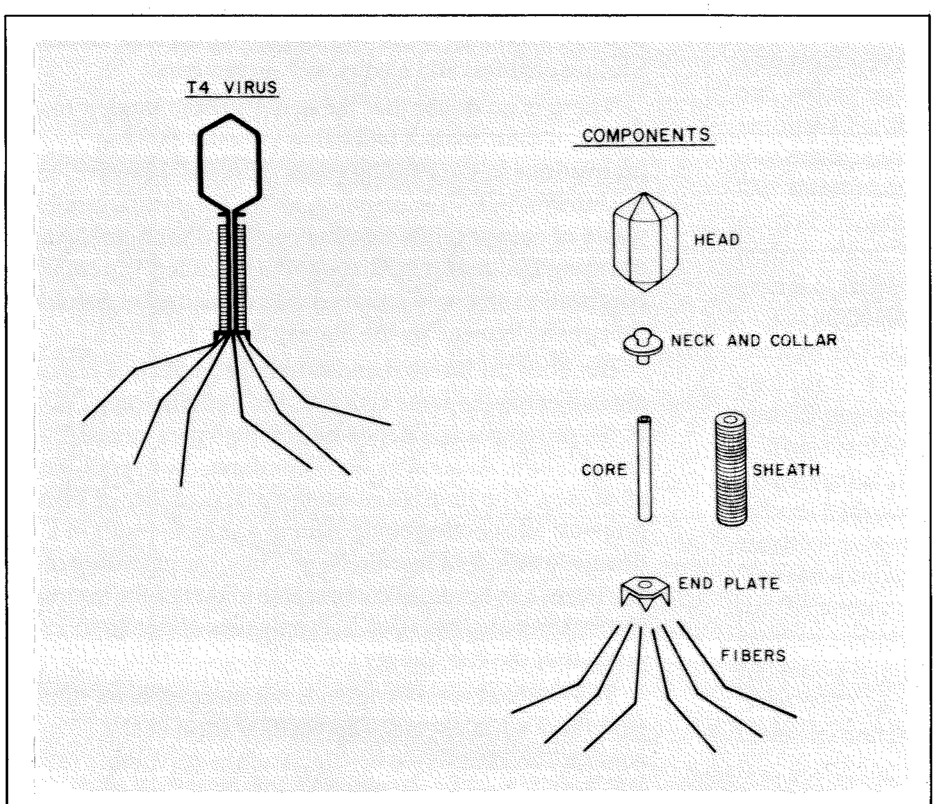
The tail fibers play a vital role in T4's reproductive life. When T4 bumps into an *E. coli*'s wall, the tail fibers of the T4 somehow grab the cell surface and hang on. The attachment is some sort of chemical bonding, but its exact nature is not yet known. When the six tail fibers are attached to the wall, the syringe-like body of the virus is in an upright position. The virus then contracts, squirting the DNA from the T4 head into the *E. coli* cell.

Wood and his group have found that seven different types of protein take part in forming the T4's tail fibers. Four of them comprise the actual tail-fiber structure, and the three others serve as catalysts in the minute assembly line. "We know something about the three proteins that put the tail fibers together, but we don't understand how they catalyze assembly," says Wood. "This is what we would like to find out."

In addition to accessory catalytic proteins, assembly in higher creatures often depends on pre-existing structures, which guide the laying down of new material in some manner not yet understood. There are now indications that the T4 work of Wood and his associates may be able to shed some light on this feature of assembly too. In the assembly of T4, a pre-existing structure—the inner wall of the *E. coli* membrane—is used in some way to aid in constructing the heads of the viruses. Helen Revel, research associate in biology and a collaborator of Wood's, has found mutant strains of *E. coli* cells whose membrane has been changed so that T4 heads can't be made. All parts but the head are formed.

"Now we have a mutant T4 that will reproduce in the mutant cells," says Wood, "so we can ask which viral proteins interact with whatever it is that is changed in the bacterium. Experiments with these mutants will help us learn how the virus uses the host membrane to direct its own assembly."

Wood's research is supported by the U. S. Public Health Service.




*The components of the T4 virus seem to join together in assembly-line fashion, and the complete virus looks a little like a cross between a hypodermic needle and a spider.*

*William A. Fowler, Institute Professor of Physics, and Barbara Zimmerman, a member of the technical staff, go over a computer print-out that analyzes data from solar observations and experiments.*

## Much Ado about Nothing?

The sun may have the ability to turn its thermonuclear fires up and down as a thermostat does a house furnace, and it may have done so as many as ten times during the past several million years. In fact, the sun may now be going through one of these crucial up-down periods. It may have turned itself down within the last few hundred thousand years and just now be turning up, or it may now be in the act of dampening its solar fires momentarily.

This thermostat-like activity may be due to what William A. Fowler, Institute Professor of Physics, calls "transient mixing," one of two "desperate" explanations he offered in a recent issue of *Nature*, the British scientific journal, in an attempt to resolve a baffling solar mystery—the scarcity of solar neutrinos.

Most scientists believe that the sun's interior is burning at 15 million degrees above absolute zero. But at this temperature (with hydrogen fused and turned into helium by thermonuclear reactions at the core) the sun should also be emitting about 3 percent of its energy in the form of neutrinos—subatomic particles, having energy but no charge or mass, that are by-products of nuclear reactions. However, it is increasingly evident that, at most, the sun is only spewing out about one-tenth the number of neutrinos predicted by theoretical astrophysicists.

"Quite obviously something is wrong, either with some of the most basic laws of nuclear physics, or with our theories about the sun," says Fowler. "I prefer the latter explanation." Working in Kellogg Radiation Laboratory with a group that includes professors of physics Charles Barnes, Ralph Kavanaugh, Thomas Tombrello, and Ward Whaling; research fellows Arthur Huffman and Mirmira Dwarakanath; and a member of the technical staff, Barbara Zimmerman, Fowler has been attempting to find out what is wrong with our solar theories.

The first explanation he suggests—transient mixing—challenges the standard models of the sun. Current theory contends that the sun's interior is stable to convection; that is, there is no mixing of elements due to massive motions of material caused by the transfer of heat energy. Fowler speculates that perhaps the sun sometimes becomes convectively unstable and that materials at a temperature of 15 million degrees in the center of the sun are suddenly mixed with lighter, cooler materials from the sun's surface. Such mixing would cool the interior slightly and thus reduce the flow of neutrinos. Since neutrinos generated at the sun's center reach the earth in only eight minutes, any dampening of the solar fires would be evident immediately in a decrease in the number of neutrinos. There is no lessening of the sun's brightness because of this interruption, since light generated in the sun's core takes about 30 million years to work its way up to the solar surface.

Fowler's second desperate explanation—one that he is not particularly enthusiastic about—is that possibly one of the critical reactions in the core of the sun has a resonance in it; that is, it goes a lot faster than predicted. If this is so, it would, in effect, "short-circuit" the production of neutrinos, and would also make the theorists' models agree with the experimental results. Dwarakanath has searched for the necessary resonance, but has detected none so far in his experimental observations. "It doesn't appear that this particular explanation is viable, but it did seem necessary to test the possibility experimentally," says Fowler. "If true, it would have constituted a loophole in the logic of solar nuclear physics, but what a letdown it would have been. Not understanding something in the nuclear reactions would have been an answer all right, but not a very exciting one. It wouldn't have led to anything new."

But the transient-mixing explanation does, as Robert Rood, a former research fellow under Fowler who is now assistant professor of astronomy at the University of Virginia, found out. He took Fowler's suggestion seriously enough to develop an elaborate theoretical model, the results of which were published in *Nature* in December. Rood's calculations indicate that the sun—and thus similar stars—could undergo transient mixing as many as ten times before the flow of neutrinos would be reduced to the few that have been observed.

Where the sun is in this mixing process—whether it is due to heat up or cool down—determines whether the earth is headed for another ice age, or for a long-term tropical heat wave. "If, for instance, the sun has been cooling off over the last 30 million to 100 million years, has its lowering temperature affected the earth?" asks Fowler. "If it has, one immediately thinks of glaciation in the very recent geological past. But we aren't sure there's any relation between the two phenomena. When you're speculating about theories of solar activity, you can't be very positive about effects on earth. 'Much ado about nothing' may turn out to be the appropriate way to describe the search for solar neutrinos, but the 'ado' has been exciting and the 'nothing' now poses serious problems in physics and astronomy."

# Probing for Neutrons on the Moon

*A volcanic area of the Owens Valley—similar to Littrow Crater on the moon—makes an ideal site for terrestrial tests of the lunar neutron probe. Don Burnett and assistant Jim Weiss begin a trial run by measuring distances.*

One of the many instruments taken to the moon during the Apollo 17 mission in December was a 6½-foot-long tube that measured the rates at which neutrons reacted with lunar materials. Astronauts Eugene Cernan and Harrison Schmitt placed the tube—called the lunar neutron probe—in the hole they had drilled to obtain a deep core sample of the lunar surface, left it there for 40 hours, and then returned it to the lunar module for the long trip back to the earth and—eventually—Caltech.

The probe was designed by Donald Burnett, associate professor of nuclear geochemistry; Dorothy Woolum, research fellow in geology and physics; and Curtis Bauman, research engineer. It was constructed in Caltech's central shop for the National Aeronautics and Space Administration.

The neutrons tracked by the probe are secondary particles produced by the impact of cosmic rays on the moon. These rays strike the lunar surface and penetrate a few yards into it. When they collide with the atoms in the lunar rocks, complicated reactions occur in which the atoms of the lunar material are partially fragmented. The resulting secondary particles include neutrons.

The upper few yards of the lunar surface have been bombarded with these neutrons for billions of years—an assault that has produced small, but accurately measurable, changes in the isotopic composition of some elements found in lunar samples. Many measurements—primarily those made by G. Price Russ, graduate student in chemistry, and Gerald Wasserburg, professor of geology and geophysics—show the extent of this long-term neutron bombardment.

The number of neutrons that have reacted with a given sample of lunar material depends on how long (and where) the sample has been in the upper few yards of the lunar surface. Consequently, the measurable effects of the neutron bombardment help us to understand the processes that move and mix material on the moon's surface. But for accurate interpretation of lunar-sample data, it is necessary to know the rates at which neutrons react with lunar material, and how depth causes these rates to vary. The neutron probe should provide this information. "We already have theoretical estimates of how neutron-capture rates vary with depth," says Burnett. "With these we can build up fairly detailed models of what we think is going on. But if, instead of theoretical estimates, we have experimental data on the rate at which neutrons react down to a depth of six feet, we should be able to work out the history of the lunar samples with considerably more accuracy."

Burnett and his co-workers are now analyzing the results of the probe experiment and hope that it will provide this direct experimental information. They designed the probe in the form of a hollow tube, into which a rod is inserted. The apparatus contains two neutron detectors. The inner side of the tube has a strip of uranium 235 down one side and a strip of plastic down the other. The outside of the rod has a strip of boron 10 on one side and pieces of mica in a strip on the opposite side. When the astronauts placed the probe in the hole, they rotated the rod so that the uranium and mica strips faced each other to form one detector; the boron and plastic also faced each other to act as the second. When neutrons reacted with the boron, alpha particles were given off. They struck the plastic, leaving little tracks. When the neutrons reacted with the uranium, nuclear fission took place, causing the individual uranium atoms to break, or fission. When the subatomic fragments of this fissioning entered the mica, they also produced tracks.

Because of their uncertainty about the extremes of temperature the moon probe might have to undergo, Burnett and his co-workers designed it to collect information over a very wide temperature range. Temperatures on the moon vary from about 210 degrees Fahrenheit to about 240 degrees below zero. The boron-plastic recording method is more sensitive than the uranium-mica one, but loses its ability to detect alpha particles above 160 degrees. However, if the temperature had climbed above this point, the less sensitive, but hardier, uranium-mica recorder would have still registered neutron hits.

Although the probe's detectors appear to have done their job, Burnett and his co-workers are now trying to determine how much correction will have to be made for the effect of the radioactive isotope generator used to power the other instruments in the ALSEP (Apollo Lunar Scientific Experiment Package). When isotopes break down to produce heat and electricity in the generator, they produce neutrons as a by-product. To test this before the Apollo 17 mission, Burnett took the probe to California's Owens Valley, and in an area resembling the lunar landscape he analyzed the effect of an intense neutron source similar to the one in the ALSEP generator. He plans to run another series of similar tests within the next few months so that he can double check his results.

"One thing we *didn't* have to worry about was what would happen if the astronauts couldn't dig a hole for the probe and had to hammer it in," says Burnett. "We made sure it was sturdy enough by testing it thoroughly before the mission. Our standard procedure was to take it out to the flower bed in front of Mudd every now and then and pound the thing into the ground."

## Quasars—A Stage in the Evolution of Galaxies?

"Things are seldom what they seem" could be the theme for much of modern astronomy. For example, the results of a study by Jerome Kristian, staff member of the Hale Observatories, provide new support for the idea that quasars, rather than being a distinct class of astronomical objects, may reside in the centers of giant galaxies.

This view, which has been argued for since the early 1960's by Allan Sandage of the Hale Observatories staff, is based on several lines of evidence. Among the strongest of these are studies of two special types of galaxies—Seyferts and N galaxies. These have very bright, small nuclei, or central cores, which look like "mini-quasars." Although they are fainter than quasars, they have spectra and colors similar to quasars, and they change brightness in times as short as weeks. Such rapid change is one of the most striking properties of quasars, implying sizes as small as a few light weeks in diameter. This is a million times smaller than the sizes of giant galaxies, although some quasars are hundreds of times brighter than the brightest galaxies. The source of the quasars' great energy is still a puzzle.

More recent evidence that links quasars and galaxies includes studies by John Bahcall, former associate professor of theoretical physics at Caltech and now of the Princeton Institute of Advanced Studies; James Gunn, professor of astronomy and a staff member of the Hale Observatories; and their colleagues. These studies place some quasars in large clusters of galaxies.

Kristian's new results were based on a search for underlying galaxies on photographs of quasars taken with the 200-inch Hale telescope at Mt. Palomar. At the Sixth Texas Symposium on Relativistic Astrophysics in December he reported evidence for galaxies surrounding at least six quasars and possibly four more. He offered as an explanation for the fact that galaxies are not seen around all quasars—even though they may be present—that the quasars' brilliance may simply swamp the fainter image of the galaxies.

Although quasars are much smaller than galaxies, observing them is complicated by what happens when their light passes through the earth's atmosphere. This distorts what would otherwise be a very small image and smears it into an image which is progressively larger for brighter quasars. The image size of a larger, extended galaxy, however, depends mainly on how far away it is, as measured by its redshift. If a distant galaxy has a very bright quasar in its nucleus, the quasar image can be larger than the galaxy image, and the galaxy may not be seen at all. From measurements of the image sizes of galaxies and stars, Kristian was able to predict for each of 26 quasars studied whether a galaxy should be seen or not. "The results were as predicted," he says. "Where you expect to see a galaxy you do, and—at least as important—where you expect not to see one, you don't. This association of quasars and galaxies makes quasars look a little less exotic and galaxies more so. We still don't know what is happening in quasars, but it looks as though they may be a stage in galaxy evolution."

If this is true, it raises many interesting questions. What fraction of galaxies go through a quasar stage? How long-lived is a quasar? What is its effect on the history of a galaxy? Is it an incidental thing that only happens under special conditions, or is it related in some fundamental way to galaxy evolution in general? Does the apparent absence of quasars with redshifts larger than 2.8 point to the time at which galaxies were born?

Kristian, Sandage, and James Westphal, associate professor of planetary science, are planning further studies of quasars over the next year using a newly developed silicon diode vidicon photometer (*E&S*, June 1972) to give the 200-inch telescope more sensitivity at great distances.