Adventures in Science

An imaginary tour of some of the laboratories where great adventures are taking place today.

by L. A. DuBridge

With manmade satellites whizzing around the earth, with pot shots being taken at the moon every month or so, and with lots of talk about shooting next for Venus or Mars, no one has any doubt any more that great adventures are to be found in the field of science.

Science and technology have indeed suddenly burst open a new geographic frontier—the frontier of space. Just as the 15th- and 16th-century adventurers opened new frontiers by sailing the seven seas; and just as the early aviation pioneers opened new frontiers by flying through the air, so today we are about to see new adventures on the great frontiers of space. So far, we have taken only the first steps in this new exploration, but the essential tools are at hand. And though it will be slow, expensive and dangerous, we shall in the next 50 years see many a space vehicle launched to bring back new knowledge of our solar system, millions of miles away from our tiny earth.

But geographic exploration is not the only field of adventure that human beings have enjoyed. In fact, only a fraction of the exciting adventures which have taken place in the last 300 years have anything to do with geography at all. The great adventures of mankind today are at the frontiers of the mind — the frontiers of knowledge.

The entire world was thrilled when Sputnik I sailed successfully into orbit. But 300 years ago a man in Italy was getting a great thrill out of watching marbles roll down an inclined plane, timing them and discovering for the first time the "law of motion." That man was Galileo and he, too, startled the world of his day by showing that a heavy stone and a light stone, when dropped from the leaning tower in Pisa, hit the earth at nearly the same instant. The stone twice as heavy did not fall twice as fast — as everyone had thought for many centuries.

At almost the same moment, way up in Denmark, another man named Tycho Brahe was patiently making an extensive series of accurate observations on the position of the planets in the sky. He plotted the course of Venus and Mars and Saturn more accurately than anyone had ever done. And his measurements enabled another man in Prague — Johannes Kepler — to prove that the earth and the other planets traveled in elliptical orbits about the sun, with the sun at one focus. And the exact laws of planetary motion which he deduced — together with the law of motion which Galileo found for his marbles — enabled Isaac Newton to evolve the laws of the relation between force and motion and deduce the law of gravity. And it was Newton who pointed out that, knowing the way the moon stayed in orbit about the earth, a man could put an artificial moon into another orbit about the earth — provided he could get away from the atmosphere and provided he could hurl his little moon with an unimaginable speed of 5 miles per second, or over 18,000 miles per hour.

Three hundred years later men, in fact, learned how to do just that. But the intellectual adventure which paved the way for that achievement took place in the 17th century in the minds of Galileo, Tycho Brahe, Kepler and Newton.

But adventures like that — great discoveries at the frontiers of our ignorance — have been taking place in the laboratories and work rooms, the field stations and observatories of scientists every since. Some have had less sweeping and less astonishing consequences than those of Newton. But still others have rivaled Newton's in their depth and their world-shaking results.

It would require a recital of the whole history of science to tell about these great discoveries — and many of you are already thoroughly familiar with the discoveries in chemistry, atomic physics, electricity and mechanics which converted the world of the Middle Ages into the world of 1958. From the conquest of space to the conquest of disease, these discoveries have led to adventure after adventure in improving man's knowledge and adding to his comfort.

But these adventures are not just matters of history; they are taking place today in the laboratories of universities, of industry, and of governments. All over the world scientists, engineers and doctors are penetrating new frontiers, laying the basis for the new things of the 21st century.

I am going to ask you to take a little imaginary tour of some of these laboratories in order to inquire what frontiers of knowledge are being attacked today.

In attacking a frontier of knowledge — a frontier of the mind — one begins, not by taking a far journey, but by staying home and asking questions. What are some questions being asked today in the laboratories of science throughout the world? There are thousands of them, of course, so the problem is where to start. I'll have to start in some laboratories with which I am familiar — namely, those at Caltech. But I'll start with one of the laboratories with which I personally am least familiar — the laboratories of biology.

The question biologists ask

I am not a biologist, but the general theme of the questions the biologists ask is one which we can all understand: What is Life?

That, of course, is a question which scientists of all kinds have been asking for hundreds of years. In the old days an approach to the answer was attempted solely by the process of cataloging and describing all the different kinds of life which could be found on the earth. That was a necessary start, and it told us what different forms of life exist — but it hardly answered the question. Then for many generations scientists argued about how life began. Only a few hundred years ago it was commonly believed that certain kinds of life — rats, bugs, spiders — would be spontaneously generated wherever dirt or spoiled food was found. It took long and careful experiments to show that such forms of life did not generate in such places, but simply migrated to them in search of food or shelter.

Later on, when the microscope was invented and microorganisms, such as bacteria, were discovered, it was thought for a long time that *they* were generated spontaneously in decaying matter. It was Pasteur who showed that bacteria caused decay and not vice versa; that even bacteria did not spontaneously generate themselves.

Finally it was concluded that no known form of life ever generated itself spontaneously, but that every living thing was a direct descendant from another living thing. And then the stage was set for Darwin to evolve the theory of evolution which proposed that, while all living things were born from similar parents, there were from time to time small variations or "mutations" among the offspring and that these mutated forms — if they were properly adapted to their environment — would multiply their kind and then eventually another mutation would occur. Thus, in the course of time, new species would arise and old ones, less adapted to the struggle for existence, would die out. The theory of evolution, hotly contested only a few years ago, is now the basic concept of all biology.

But all of this only pushes the question back a few more stages — whence arose the *original* living thing?

The clue to the answer

The clue to the answer to this comes from a study of the simplest forms of life — first, the bacteria and other single cells, then the parts of the cells, then a particle called a virus and, finally, a particular part of the virus called a nucleic acid. Certain nucleic acid molecules, it is found, possess the ability under proper conditions to multiply — to reproduce their kind. That is the first requirement of life. But also, in reproducing themselves it is found that these molecules occasionally make mistakes; the daughter molecule is not quite like the mother. Maybe the daughter will die — will not be able to reproduce itself. Maybe, however, it will reproduce other daughters which will contain the same mistake. Maybe, in short, a mutation will take place. Reproduction and mutation — these are the essential features of life — and if once, millions of years ago, a single nucleic acid molecule was formed in the soupy substance of some primordial sea, then all of earth's living things might have descended from that one molecule.

Scientists are learning a great deal about nucleic acid molecules and about the protein molecules which are the raw materials from which living things are built. Certain types of protein molecules — the hemoglobin protein in blood, for instance — have recently been synthesized in the laboratory in Pasadena. Possibly some day a nucleic acid molecule can be synthesized — one which can reproduce itself — and a new chain of living things can be begun.

And so the pursuit of mystery goes on, and in the process more is learned about bacteria and viruses, about genes — the element of heredity — and about enzymes — the proteins which help in the manufacture of the material from which living things are built. Thus, in asking questions about the origin and nature of life, scientists learn answers to questions about the nature of the living material of which we ourselves are made — and help us understand the problems of human suffering and disease.

But life did not always exist on the earth. This planet probably whirled in its orbit around the sun for two or three billion years before that first speck of life — that first nucleic acid molecule — appeared. What was the earth like during those eons? How, in fact, did the earth itself come into being? These are questions that the geologist wrestles with. So let's walk across the campus and talk to some geologists.

Here is one who traces the history of oceans and mountains; another examines the structure of the interior of the earth by observing how earthquake waves travel through it. This geologist examines the structure and history of rocks and asks why some contain minerals and others contain oil. And, since oil itself is a product of living material, the geologist joins the biologist in examining the history of the various forms of life whose remains can be traced in ancient rocks.

How old are these rocks themselves? Here the geologist joins with the physicist. The physicist points out that the element called uranium exists on earth and that uranium atoms are unstable – i.e., they die off just as living things do. Only they live much longer. The average uranium atom lives, not threescore and ten years, but for 4½ billion years. Now, if the earth were *infinitely* old, then all the uranium atoms would be long since dead – would have been converted, in fact, into lead. There would be no atomic bomb – no Atomic Energy Commission – no atomic power! But by measuring how much uranium and how much lead actually do exist in a particular rock, the age of that rock can be accurately determined. It is not really as easy as it sounds, and it has taken long and exhaustive measurements to arrive at an acceptable figure for the age of the earth itself – but 4½ billion years is the current figure. By coincidence the earth is of just such an age that just about half of all the uranium that originally existed has now decayed into lead.

A talk with the astronomers

A few years ago a figure of 4½ billion years for the age of the earth would have brought howls of anguish from the astronomers. Maybe we should walk over and talk with *them*. They, too, are interested in the age of things. They worry about the age of the earth, the sun, the stars, the galaxies – of the universe itself. They, too, know that the universe is not infinitely old – because they discovered some 30 years ago that the universe is expanding. Now a universe which is known to be expanding could hardly be infinitely old – else all the rest of the universe would have been expanded out of sight and our poor earth would be all alone in an empty void. As a matter of fact, we can actually measure the speed of expansion – and from that we can figure back to how long ago it was that the expansion began.

Such measurements, however, are not easy; it is difficult to make them exactly, and it is difficult even to know how large the errors of measurement might be. And so it happened that, only 20 years ago, it was confidently believed from expansion measurements that the universe was just about 2 or 3 billion years old.

You can see why it was embarrassing to have the earth 4½ billion years old! The universe can't be younger than its parts – younger than the earth itself. So, as the geophysicists began talking about an earth that was over 4 billion years old, the astronomers began checking their measurements of the distances to the faraway galaxies which were receding from us so rapidly. They found some errors in previous measurements – some pretty big errors, in fact. And now the astronomers are sure that the universe is not a mere 4 billion years old, but probably between 10 and 15 billion years old. We can see some distant galaxies so far away and moving at such a speed that they must have been on their way for 10 billion years or more to get where they are now.

But this only leads to another puzzle. If the earth is only 4½ billion years old, while the universe is 10 or 15 billion years old, was the universe itself not all created at once? The answer is *no*. The universe is a living thing; new stars are being born all the time, and old stars are dying, too. The story of how the first stars were condensed out of clouds of hydrogen; how some of them after a strenuous life of a billion years or more, blew up into vast clouds of dust and debris; and then how new stars, of which our sun is one, were condensed out of that cosmic dust – these are the stories being pieced together by astronomers, astrophysicists and nuclear physicists.

Thermonuclear reactions

We pride ourselves as scientists on having discovered rather recently how to make a thermonuclear explosion. But in the universe thermonuclear explosions have been going on for billions of years. Indeed, all the energy of the whole universe itself comes from thermonuclear reactions – the fusion of hydrogen into helium and heavier elements. And since the universe is still composed of 90 percent hydrogen, these reactions have a good chance of continuing for another 10 or possibly 100 billion years. Our own sun will be burned up long before then, however – in fact, it may have only a measly 4 or 5 billion years more to live. Always there is *something* to worry about!

And so it is that night after night the great 200-inch Hale telescope on Palomar Mountain peers out into the vast reaches of space, trying to put together these mighty secrets of how the universe was born, how it evolved into its present state, and what its future might be. Just recently the colossal radio telescopes – which pick up radio waves from space as the optical telescope picks up light waves – have joined in the search and are adding valuable bits and pieces to the solution of the cosmic mystery story.

Speaking of space brings us back to the fact that within recent months men have decided that they will not be content forever to sit at the receiving end of telescopes to *watch* what goes on in space; they want to get out there – or at least send instruments out there – to get a better look at what is going on.

The exploration of space has, of course, long been a dream of men everywhere. Most people thought, however, that it was a dream only to be realized in the next century and not in this one — until Sputnik I woke us up to the fact that the age of space is at hand.

Possibly a word of caution is appropriate here — to remind us that "space" to the astronomer may mean a different thing from what it means to the rocket and satellite expert. The astronomer is accustomed to dealing with objects so far away that it takes *light*, traveling at 186,000 miles per second, millions or even billions of years to reach us. Even the very nearest star to our sun — the nearest object outside our solar system — is 4 light years away. An earth satellite, however — like the Sputniks or Explorers — travels, not 186,000 miles per second, but only 5 miles per second. Hence, even if a satellite could get away from the gravitational field of the earth, and then get away from the very much stronger field of the sun, and if it could even then continue with a speed of 5 miles per second, *it would still take over 150,000 years to reach* that nearest star.

In other words, space travelers are likely to stay relatively close to home — astronomically speaking — for the next few years at least.

Travel within the solar system

But travel within the solar system will offer some exciting adventures. Travel to the moon will take only a couple of days, to Venus or Mars a few weeks, and to the outer planets — Uranus and Pluto — a few years. On the way there will be exciting things to examine, too. Already the Explorer satellites have uncovered a new and unsuspected cloud of high energy charged particles high above the earth. Trapped in the earth's magnetic field, these particles orbit down to within 500 to 600 miles of the earth's surface and then swing out to 5,000 or 10,000 miles into space. At 5,000 miles up they form an exceedingly dense cloud — one that can produce X-rays intense enough to kill a man in a few hours. From there on out they gradually get weaker, and at 30,000 or 40,000 miles out they may be down to negligible intensities. However, their discovery was a great surprise both to the scientist who puzzles about where the particles come from and to the engineer who is puzzled about how to get photographic film and other sensitive instruments — to say nothing of men themselves — to function in such an environment.

When I speak of "travel" to these distant places, I am thinking primarily of travel by unmanned instrumented vehicles. As our rocket techniques improve we will be able to send larger and more complex instrument packages into space, and we will be able to equip them with energy supplies large enough to broadcast their findings to earth for a longer time. And all the measurements we wish to make — of cosmic rays, magnetic fields, radiations in space, weather observations — can be made with such automatic instruments.

What, then, is all the talk about a man in space? This is a topic to which we should give careful attention. Clearly, there are some operations and some observations which it will be very difficult to achieve with automatic instruments. Navigating an accurate course close to or around a distant planet may be an example. Keeping a telescope pointed at a particular star in order to get a good photograph may be another. Also, men want to *see*.

Clearly, however, sending up a man is going to add enormously to the expense of the venture. Men are not yet "miniaturized"— they are heavy and bulky. They need a lot of fuel — oxygen, water and food — to keep them going, and they can't stand very high or low temperatures. Furthermore, they insist on coming back alive.

This is a most difficult requirement indeed, for it means carrying along fuel (to fire retro-rockets to slow down on re-entry), wings and other flying equipment to come in to a safe landing — preferably not in the middle of the ocean. All of this stuff must be included in the initial payload at takeoff. So, when we recall that every pound of payload requires about 100 pounds of fuel to get it into orbit, we see that getting a man and all his auxiliary equipment into space and back again may require rockets of effective thrusts of a million pounds or so, just to get into an orbit around the earth.

Human space travel

They had better be pretty reliable rockets, too. We won't like it if very many men come plunging to earth as a result of rocket failures. When we recall that the U.S. agencies have succeeded in getting only 4 objects into orbit after some 15 tries, we see that human space travel may have to wait for more reliable equipment.

But reliability will come — slowly perhaps. Airplanes and even automobiles still sometimes fail — and we won't expect ever to get 100 percent safety. However, since automatic instruments alone can do so much for us in the meantime, we can afford to wait before risking a man. We need to do research on man in space, of course, but do not be disappointed if it takes a few years for the research to pay off.

These, then, are just a few of the adventures in science that scientists and engineers are engaging in these days. And exciting adventures they are — full of promise for the future, and full of mystery. These adventures will change the lives of our children and grandchildren in ways we cannot possibly predict. We cannot predict because every day the adventures uncover new knowledge, and often the new discovery knocks all previous predictions into a cocked hat. The only prediction that we can be absolutely sure of is this: The world of tomorrow will not be the same as the world of today.