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A LAKEHEAD UNIVERSITY SCIENCE REVIEW

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THE VIEWS EXPRESSED IN CARET DO NOT NECESSARILY REFLECT THE OPINIONS OF THE
EDITOR, THE FACULTY OR THE UNIVERSITY.

OUR COVER was inspired from our article "Are we alone?" and was designed by B. Kaminski

A NEW SCIENCE PROGRAMME AT LU

THE INTEGRATED SCIENCE PROGRAMME FOR SEMESTER SYSTEM STUDENTS

Lakehead is designing a new, and to us exciting, first year Science programme. It is time-tabled to meet the special needs of **semester students** (February to May). The emphasis is on the unity of Science rather than separate traditional subjects.

There are few other examples of such a programme, though much interest in this approach has been shown recently. Science departments from across the province of Ontario met and discussed such an integrated programme a few years ago, but no action was taken until now. The Open University in Britain operates an integrated science course and we are examining their films and programmed learning books.

Much of modern research involves tackling problems which may require knowledge of everything from Physics to Biology. We feel that a course such as ours can produce better scientists as well as a vigorous new approach to teaching Science. If you want to be an applied scientist it's a good place to start too.

Looking forward to seeing you in February!

LETTERS TO THE EDITOR

July 23, 1974

In a recent publication of CARET (Vol. 1, No. 3) appears an article "A Geological Traverse Across Africa" by John S. Mothersill. On page 37 it states: "In addition, a visit to Olduvai Gorge where Professor Leaky discovered the bones of Zinganthropus and *Homo erectus* ... which many scientists believe to be direct ancestors of man proved to be most interesting. Work was still being carried out at 'the dig' under the direction of Professor Leaky's widow."

I was under the impression Mrs. Leaky was responsible for the actual find as her husband lay ill in the tent. I intend to undermine neither the valuable work of the Late Professor Leaky nor the find itself but feel credit should be given where credit is due.

One small step for Women's lib — One large step for mankind.

Yours sincerely,

M. Susan McBride, Secretary
Thunder Bay, Ontario.

Dr. Mothersill's reply:

Mrs. Leaky, did in fact, physically unearth the first bones of *Homo erectus leakii*. However 'the dig' was under the direction of Professor Leaky and he supervised the 'construction' of this species. It is not so much a matter of 'women's lib' but rather the senior scientist receiving credit for a team effort.

November 21, 1974

We should like to express our appreciation of Caret. It is a very valuable publication indeed. We have found that articles have a very wide range of interest and use within the school, not confined to the science and mathematics departments, but including History (Archaeological dating, for example) and English as well ... We look forward to further issues ... We feel we cannot afford to miss Caret.

Sincerely,

M.S. Dunnell, Librarian
Thornlea Secondary School,
Thornhill, Ontario

I wish to thank you all for writing, and to follow this by a brief note on p. 27. — *Editor.*

NOTA BENE

Dr. A. D. Booth, President, Lakehead University, has graciously accepted to review for caret a number of books on a variety of topics, in particular Astronomy, Crystallography, Information Theory and Photography.

Why not take advantage of this free offer for expert comments?

Send in your books or titles NOW.

PRIZES! . . . PRIZES!

COMPETITION

A couple of years ago, we ran a competition to name "Caret". The response was gratifying, we had an almost overwhelming number of excellent suggestions, and we always promised ourselves that we would have another of the same as soon as we could build up an adequate prize fund. Well, we now have a little cash put away, and we are going to spend it on an essay competition.

The **Faculty of Science of Lakehead University** is establishing a new programme, called "Energy and Fuel Science" (leading to a B.Sc. degree) which is sure to attract attention from government and industry personnel officers. We want to couple our competition to the new degree.

There have been torrents of words written about the energy crisis, but a dispassionate observer would have to conclude that much of the material we see in the newspapers and magazines is inadequate or inaccurate.

Perhaps you can do better! If you think so, we want to give you a chance to express your views, and we will reward you handsomely for an essay on the subject. Why not write one for us?

Your essay, which should run to about 3,000 words, may cover one of the following topics:

1. Renewable or non-renewable energy resources?
2. Energy versus Environment.
3. Unusual energy sources.
4. Energy in Northwestern Ontario, present and future.
5. Is Canada habitable?

There will be two prizes, each covering the first instalment of tuition fees in the **Faculty of Science** (but not necessarily in the Energy and Fuel Science programme). One prize will go to an entrant from Northwestern Ontario, the other to somebody from outside the region. There will be two consolation prizes of inscribed writing sets to the value of \$20.00 each.

The competition is open to bona fide **high school students**, resident in Ontario. It is not open to relatives of staff of the University. Each essay, which becomes the property of the University, **must be signed** by an officer of the high school, certifying that it is the **unassisted** work of a student in the school. The decision of the judges is final.

Essays may be neatly handwritten or typed by the student. Professionally typed essays are **not** eligible. Do not forget to include your address.

And, the best two essays will be published in **Caret**.

CLOSING DATE 1 JUNE 1975

ARE WE ALONE?

by: Dr. Richard Reis

Because our own fate as a species ultimately depends on our willingness to recognize ourselves as evolving creatures in an evolving environment, we cannot afford to wait much longer before beginning to listen seriously for clues to the whereabouts of intelligent extraterrestrial civilizations, locate them, and try to engage them in conversations . . .

Committee on Science and Public Policy
National Academy of Sciences (U.S.)
1972

At a time of political unrest, population explosions, starvation, and pressing domestic and interpersonal problems, talk of trying to communicate with intelligent life beyond the earth may seem at best, the fantasies of a science fiction writer and at worst, a dangerous attempt to divert our attention from important work here at home.

I disagree. I cannot imagine an experience more profound for every individual and for the population of the world as a whole than that of communicating with intelligent life in another solar system. Such communication offers the opportunity for us to develop our human potential in ways that will never be possible as long as we remain alone. Once contact is made, our society and our culture will be completely transformed.

Any serious examination of possible communication with extraterrestrials must consider three things. First, what are the possibilities of intelligent life existing elsewhere in our galaxy and of our chances of making contact with such an intelligence? Second, what means are available to enable us to understand communication with extraterrestrials? And third, what are the potential, wide-ranging effects such contact would have on us as individuals and on our society as a whole? Let us examine each of these questions in turn.

Until recently the argument for the existence of intelligent life in other parts of the galaxy has been based on statistical grounds. Such grounds still provide the strongest basis for building the case for the existence of extraterrestrials. But two important discoveries in the last decade have

enabled us to go beyond statistical probability alone. The first is the almost certain discovery of another solar system in our galaxy, and the second is the discovery in deep space of chemically-stable, life-forming molecules such as carbon dioxide, formaldehyde and water.

First let us consider the statistical evidence. Much of the mathematical discussion that follows is based on the article: "Is There Intelligent Life Beyond the Earth?" by I.S. Shklovski and Carl Sagan appearing in the Harvard Project Physics Reader, *Motion in the Heavens*.

While it is possible that in the universe life could exist in forms entirely different from anything we know on earth (for example a life form based on silicon rather than carbon) attempts to determine the statistical probability of extraterrestrial life are based on conservative assumptions. While this necessarily limits our scope, it ensures us that our probability is a minimum and thus gives us some idea of the least that we can expect. Let us ask ourselves this question; what are the number of advanced technical civilizations possessing both the interest and capability for interstellar communication? In asking this question we are eliminating all forms of life not sufficiently advanced to want to or be able to communicate with us. We may be eliminating large numbers, but our greatest interest is in those forms of life with which we can communicate. The answer to our question can be expressed by the formula:

$$N = (R_*)(f_p)(n_e)(f_i)(f_c)(L)$$

In this formula N equals the number of civilizations mentioned above, R_* is the average rate of star formation, averaged over the lifetime of the galaxy, f_p is the fraction of stars with planetary systems, n_e is the average number of planets in each system with environments favourable for the origin of life as we know it, f_i is the fraction of such planets on which life does develop, f_c is

the fraction of such inhabited planets on which intelligent life with manipulative abilities arises during the lifetime of the local sun, f_c is the fraction of planets populated by intelligent beings on which an advanced technical civilization arises during the lifetime of the local sun and L is the lifetime of the technical civilization.

The formula itself is simple, estimating the values for each of its parameters is not so easy. The methods by which these values are estimated will not be presented here. They are explained in detail in the reference cited above. The values, based on the most conservative estimates are: $R \sim 10$ stars per year, $f_p \sim 1$, $n_e \sim 1$, $f_i \sim 1$, $f_l \sim 0.1$, $f_c \sim 0.1$. The multiplication of these factors gives:

$$N = 10 \times 1 \times 1 \times 1 \times 0.1 \times 0.1 \times L \\ = 0.1 L.$$

L is the mean lifetime in years of a technical civilization possessing both the interest and capability for interstellar communication. As Dr. Sagan points out "fortunately for us but not for the discussion we do not have even one terrestrial example."¹ If L is very small, say 100 years, then N is so small that we might as well not bother looking. If on the other hand a civilization can survive without annihilating itself for a million or so years then the value of N becomes approximately one million. That is, there are approximately one million stars in our galaxy which have planets on which intelligent civilizations reside. This corresponds to 0.001 per cent of the solar systems in our galaxy.

Once contact is made our society and our culture will be completely transformed.

It is important to realize that the above is a conservative estimate. As we will see later, it may not be necessary for an extraterrestrial civilization to want to communicate with us in order for us to communicate with them.

The preceeding argument is based on statistical probabilities. Is there any direct

evidence that, for example, there are any other stars with planets in our galaxy? The answer now seems to be yes, because planets shine by reflected light and because even the nearest stars directly observe a planet orbiting another star. But if other planets were orbiting another star it might be possible to observe the effects of the pulls of these planets on their sun as the sun moves through space. Careful observations over the past three decades of Barnard's star, a star some 20 light years away, has indicated the presence of at least one and possibly two planets. One of the planets is about the size of Jupiter and is about 400,000,000 miles from its local sun. To be able to establish directly that there is even one other solar system gives strong support to the statistical estimation that there may be at least fifty million planets in our galaxy.

It may not be necessary for an extraterrestrial civilization to want to communicate with us in order for us to communicate with them.

Furthermore, until recently it was assumed that the presence of ultraviolet radiation in extraterrestrial space would annihilate all conceivable combinations of atoms. But the discovery of complex molecules in deep space indicates that the same chemical concatenations that led to life here on earth may be underway elsewhere.

According to Professor Frank Drake, Director of the National Astronomy and Ionosphere Centre at Cornell University:

Each passing year has seen the probability of life in space increase, along with our capabilities of detecting it. More and more scientists are recognizing that contact with other civilizations is no longer something beyond our dreams but an inevitable event in the history of mankind that will occur perhaps in the lifetime of many of us now alive.

But how will it be possible for us to communicate with extraterrestrials? Actually "communicate" may be the wrong word. If by communicate we mean a two-way

exchange of information, then our chances of communication are slim. Let us again take the most conservative stance. It is reasonable to assume that an intelligent civilization trying to send a signal to us will do so using the electromagnetic spectrum. That is, such a civilization will send signals to us at the speed of light at any of a variety of wavelengths. It has been speculated that the most likely wavelength would be 21 centimeters, that of the natural frequency of the simplest atom, hydrogen. If communication is limited by the speed of light, 186,000 miles per second, then it would take at least 20 years for a signal to reach us from Barnard's star. If we answered immediately it would take another 20 years for our answer to reach them. And it is very unlikely that the planets around Barnard's star have intelligent life.

For stars farther away the round trip communication time becomes much greater than the maximum human life span. Although we may want to attempt such an undertaking in the future, the most promising form of communication is "one-way communication" in which we listen to signals from extraterrestrials. This can be done with the use of large radio telescopes.

The National Academy of Science panel has proposed such an undertaking. Code named, Project Cyclops, after the one-eyed creature in Greek mythology, the giant telescope would be located on a 3,000 acre desert site 50 miles west of Socorro, New Mexico. The United States government has announced plans to build the proposed telescope which will consist of 27 dish antennas, each 85 feet in diameter and set up in a vast Y, each arm 13 miles long. Mounted on railroad tracks, the VLA (for very large array of antennas) will be easily moveable for sharp focusing. The cost: an estimated \$76 million.³

Of course we should be sending signals as well as listening for them, "even" if we do not know to whom we are sending. After all if everybody is listening, and nobody is saying anything, then there will be nothing to hear. In fact, we have been sending signals.

Recently a special attempt was made to send a specific message into space. The Pioneer 10 spacecraft launched on March 10, 1972, is designed to pass Jupiter and then swing out of the solar system toward the centre of our galaxy. Although the probability of it being "captured" by another civilization is very, very remote, a special drawing designed by Carl Sagan and Frank Drake and executed by Dr. Sagan's wife, Linda, was etched into the side of the spacecraft.

Like it or not we have announced our presence to the universe.

The symbol at the upper left of the plaque represents two states of the hydrogen atom, and the little vertical line between the two circles denotes the 21-centimetre-long wave of electromagnetic energy that the hydrogen atom emits. Any advanced society, the designers believe, would not only recognize the atom symbol, but understand that the line represents the atom's characteristic wavelength and that it is meant to serve as a scale. Below the atom, 14 of the radiating lines depict pulsars — stars that send out radio waves in pulsed rhythms — and their positions in relation to the earth. At bottom are the sun and the planets; the bent line with an arrowhead pointing to a depiction of Pioneer 10 shows that the craft came from the third planet out from the sun and was ejected from the solar system by Jupiter's gravity. The man, with his hand upraised to show the unique opposed human thumb, and the woman beside him stand in front of a schematic sketch of Pioneer 10 to show their size relative to the vehicle.⁴

More important is the fact that as a result of communication between points on earth and manned and unmanned spacecrafts during the past 20 years, we have been sending high intensity signals out into all regions of space. Some of these signals have now reached out 20 light years past the star

Vega. Like it or not we have announced our presence to the universe.

Now we may ask, how could we possibly decipher a message sent to us from a civilization we know nothing about? It may not be as difficult as it first seems. A message would not of course be sent in some specific language as English or French. It would probably be sent in the form of a binary code consisting of signals that are alternately on and off. The decoding of such a deliberate message is relatively simple. However, it is now thought by many astronomers that what we are more likely to do is to "catch" messages of conversations between members of an extraterrestrial civilization much as they can now catch messages we have been sending to our astronauts in space. The deciphering of these messages would be more difficult but by no means impossible.

At this point the reader might well feel that we have taken a much too conservative view concerning the possible forms of communication. Perhaps we should be more bold. Must we assume that communication would be by use of electromagnetic waves? Perhaps a highly advanced civilization can dispense with the electromagnetic spectrum and can send "thought waves" instantaneously to us. There are people who claim to have received such signals. We tend to dismiss such people as kooks, or interestingly enough religious fanatics. But can we be so sure that they are just imagining things? Does it follow that another intelligence would want to send signals to all of us? It is possible that only certain people, for whatever reasons, are sensitive to these signals? The answer is yes, it is possible. But if this is the case then the majority of us are not receiving these messages. For universal benefit it is more useful to concentrate on listening for signals that can be interpreted by everyone.

Now let us turn to the last and by far the most interesting question. What effect would the receipt of signals from extraterrestrials have on us?

Let us again recognize that for at least

many generations to come the communication is likely to be one-way; we receive but we do not respond. Also, as discussed earlier, the most likely situation is one of our "listening in on" conversations between members of an extraterrestrial race rather than listening to signals sent out specifically for our benefit. This makes the deciphering of the conversations much more difficult, but the payoff is correspondingly greater. We can learn a great deal more about a culture by eavesdropping than we can by listening only to what they want us to hear.

So what are the possible outcomes? The first thing that comes to mind is the possibility of learning something new in the area of science and technology. Have the extraterrestrials discovered some new laws of physics, or some new all powerful energy source? The idea that we would learn some new technological information that could solve our material problems here on earth is intriguing and pervasive. I think, however, that we should be careful here. It is just as likely that we would be in a position to teach them much more than they can teach us about science and technology. While acknowledging the possibility of learning something new in this area, it should be placed at the bottom of the hierarchy of possible benefits to expect.

The most important benefits are likely to occur in changes in our thinking in the social sciences, arts, philosophy, ethics and religion.

It will be extremely interesting to simply know how these beings get along, how they spend their time, what they believe, and how they structure their society. It would be fascinating to know not only how we are different but also in what ways we are similar. Do they experience similar emotions of fear, love and hate? The answers could be disappointing on the one hand and refreshing and comforting on the other.

Is it possible that only certain people, for whatever reasons, are sensitive to signals from extraterrestrials?

It would be particularly valuable to know how a foreign society deals with the phenomenon of death. The problem of death, and for us it is a problem, may be dealt with in an entirely different way by an extraterrestrial community. Whatever way this may be it will give us a useful new perspective on our greatest single preoccupation.

Another area of interest is that of beauty. What is beautiful? We know that to us humans who see only a tiny fraction of the electromagnetic spectrum, some things appear beautiful and others do not, but we are not really sure why.

Again, the idea that we might share some common appreciation of beauty is as intriguing as the idea that they may "see" far beyond what it is possible for us to perceive.

In the areas of philosophy and religion it is difficult to generalize about the effects because they will be to a large extent unique to each individual. But there may be some common denominators.

It would be fascinating to know not only in what ways we are different, but also in what ways we are similar.

We might ask ourselves, "What the position is of the organized religion on the possibility of the existence of extraterrestrial life?" According to Rabbi Norman Lamm, Erna Michael Professor of Jewish Philosophy at Yeshiva University in New York:

Judaism has throughout the ages generally confined itself to the problem of man as the sole concern of God in this world. As a result, there has come about the idea that man is the purpose of the entire universe. This has been a rather general tendency, and never formally incorporated in Jewish doctrine. However, one of the very greatest of all Jewish thinkers, perhaps the most eminent Jewish philosopher of all time, Moses Maimonides — who flourished about eight hundred years ago — strongly opposed "anthropocentrism," the

view that man is the purpose of all creation. He maintained that man may be the superior creature on Earth, but he need not therefore be considered the purpose of the universe. In fact, he is not necessarily the most advanced being in the world. According to his approach, Judaism today can welcome with a remarkable openness the idea that intelligent races, even more intelligent than man, exist elsewhere.⁵

Of course organized religion has not always been so openminded. We have only to recall the refusal of the Catholic Bishops to even look through Galileo's telescope.

We may ask, what difference does it make? If extraterrestrials are out there, they are out there, and whether or not we want them to be there makes no difference. But it does make a difference. It is the difference between hearing them or just listening to them, between changing and not changing. Are we ready?

Some time ago a survey was conducted among the leading newscasters in North America asking them to imagine the most spectacular news story possible — bar none. Some named a cure for cancer, others an international declaration of peace. But the two at the top of the list, far above all others were (1) the second coming of Christ, and (2) contact with extraterrestrials.

At first glance these two may seem quite different. But are they really? Of course not. Either one would provide a clear negative answer to our oldest of all questions. ARE WE ALONE?

References

1. Sagan, Carl, and Shklovski, J.S. "Is There Intelligent Life Beyond The Earth?" *Motion in the Heavens*, Harvard Project Physics Reader, 1966.
2. Lear, John. *The Search for Man's Relatives Among The Stars*, Saturday Review, June 10, 1972, p. 34.
3. 1973 *Nature/Science Annual*, "Summing up the Year", p. 166. Time-Life Books, Inc., N.Y., 1972.
4. *Ibid.*, p. 167.
5. Agel, Jerome, Ed. *The Making of Kubrick's 2001*, New American Library, Inc., N.Y. 1970, p. 55.

The Teaching of Science

by: Roland Baird

In the teaching of science one should "teach the children to think by thinking" and "science should provide students with deeper insight into the logic and methods of the professional scientist".¹ A series of learning experiences for eight grade eight pupils from Shuniah School in Thunder Bay was planned with this in mind. By describing the activities that were experienced, and the results of these experiences, it is hoped that through this one actual example the reader will see how pupils can learn to think by thinking, and how they can gain deeper insight into the logic and methods of the professional scientist, if they are properly guided by their teacher.

The Lesson

During the first meeting with the pupils we discussed the observations that have been made in the past about solids, liquids and gasses. They recalled that some substances changed from a solid to liquid form, and some from a liquid to a gaseous state. They saw that cooling some substances caused them to change from a gaseous state to a liquid state and from a liquid to a solid form. On being asked why all these things happened most of the pupils were very puzzled and it became necessary to recall the fact that solids, liquids and gases are made of molecules.

The first task given to the pupils was to have them formulate their own individual theory on why a solid can change to a liquid or a liquid may change to a gas and so on. The pupils were informed that scientists of years ago also had to formulate theories on why these things happened. The pupils were also made to realize that they had an advantage over the scientists of years ago, because they are familiar to some extent with molecules and atoms.

The pupils at some time during the learning experience should become aware of

what they are doing; "they should come to realize that they are employing processes through which men learn".² In formulating their own theories the pupils are learning by thinking, and they are using the methods of the professional scientist.

The resulting theories were very interesting and showed evidence of a lot of thought on the part of each pupil. The pupils were separated for one half hour and then were grouped together to discuss their theories. Below are some of the results of their efforts.

- "the liquid is heated to its boiling point which will cause the *molecules to break up* and form a gas"
- "and then the *molecules are expanded* forming a liquid"
- "the heat when making contact with the molecules of the substance quickens up the movement of the molecules, by melting them and they become lighter. The molecules are now sort of *blended together, lighter, faster and slipperier*. This is how a solid changes to a liquid."
- Finally, one boy when talking of how a gas changes to a liquid state, in his theory, makes the statement "*molecules begin to pile onto each other*" and one of the girls states, "I think liquids turn to gases when heated because the *molecules in the liquid get even more spread out* and rise into the air, becoming a gas."

The discussion about the theories proved to be perhaps the most beneficial part of the entire lesson. All students were eager to comment on the theories that had been formulated. The pupils were encouraged to realize that, "science is not just a body of facts — very important too, are the techniques used in discovering these facts."³

Much of a scientist's time is spent on experimental research, and it is often a good idea to work with a partner. This point was given to the pupils, and it was mentioned that by working with a partner you often

save a lot of time. One person working alone often becomes too fond of his own ideas and without realizing it, he sometimes does not see, or ignores an easier or better method of accomplishing a certain task. By working with a partner this can often be avoided. It is important that both partners be open-minded, and that they discuss many possibilities.

Through their discussion they were using the methods of the scientist, and it was good that they were able to criticize their own work and evaluate their own performance. At times it did become necessary for me to moderate the student's opinion of the work, or to confirm it.

The Pupils' Second Task

The second task given to the pupils was to use the school library, and find out all they could about molecules and the Molecular Theory. They were to work in pairs, and the information they gathered was to be put onto a sheet entitled "What Scientists Know About Molecules". They were also asked to read about some of the experiments that had been done in finding out about molecules. The task was accepted readily by most of the group because they were quite anxious to find out just how accurate the theory was that they had formulated.

Here are the facts that were gathered by the pupils. They had met as one group, and under teacher guidance, listed what was thought to be most important.

What Scientists Know About Molecules

1. "All matter is made up of molecules." *World Book Encyclopedia*, (Vol. 13), Field Enterprises Educational Corporation, U.S.A., 1972, p. 576.
2. "A molecule is the smallest possible particle of a given compound. Ex. A volume of air the size of a pin head holds 30 million times as many molecules as there are people on earth." *Popular Science*, (Vol. 10), Grolier Inc., New York, 1966, p. 458.
3. "A molecule is a combination of two or more atoms that form a particular substance." *The New Book of Knowledge*, (Vol. 15), Grolier Inc., New York, 1973, p. 236.

4. "Molecules are believed to be constantly in motion, except at the theoretical temperature that we call absolute zero." *The Book of Popular Science*, (Vol. 1), Grolier Inc., U.S.A., 1966, p. 163.

5. "The rate at which molecules move depends upon the degree of hotness of a given substance." When more heat is applied the rate of speed increases and the molecules collide more frequently and with greater force. They take up more space as they bounce farther apart. "The rate of movement of molecules gradually diminishes as the temperature drops. When we reach approx. -273 degrees C the motion of the molecules stops and there is no longer any heat to measure." *Ibid.*, p. 164.

6. Cooling Molecules — "they will move more slowly and they will collide less frequently and usually occupy less space. When molecules move together into less space, the substance contracts." *The Teaching of Science* by June E. Lewis and Irene C. Potter, Prentice-Hall International, Inc., London, 1966, p. 138.
7. "The relative distance between the molecule of a substance and their relative speed usually determines whether the substance is solid, liquid or gas." *Ibid.*

With all the information gathered on molecules and the Molecular Theory the pupils could now see what happens when substances change their physical form. They were now aware also, of why most solids, liquids, and gases expand when heated and contract when they are cooled. Some of the pupils realized that their theory had been incorrect, and others saw that some parts were quite accurate. The pupils had played the role of a scientist, and after careful research some had enjoyed partial success and others total failure.

The Pupils' Third Task

On the third meeting with the pupils they were asked to read over all that they had found out about molecules. The pupils were asked to think of a way (an experiment) of providing one or more parts of the

Molecular Theory. It was important that they realize that the professional scientist does not always accept what he reads — he often sets up various experiments in an effort to prove a given statement or theory right or wrong.

In doing the various experiments, the pupils were encouraged to question each other, as they experimented, to clarify their thinking. By this kind of friendly challenge the children can stimulate each other to do critical thinking. Again, the pupils have been encouraged to use the methods of the professional scientist. When the pupils are encouraged to use their initiative in experiences like this they have excellent opportunities to practise the scientific method, and to develop problem solving skills and scientific attitudes.

"The **nonrigid individual** has the ability to see and to state the relationships existing and necessary for the correct solution of a problem. He can take the individual facts under consideration and organize them into a single unified structure. The thought processes are broad and integrated and take all the pertinent facts into consideration in arriving at a solution to the problems."⁴ Before the pupils were to begin their fourth and final task, we reviewed everything that had been accomplished thus far. A scientist should be a non rigid individual, as stated above, and the scientist must be able to review his facts, and to use them to help him solve a problem. The pupils had their facts gathered, they had some experiments, and there had been several discussions — now they would have to organize their thinking and use the knowledge gained to solve a problem.

The Pupils' Fourth Task

A drop of ink was dropped on the surface of water in a glass beaker. The pupils watched the ink slowly diffuse with the water. A discussion followed the observations and then the pupils were asked to write down their conclusions. It was encouraging to see that all pupils had concluded that moving molecules was the cause of the diffusion. Some of their conclusions

are listed below:

- "The molecules in the ink started to spread because the water molecules were bouncing off the ink molecules which led to the molecules mixing."
- "The ink started to spread out because the water molecules were hitting the ink molecules and forcing them to spread out."
- "When the ink hit the water, the molecules in the water started pushing the ink around. The water and the ink mixed, filling in the spaces between the molecules."

Some pupils were able to express their conclusions very clearly — "The molecules in the water are moving about and so are the ink molecules. When a drop of ink was placed in the water, the water and ink molecules hit off each other causing the ink to spread. This shows that the molecules are constantly moving." Some pupils could not quite grasp what was taking place, "When the ink hit the water it began to spread all over and so the molecules in the ink must move fast because the ink was all through the water in just a few minutes." This pupil had the idea of moving molecules, but she only talks about the ink molecules, and neglects to mention the collisions between water and ink molecules. The important thing, however, was that the pupil was learning to think by thinking and she was recalling facts that she had gathered in an effort to solve a problem. She was having some difficulty with the material, but she was experiencing problems that all scientists face. She had seen an experiment take place, and she wasn't quite sure what had happened. How many thousands of scientists must have had this same experience?

After a group discussion it was decided that there was a simple way of proving the diffusion was caused by the colliding molecules of both the liquids — ink and water. Scientists are often not satisfied with one experiment — they often devise other experiments to prove that a conclusion is correct. It was decided that two beakers be filled with water. Before a drop of ink was added

to each, one of the beakers was cooled (put in the snow) and the other beaker was heated over a bunsen burner. The pupils saw that the ink diffused immediately in the hot water. The experiment satisfied the pupils that it was the action of the molecules that caused the diffusion. In the hot water the molecules are moving about very quickly and they therefore collide much more with ink molecules — diffusion takes place almost immediately. As one grade 8 pupil states, "The ink drop in the jar of hot water diffused much faster than the drop in cold water because the molecules were bouncing around and hitting each other much faster with heat, and therefore spread the ink much faster. In the hot water many more collisions occurred than in the cold water."

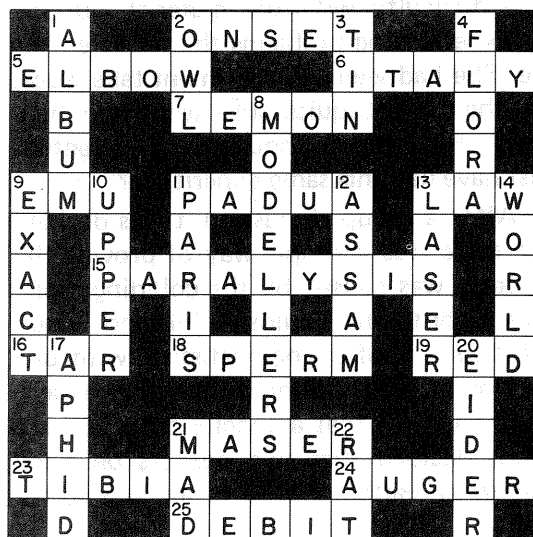
"Most definitions of science agree that science begins with the search for knowledge or truth."⁵ The pupils have experienced this search for knowledge as they have experimented with and discussed molecules. They have learned certain facts about molecules, but more important, they have been made to think, and they have experimented, theorized, and discussed just like the professional scientist. In the teaching of science it is

important that the pupil not just learn what has been discovered, but how, and by what method the discovery took place. In having the pupils learn the methods of the scientists the science program benefits, "children should make inquiries — the child should have the opportunity to develop his resourcefulness, his imagination, his technical inventiveness and his theoretical reasoning ability . . . A science program should be rich in opportunities for the development of the student's creative abilities."⁶

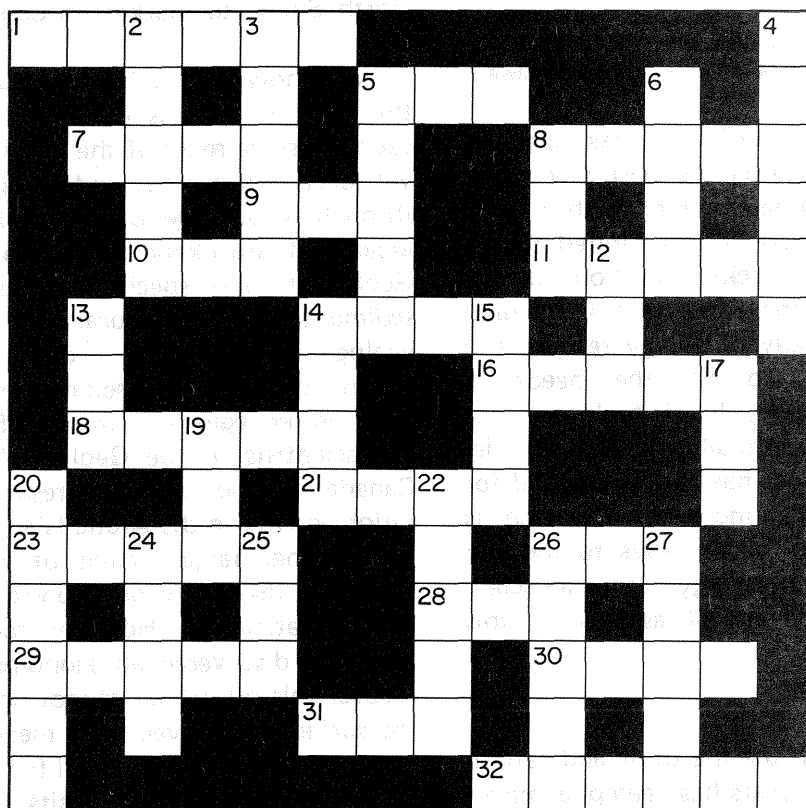
Footnotes

1. *Science*. Intermediate Division Interim Revision. p. 9, Department of Education.
2. *Ibid.*
3. *Ibid.*
4. *Educational Psychology in the Classroom* by Henry Clay Lindgren, New York, London, 1962. p. 149.
5. "How To Do An Experiment" by Philip Goldstein. New York, Chicago, 1957. p. 8.
6. *Science*, Ontario Department of Education, (Intermediate Division, 1972). p. 9.

SOLUTIONS TO PREVIOUS PUZZLES:



THE AVIARY



Clues marked with an asterisk involve the common or ornithological name of a bird. A field guide to the birds would be helpful.

ACROSS

- 1* Trailing legs and S-shaped legs identify them (6)
- 7. A means of propulsion (4)
- 8. The dendrocopus keeps his pecker up in here (5)
- 9* One laid a 25 down or two for gentlemen (3)
- 10. A plant for the encouragement of 9 across (3)
- 11* A poor flier but expert diver (5)
- 16* Another 1 across (5)
- 18. Where waders may be found (5)
- 21* A phlegmy cry for sale (4)
- 23* The American symbol of war and peace (5)
- 26. The attitude of 9 across while concerned with 25 down (3)
- 28. A short healer appropriate to the subject at hand (3)
- 29. 13 down may easily be this by a bunko expert (5)
- 30* An ancient Egyptian object of worship (4)
- 31* A careless walker (3)
- 32* Wagers driven by bitterns (6)

DOWN

- 2* Birds under street cars (5)
- 3 down and 5 across*
A goat milk thief is a container for moonbeams (5,3)
- 4* He goes by in the street (6)
- 5* He sounds like a slate-coloured dope fiend, more or less (5)
- 6* Someone entered the water precipitately (4)
- 8* A witty European fellow, but lacking a tail (3)
- 12 down and 14 across
A left-wing election (3,4)
- 13* Take away one chump, and you leave another (3)
- 14. Shove (4)
- 15* A practical joke (4)
- 17. This eater is animal but not avian, though it might arouse a flicker (3)
- 19* The epitome of avian wisdom (3)
- 20* An admiral sparrow, with a bright ochre-buff breast (5)
- 22* We are in for a rough sea according to the sound of things (5)
- 24* To speak plainly about it, a lifter at the docks (4)
- 26* A leg expander (5)
- 27. For a treat, a pet budgie may perform it (5)

LOOKING AHEAD TO THE FUTURE ENERGY FUELS

by: *Frank Jefferies and
Ron Scammell*

Public Relations and Information Services
Dept. of Energy, Mines & Resources, Ottawa

Energy is a word that has been on everyone's lips during the past few years, especially during last winter with the so-called "energy crisis" in the United States. Canada is in a lucky situation at the moment in that there is a relatively abundant potential supply of energy resources in Canada, enough to fill the needs of Canadians. However, fossil fuels are not renewable and eventually Canada will deplete what she now has as the demand for energy continually increases. Research is going on to find better ways to use our present resources of energy. Canadian scientists are involved in all aspects of this research.

PETROLEUM

The growth in the use of oil and natural gas in the last 25 years has been phenomenal. In 1950, oil and gas contributed to about one quarter of Canada's energy needs. Today, oil and gas contribute to more than two thirds of all the energy required. But present reserves of conventional oil and gas in Alberta - which provide more than 75 per cent of all Canadian petroleum needs - will soon reach maximum production limits. And with the demand for oil and gas expected to at least triple by the year 2000, it is clear that new reserves must soon be found and brought into production.

The most promising prospects for more petroleum exist in the Canadian frontier areas, such as the continental shelves and slopes, and the mainland and islands in the Arctic areas. Deposits of natural gas and oil have been found in the Mackenzie Delta area and also in the Arctic Islands. A 27-company consortium of Canadian and American firms recently applied for a permit from the federal government to construct a pipeline to move the gas from the Mackenzie Delta, along with American gas from the Alaskan

North Slope, to markets in Canada and the U.S.

Just how much oil and gas Canada has in the frontier areas is extremely difficult to estimate since most of the potential has not yet been discovered, and is only inferred through knowledge of the geology of the areas that are likely to contain petroleum. Geologists who specialize in stratigraphy, sedimentology, structural and petroleum geology combine with experts in paleontology to analyze the sedimentary basins in the frontier regions. It was a 1954 report of the scientists of the Geological Survey of Canada that spurred the present oil exploration activity in the Arctic Islands.

Another large source of crude oil is found in the heavy oil deposits in Alberta and Saskatchewan. However, scientists still have not discovered an economical way to recover this oil, which cannot be brought to the surface by conventional means as it will not flow. There is a potential for large future production from these deposits; for instance, once the technology has been developed, a possible 30 billion barrels might be recoverable, almost three times as much as the present proven Canadian reserves.

Considerable research on the heavy oil deposits has been carried out with one oil company working for ten years to develop an efficient system. Pilot-plant projects using the best method developed to date steam injection - have been undertaken. This method reduces the viscosity of the oil allowing it to be recovered by conventional methods,

Despite all the scientific work that has been carried out, the estimates of the oil and gas that may be found and recovered differ widely. However, the federal government's "ENERGY ANALYSIS", that was released in June 1973, estimated that Canada has enough conventional oil and gas to serve her own needs to beyond the year 2000. After that, oil from oil sands, and oil and gas from coal will be needed to meet domestic

requirements, and will be sufficient until at least the year 2050.

SYNTHETIC FUELS

The Athabasca Oil Sands

The possible key to the future of Canada's oil development lies under the jack pine and muskeg east and west of Athabaska River in northeastern Alberta. Here are found the Athabasca tar sands from which an estimated 300 billion barrels of oil might be recovered if the technology can be developed to extract the oil from the deep deposits. This vast amount of oil is about six times the total proved reserves of conventional oil in North America and is comparable to the present probable reserves in the Middle East.

Explorer Peter Pond in 1788, while looking for a site for a Hudson's Bay Company post, noticed that the Indians used the gooey sands to patch their canoes. One hundred years later a federal government geologist from the Geological Survey of Canada reported on the sands. This was followed in 1897 by the first of many unsuccessful wells.

It has only been since the 1960's that a concerted effort has been made to recover the synthetic crude. At the present open-pit mining is used to remove the tar sands, which are then processed to extract the oil. However, only a relatively small portion—about 30 billion barrels—of the crude can be recovered by this method and the remainder of the Scientists from both government and industry have been investigating ways to extract the oil, similar to those envisaged for recovery from the heavy oil deposits.

Instead of the picks and shovels of the old prospectors the modern tar sands developers are using massive pieces of machinery, such as the bucketwheel excavator that is over 100 feet high. These excavators can handle over 6,000 tons of material an hour. Scientists have had to develop special metal for this equipment, to withstand the extreme wear and tear of the abrasive sand and temperatures ranging from 90 degrees above in summertime to 60 degrees below in winter.

More than two dozen oil companies hold leases in the Athabasca tar sands but only one is in operation at present. Great Canadian Oil Sands Limited (GCOS), has been producing syncrude since 1967 but will be joined by a minimum of three more plants in the next ten years. GCOS produces about 50,000 barrels a day. A consortium, Syncrude Canada Limited, is planning to produce 125,000 barrels a day; and a third operator, Shell Canada Limited, 100,000 a day.

Coal Gasification

Potential fuels for the future are synthetic gas and oil made from coal. By reacting coal with water and heat, it is possible to obtain methane gas and oil. In theory, coal gasification presents an attractive alternative to coal as a fuel because oil and gas are relatively clean burning, and Canada has a large resource base of coal.

However, there are many scientific and technical problems to be overcome. The technology for coal gasification has come a long way from the crude techniques used in the early 19th century to provide gas lighting in the streets and homes in Europe. Gasification in those days produced a gas with a low heat value. Modern gasification techniques can produce a heat value that compares to that of natural gas. The costs for full-scale development, however, are so high that gas and oil prices have to rise sharply to make the process possible on a large combustion heating it is cheaper to burn directly oil or coal than it is to produce synthetic oil and gas from coal. But, with tighter environmental controls and rising oil and gas prices, coal gasification could be an important energy source in the future.

Added to the problem of the high costs of gasification is the limit on availability plant sites. Canada may have only five areas with enough water and readily available coal to make gasification plants feasible. Although Canada's estimated coal reserves of 120 billion tons may seem like an unlimited supply, just how much is available technically and economically has not yet been defined.

ATOMIC ENERGY

Nuclear power, fueled by the abundant supplies of Canadian uranium, promises to be the dominant source of future energy in Canada. Of all the electricity produced in Canada today, only three per cent comes from nuclear power, with hydroelectricity supplying 75 per cent and fossil fuel plants supplying 22 per cent. But by the year 2000, it is estimated that at least 40 per cent of all electrical energy will come from nuclear generating stations. By the year 2050, Canada will have moved into the era of the "electrical society" with about 90 per cent of all energy needs supplied by electricity, compared to about 25 per cent today. And that electricity will come primarily from nuclear power.

The CANDU Reactor

The unique CANDU (Canadian Deuterium Uranium) nuclear reactor, designed and built in Canada, is a proven source of nuclear power that is now attracting worldwide attention. Unlike most other reactors, CANDU uses natural uranium as a fuel, and so avoids the need for uranium enrichment plants. Proven Canadian resources of natural uranium are sufficient for at least the next 100 years. And, as improvements are made in the CANDU design, nuclear fuel resources can be utilized for an appreciably longer period in the future.

Compared to the cost of the fossil fuels, uranium is cheap. One cent's worth of natural uranium produces about 25 kilowatt hours of electricity compared to about 2 Kilowatt hours for one cent's worth of coal or oil. Also, the energy potential of uranium is enormous. One pound of the uranium used in the CANDU reactor releases the same amount of energy as 27,000 pounds of coal, or 2,200 gallons of fuel oil.

With the efficient natural uranium cycle that is possible with the CANDU reactor, there is no current economic incentive to reprocess the spent fuel, which is stored in water-filled bays at the nuclear power plant. If, on the other hand, the spent fuel was reprocessed, there would be the problem of storing the waste radioactive isotopes.

Despite the many advantages of Canada's nuclear power program, it is not without its challenges. Since most of the waste heat from a nuclear plant is released into the cooling water of surrounding rivers and lakes, thermal discharges require careful disposal techniques and continued attention.

Nuclear power has already begun to flex its muscles in Canada. The first full-scale nuclear power station in Canada at Pickering, Ontario, for many months has been producing more electrical power than any other nuclear power station in the world, even though the capacity of some stations is greater. Its four nuclear reactors have a capacity of 2,160,000 kilowatts - enough to supply almost 2 million homes. Two smaller prototype nuclear power stations are operating in Ontario, and another was constructed earlier in Quebec.

Under construction now on the shores of Lake Huron in Ontario is a large scale nuclear complex, the Bruce Nuclear Power Development. The first 750,000 kilowatt commercial CANDU reactor will become operational in 1975, to be followed by seven others for a total planned output exceeding 6,000,000 kilowatts. Other stations will be built in Quebec and New Brunswick and before long nuclear power plants will be located in other Canadian provinces.

NEW SOURCES OF ENERGY

Eventually completely new sources of energy must be found. All fuels, even the abundant supplies of uranium, are finite resources, and once used, cannot be replaced. Many possibilities for energy in the future are now being researched, although large-scale development of these unconventional sources of energy is many years away.

Except for fission and fusion the ultimate source of energy is solar power. So great is the energy potential of the sun that it could theoretically provide virtually unlimited supplies of energy. Already solar power is a reality in the U.S. space program but, before mass generation is possible, many technological obstacles must be overcome.

There has been some Canadian research on solar power, primarily by the Brace

Research Institute of McGill University. This has covered such facets as the heating of water, cooking, desalination, greenhouses and the drying of agricultural products.

The Brace Research Institute is also active in research on wind power for provision of electricity in remote areas as well as for water. The National Research Council and the University of Sherbrooke have also carried out work on this aspect of energy.

Another potential source of large amounts of energy is fusion power. Instead of generating energy by the splitting of atoms as today's nuclear power stations do, fusion power generates energy by combining light atoms of hydrogen. Fuel for this fusion process is an isotope of hydrogen called deuterium which exists in the oceans of the earth. If one per cent of the concentration of deuterium were withdrawn from the oceans, the energy that could be released by fusion would amount to 500,000 times the energy of the world's initial supply of fossil fuels. Again, however, the problems of

controlled fusion are difficult and a solution is decades away.

Canada is not active in research in this field but a study is under way to determine the possibility of establishing a Canadian program to control nuclear fusion. Scientists at the Valcartier establishment of the Defence Research Board have carried out extensive research on lasers and their application, one of which could possibly be used in control of nuclear fusion.

A renewable resource that has been receiving much attention, particularly in Canada is tidal power. The Bay of Fundy on Canada's east coast has a great potential for electrical generation, although nowhere near the potential of solar power or fusion power. The costs at present, however, seem too great for commercial development.

Canadian scientists are in the forefront of research for new energy sources and will continue in this role in the future.

The International Congress of Mathematicians 1974

by: Dr. P. Mah

Lakehead University, Thunder Bay

The International Congress of Mathematicians, held every four years, recently brought together approximately 7000 mathematicians and their families from around the world to the campus of the University of British Columbia in Vancouver, B.C. The Congress opened on the 21st day of August and lasted for 9 days. Since one of the primary aims of the Congress was to promote personal contacts among mathematicians over the world, the organizers, chaired by Professors R.D. James and M. Sion of the University of B.C., have tried to integrate the scientific and social aspects of the programme. Efforts had been made to provide individuals with frequent opportunities to meet and exchange ideas in congenial surroundings. There was general agreement among the Fellows of the Con-

gress that the unique setting and the peaceful atmosphere of the campus of UBC have contributed greatly to the achievement of this goal. With the same goal in mind, the organizers had decided to break tradition by not setting aside Sunday as a tour day but rather, instead, scheduled a series of daily tours, barbecues and picnics for relatively small groups throughout the Congress. And although formal lectures were scheduled throughout the days of the Congress, participants usually could find at least a couple of days in which no formal sessions in their area of interest would be given.

All formal lectures were held at the University of B.C. However, the University of Victoria and Simon Fraser University held open house for mathematicians during the Congress. In addition to this, seminars on Probabilistic Methods in Differential Equations, Mathematical Logic, some aspects of Applied Mathematics, and Graph Theory were held in these universities.

There were 17 invited expository addresses of one hour duration. These were given by top men in their fields. Each address was intended to inform members of the Congress about the general evolution of mathematics in some major area and should be understood by most mathematicians working in other fields. These addresses were given in a theatre and were televised live through the campus. Moreover, the addresses were recorded on videotape and may be replayed at any convenient time. Addresses of a more specialized nature were given by 160 invited speakers. These lectures, of 45 minutes duration, were intended to present developments in more specialized fields, and were likely to be more technical. Again, these lectures were delivered by top people in their fields and their audience consisted mainly of those working in their area of interest. As well, there were approximately 700 short communications of 15 minutes duration given by the delegates. These communications contained the results of their mathematical research. In addition to these formal lectures, numerous informal seminars and discussions were arranged on individual basis.

One of the highlights of the Congress was the open ceremonies, including the announcement of the winners of the Fields Medals Awards, at the Queen Elizabeth Theatre in downtown Vancouver. The Fields Awards was named after the Canadian mathematician J.C. Fields. The award is given for top contributions made by young mathematicians (aged below 40) in their research. Although the award consists of a gold medal and a cash prize of \$1000, mathematicians all over the world have come to value the award as an equivalent of a "Nobel Prize" in mathematics. The idea of the award was first proposed in Toronto, 1924. Two awards were made at each Congress since 1936, but the organizers of the Moscow Congress in 1966 and those of the Nice Congress in 1970 found it difficult to select only two winners and so they raised the number to four (which perhaps indicated that tremendous progress has taken place in mathematics in the last two decades). This

year, the winners were Professors Enrico Bombieri, University of Pisa, Italy and David Mumford, Harvard University. A more comprehensive list of past winners will appear at the end.

The last day of the Congress was August 29 and during the closing ceremonies it was announced that the next Congress will be held in Helsinki in 1978.

Attending the Congress from Lakehead University were Professors W. Allaway, A. Day, W. Eames, C. Kent, P. Mah, S. Naimpally and J. Whitfield. Professor Allaway presented a paper entitled "The Representation of Orthogonal Polynomials in Terms of a Differential Operator Containing Their Generating Function", while Professors Day and Whitfield chaired a section of the Congress. Prior to the Congress, mathematics departments across Canada held open house for foreign mathematicians enroute to the Congress. Visiting Lakehead University for five days was Professor Ivan Singer, Head of Section of Functional Analysis and Geometry, Institute of the Academy of Sciences, Bucharest, Romania. Professor Singer is considered to be one of the leading authorities on the Theory of Best Approximation and the Theory of Bases. He has written numerous articles and books on the subjects. While he was here, he presented a colloquium talk entitled "On Best Approximation in Normal Linear Spaces".

List of Fields Medallists

Oslo, 1936	Lars Ahlfors Jesse Douglas
Cambridge, Mass., 1950	Laurent Schwartz Atle Selberg
Amsterdam, 1954	Kunihiko Kodaira Jean-Pierre Serre
Edinburgh, 1958	Klaus Friedrich Roth Rene Thom
Stockholm, 1962	Lar Hörmander John Milnor
Moscow, 1966	Michael F. Atiyah Paul J. Cohen Alexander Grothendieck Stephen Smale
Nice, 1970	Alan Baker Heisuke Hironaka S.P. Novikov John G. Thompson
Vancouver, 1974	Enrico Bombieri David Mumford

science FICTION or science FACT?

by: Professor J.S. Griffith

Lakehead University, Thunder Bay

Read through the topics listed below, then decide which are ideas of science fiction authors and which have been proposed in scientific journals.

- (a) Life on Mars
- (b) Alteration of the rotational axis of Mars so that more earth-like conditions exist on the planet
- (c) Life on Titan (a satellite of Saturn)
- (d) Manned space missions to comets and asteroids
- (e) Millions of planets moving through space unattached to stars
- (f) Millions of planetary systems in our galaxy, with a high proportion of them inhabited.

All these ideas have been taken from reputable scientific research journals for professional astronomers.

'Towards a more habitable Mars — or — the coming Martian spring' was the title of the paper that contains ideas (a) and (b). Recent observations of Mars (Mariner 9 and other probes) have shown us features which are at present only explainable in terms of the flow of water at some time in the not too distant past.

There are a large number of dried-up 'river beds' sharply concentrated towards the equator of Mars, indicating that the climate of Mars was at one time more Earth-like with flowing surface liquid water. Calculations show that a fifteen per cent increase in the heat absorbed by the polar ice caps of Mars would release sufficient carbon dioxide to increase the atmospheric pressure and hence the climatic circulation and prevent the ice caps (of carbon dioxide overlying water ice) from reforming. Four mechanisms for the ice ages of Mars are possible.

- (i) changes in the amount of heat produced by the Sun
- (ii) changes in the orientation of the rotational axis of Mars
- (iii) polar wandering, bringing the ice caps into warmer regions of the planet

- (iv) dust gradually covering the ice caps, increasing the amount of absorption of energy (like the sinking of dirt into snow banks).

Spores are known to exist for very long periods of time on the Earth, and if the excessive evolutionary pressure that Mars would exert has produced life spores that survive through an ice age to the next warm period, triggered into activity by the melting of the permafrost, then life on Mars may exist. Two of the experiments on the Viking landers involve the addition of water to samples brought into the spacecraft, and may reveal the presence of such spores.

There is a discrepancy between the predicted rate of arrival of solar neutrinos and the observed value, and it is suggested that this discrepancy is due to expansion of the solar core. There is a suggestion of such expansion (and consequent variation in brightness) in observations of other stars, and to the extent that climatic change produced by major solar variability produced major evolutionary advances on the Earth, comparable biological evolution could have occurred on all other inhabited planets in the Galaxy.

Population pressure on the Earth may lead to the desire to populate other planets. To make Mars habitable before the expected spring which is expected in about 10,000 years, it is proposed to move asteroids close to Mars, so that their gravitational field tips the poles of Mars and moves the ice caps into warmer areas. The energy for this movement of asteroids would come from solar radiation.

Titan - a greenhouse

Life on Titan is suggested because it has a greenhouse atmosphere. Unlike the Venusian and terrestrial atmosphere greenhouses where carbon dioxide is a prominent factor, on Titan hydrogen plays a dominant role, with surface temperatures as high as 200K and abundant organic compounds in the clouds, atmosphere and surface. Biological action under these circumstances is by no

means out of the question, and Mariner flyby missions or even landings are proposed.

Planetary systems around other stars are difficult to detect, and the suggestion that Barnard's star has planets has been questioned. However it is proposed that the majority of single main-sequence stars of spectral type later than F5 possess planetary systems, because these stars have slower rotational rates than O, B and A stars. The slowing of rotation is due to magnetic linkage with a surrounding disk of protoplanetary material. Many such disks have been observed, and it is probable that we are witnessing the formation of a large number of planetary systems. In some cases a part of the proto-planetary material acquires a spin sufficient for it to be detached from its gravitational orbit around the star, and from these fragments and from conglomerations of dust and gas insufficient in mass to form both planets and stars, the existence of planet-like objects, unattached to stars, exceeding stars in number, is deduced.

Life on Comets?

We still do not know precisely how our

own solar system evolved, and cometary and asteroidal material is thought to represent the Rosetta stone to our understanding of the evolution of the solar system, being virtually uncontaminated primeval material. A recent NASA report contains the quotation that possibly "comets even harbor very primitive forms of live organisms". Flyby missions, followed by sample collection would greatly increase our knowledge. "The ultimate in small body exploration would be a manned mission." Flyby missions would, for example, let us decide which asteroids were spoiled by internal heating, differentiation and the effects of shock waves and heat changes with no clues left as to how they were formed.

In these six areas, science fiction is becoming science fact. Man's imagination is often limited to extrapolation of accepted scientific facts, so it is not really surprising that many of these extrapolations are becoming overtaken by the march of science. After all, in the nineteenth century any form of powered flying machine would have been science fiction.

Open University Maths

by: *Professor C.F. Kent*

Lakehead University, Thunder Bay

In the spring of 1974 Lakehead University's Department of Mathematical Sciences decided to offer three of its first year courses by use of Open University course materials. The Open University in Britain is a full degree-granting university operating for off-campus "extension" students. The O.U. makes extensive use of television and radio and operates regional tutorial centres in many parts of Britain. The faculty of the O.U. has produced much high quality educational material and it is interesting to test their booklets and films in the Canadian context.

The Ministry of Colleges and Universities through its Committee on Instructional Development, assisted the Department of Mathematical Sciences with the cost of purchase of some of the necessary equipment, and sections of three courses, Math 1160, 1181 and 1281 are being offered this year via the O.U. pathway. Two sections of M1181, Calculus and Algebra (with computer) and one section of M1281, Introduction to Pure Math are in progress on the Thunder Bay campus.

An extension section of M1281 is in progress in Dryden, and other off-campus students are using O.U. materials to study the calculus. All of these students will be

scheduled to meet with L.U. math faculty members regularly during the year.

In Britain, the Open University telecasts twice each week a 25 minute film for the lesson unit under study that week. There are also radio tapes broadcast each week. At two-week intervals British students meet a tutor for a one-hour help session at a regional resource centre. The O.U. math instructors generally feel that students could use more help than they get.

The Open University admits any applicant who is 21 years old to any of its programs of study, without regard to academic prerequisites. The success rate of their students in non-science courses is quite high, while in science courses success rates fall off. Unfortunately, in mathematics the success rate is lowest. This only points up something that most of us already know, that mathematics is a subject which people have difficulty learning, for a variety of reasons. But, the O.U. experience has also shown that the students who complete their program compare well with graduates of other British universities.

The L.U. Department of Math Sciences is well aware of the help that many students require with math, and it tries to establish a firm contact between students using the O.U. materials and mathematics staff. The O.U. films for the courses offered are owned by L.U. and are used to supplement the texts written by the O.U. course teams for each lesson unit. Unfortunately it is not technically possible, nor financially feasible to telecast these films in N.W. Ontario. The course texts are independent of the films, but the films are a valuable supplement to the texts and provision is made for off-campus students to see the films. The O.U. course teams have made very effective use of the film medium to present background material which is too time consuming and costly for an individual math instructor to prepare. Interviews and short film documentaries on the applications of math in the everyday world, elaborate and effective models and devices for illustrating mathematical ideas, and effective use of computer graphics are intermixed in the films.

Mathematics in today's world is a vital and changing subject. There was a major change in mathematics teaching which generally acquired the name "new math". That name meant that the infusion of unifying ideas from set theory devised in the 19th century finally caught on in school teaching in the middle of the 20th century. But, that is now yesterday's story. There is a "newer math", and that is computational math. The O.U. math materials are prepared to emphasize the importance of computations which were not possible several years ago, but can now be performed by the rapidly growing generation of computers which will soon be available nearly everywhere. Many such computational procedures can be carried out on the very small calculators and should be introduced to anyone who intends to use or teach math. One example of the O.U. approach to this subject will conclude this account.

For many years, in fact centuries, it was necessary to develop mathematical techniques to short circuit calculation. Such formulas as the "quadratic formula" for solving equations like

$$AX^2 + BX + C = 0 \quad (1)$$

do this very effectively by writing

$$X = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A} \quad (2)$$

Unfortunately, other classes of equations do not submit to this kind of treatment. An equation like

$$\sin(X) - X^{1.5} = 0 \quad (3)$$

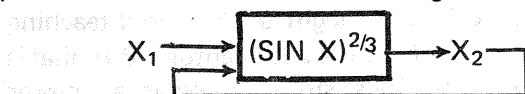
would, until recently, have been regarded with horror by generations of math users.

To the computer age student, equation (3) is no more troublesome than equation (1), and there are several very simple ideas for its computer solution. Equation (3) can be rewritten as

$$X = (\sin X)^{2/3} \quad (4)$$

and what equation (4) "says" is that we want a value for X which is unchanged by the calculation of the right side, $(\sin X)^{2/3}$. Such values can often be found by guessing an initial value, X_1 , passing X_1 through the calculation $(\sin X)^{2/3}$ to get a better value

X_2 , and by repeating this process until a stable value of X is found. Stable means that the number X , expressed to as much accuracy as we are interested in, emerges unchanged from the calculation box. The procedure is summarized in the diagram.



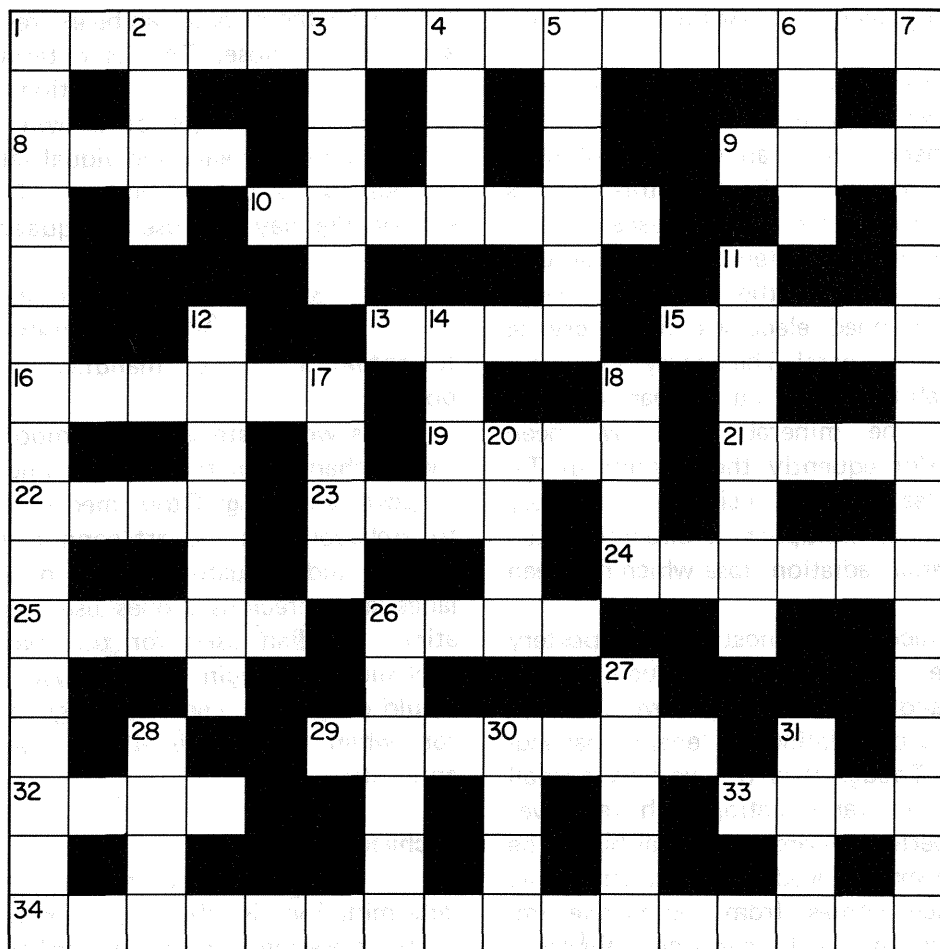
A short computer program which performs

this procedure is given below. It is written in the APL computer language used on the LU computer, but the thing to note is how short and concise the instructions to the computer are. There is also a computer printout of a solution to equation (3), to 5 decimal place accuracy. The same solution was carried out on a hand-held Texas Instrument calculator, in the same number of steps, in 70 seconds.

| APL INSTRUCTION | EXPLANATION | |----------------------|---| | ∇ K SOLN X | | | [1] XN←X | [1] Choose X as first guess | | [2] XN | [2] Print the current value | | [3] XM←(1+XN)*2÷3 | [3] Compute the function $(\text{SIN}(XN))^{2/3}$ | | [4] →(((XN-XM))≤K)/O | [4] If the difference in the last two values is $\leq K$, stop | | [5] XN←XM | [5] Change the guess to the new value from [3] | | [6] →2 | [6] Go back to line [2]. | | ∇ | | | .00001 SOLN 1.0 | Starting with a guess of 1, compute to accuracy .00001. | | 1 | | | 0.8913044954 | | | 0.8458231997 | | | 0.8243934626 | | | 0.813800048 | | | 0.8084452283 | | | 0.8057085975 | | | 0.8043022638 | | | 0.803577518 | | | 0.8032034828 | | | 0.8030103024 | | | 0.8029104907 | | | 0.8028589102 | | | 0.8028322518 | | | 0.8028184731 | |

The "convergence" of the successive test values to a solution to equation (3) which the above table illustrates, is one of the cornerstone ideas of the calculus. Introducing the calculus student to the idea behind the computer solution not only teaches him a useful computational technique, but helps him to understand one concept of the calculus in a concrete situation.

UNITS



ACROSS

1. The Canadian body responsible for metrication (6,10)
8. 1/100 chain (NOT an SI Unit) (4)
9. 1/12 of this carbon entity is 1 u (4)
10. A quality measured in kg m^{-3} (7)
13. 1a (4)
15. The old name for 1 fm (5)
16. Happenings without units (6)
19. A width (4)
21. The general term for a creative mental exercise (4)
22. Anti-front? (4)
23. 10^{18} (4)
24. The consumption of this device is normally measured in kWh (6)
25. The units of this might be m km^{-1} (5)
26. 100 fm^2 — not SI. (4)
29. 10^4 m^2 (7)
32. A low pH (4)
33. Fishy non-SI measure of capacity (4)
34. Children here now will be accustomed to SI Units (10,6)

DOWN

1. A loose way of describing a plane figure of area 10^{-6} m^2 (10,6)
2. Factors for metric units (4)
3. Hurrah! for SI Units? (5)
4. Units of electrical resistance (4)
5. The quality characteristic of mass (6)
6. A very small amount — but not an SI Unit (4)
7. The answers to metric calculations, excluding the units (9,7)
11. The base of SI multiples (7)
12. The quality measured in JK^{-1} (7)
14. $\pi/2$ radians from N (4)
17. The next nearest one is about 4 light years (4)
18. A non-SI Unit of length (4)
20. Unsatisfactory (4)
26. The outside of a chest (6)
27. Incorrect (5)
28. A non-SI Unit of length (1.609344 km) (4)
30. 101325/760 Pa (4)
31. Liable to be high when the barometer reads a low value of 30 (4)

Throwing Light on the Past of Ceramics and Bronzes

by: Dr. S.J. Fleming

Research Laboratory for Archaeology, Oxford

The phenomenon of thermoluminescence (TL) is exhibited to a varying degree by many minerals. It is an emission of light when the mineral is heated: this light is additional to the usual incandescence that occurs at elevated temperatures around 400°C. It represents the release of energy stored as trapped electrons in the crystal lattice of the mineral. The energy is accumulated by absorption from nuclear radiation to which the mineral may have been exposed. Consequently the amount of TL observed (as measured using an extremely sensitive photo-multiplier) is directly related to the overall radiation dose which has been received.

In terracotta and most types of pottery there are crystalline constituents (like quartzes and feldspars) that have this capacity for accumulating TL energy particularly well. Though they receive only a small dosage of nuclear radiation each year over the long periods of archaeological burial the total dose experienced is quite appreciable. The dosage comes from radioactive impurities (around 1–10 parts per million — ppm — of uranium and thorium and a few per cent of potassium) in the clay fabric itself and in the surrounding burial media; cosmic radiation also makes a small contribution. The concentrations of the radioactive impurities can be measured using standard laboratory techniques.

Time-zero for pottery

In a geological condition the relevant minerals will have accrued huge levels of TL energy but this will have been driven off during the process of kiln-firing when ancient man included some sand in his clay stock to help the pottery fabric withstand the rigours of extreme heating.

Immediately after its manufacture the pottery's stored TL is nil. A time-zero has been set that is directly related to the age of

the pottery. In present times the natural TL carried by the sample can be expressed as an accumulated dose. This is determined by exposing the sample to radiation from an artificial radio-isotope of known strength, hence calibrating each individual fabric with respect to its susceptibility to TL energy storage. We may then use the equation:

$$\text{Age} = \frac{\text{Accumulated dose}}{\text{Annual dose-rate}}$$

to obtain a date of manufacture for the pottery.

It is worth stressing the importance of the mechanism of time-zero setting peculiar to pottery-making. Other media of interest to archaeologists and art connoisseurs, like marble and sandstone used in sculpture, jades and precious stones used for decoration, obsidian used for tool-making, are geological in origin. TL analysis of these would duly yield a geological age, not a date for when the material was worked in antiquity.

Archaeological dating

A major limitation in accurate TL age determination is the dependence of the annual dose-rate on external environmental factors. Even in homogeneous burial contexts there are a number of difficulties associated with evaluation of the gamma radiation dose-rate from radioactivity analysis of an extracted soil sample.

The most obvious is that groundwater (low in self-radioactivity) directly dilutes the dosage from the burial medium by acting as an energy absorber itself. This correction for the presence of water is also applicable to the internal dose components of the pottery (short-range alpha and beta radiation) but saturation uptake rarely exceeds 20 per cent while uptake in soil media reaches levels of 70 per cent of the dry material weight.

Further, the decay chain of uranium includes an isotope of particular importance, radon (Rn^{222}), which is gaseous and thus capable of high mobility about the soil and

of free movement to the outer atmosphere. Close to 98 per cent of the total gamma-ray energy associated with the uranium chain lies beyond this gaseous decay product. The radioactive half-life of radon, of 3.84 days, allows a degree of diffusion — dependent upon the soil's porosity — comparable in distance with the influential range of gamma-radiation of about 30 cm that affects the pottery sherd's dosage. The presence of soil moisture reduces this diffusion by an order of magnitude, but now a transportation mechanism during groundwater flow allows radon displacement of up to 2 m.

Inevitably these factors result in the environmental dose-rate being subject to seasonal fluctuations.

As a short-term solution at present a measure of the integrated annual gamma dosage is obtained by placing a small capsule of annealed fluorite in as similar a burial position as possible to that from which the sherd was removed. This dosimetry phosphor has a susceptibility to radiation many orders of magnitude greater than pottery minerals and so an accurate measurement of the environmental dosage is easily obtained at the end of the year's burial.

The level to which such a short-term measurement correctly reflects the levels experienced in the long-term archaeological burial is questionable and comparison of two sherds from an original test programme of the TL method may well show this (See table below). The distinguishing feature between the two sherds is the different dependence on the environmental dose-rate (the $0.080 \text{ rad yr}^{-1}$ being the value obtained at the site during 1968-69 using the monitor capsule approach). For the sherd *d2* which has a high internal dose-component the surroundings contribute less than 21 per cent of the total dose-rate, but for sherd *d4* that dependence reaches a level of 57 per cent. Thus it is reasonable that while *d2* yields a TL age within 2 per cent of the known age for the Roman Fort, *d4* is about 11 per cent in error. Yet with a change of only $0.016 \text{ rad yr}^{-1}$ in the environmental dose-rate both sherds lie within 2 per cent of the known age — such a variation is certainly

a reasonable level to be expected in long-term fluctuations.

Accuracy of the TL dating method has been shown to be close to ± 7 per cent per sherd, on average (expressed as one standard deviation, statistically). In application thermoluminescence has been used on pottery from the Nok culture of Nigeria, from the Early Bronze Age phase of Crete (at the site of Myrtos), from the Jomon Culture of Japan (placing the early occupation of the important site of Fukuie Cave as far back as the eleventh millennium BC). Aboriginal hearth material from Mungo Lake, Australia, has been provisionally dated to around 35,000 years old. The neolithic levels of the Cretan site of Knossos are now under investigation through study of the six-metre-deep strata below the renowned Minoan Palace site.

Authenticity studies on ceramics

From the outline of the principles of the TL method given above the distinction between an authentic art ceramic and one of modern origin (be it imitation or forgery) is now apparent. The modern ware will yield only a small fraction of the TL observed from its genuine counterpart.

There are special restrictions upon the accuracy the TL method can achieve in dating art ceramics, however. To prevent physical damage to the piece the sampling process involves drilling a hole only about 2-3 mm diameter in the piece. The small quantity of material collected allows only approximate assessment of the radioactivity content of the clay. Also, the cleaning of the ceramic prior to sale or display removes the adhering soil that could have given some indication of the piece's burial environment so the latter quantity, in terms of radioactivity, is an unknown in our age calculations. Accuracy of dating of authentic wares is then usually around ± 15 per cent, at best. With modern wares the lack of sufficient time to build up a significant TL signal means that it is rarely distinguishable against the background incandescence also measured for each sample. Then only a *limit* can be set on the piece's age.

The examples discussed below have been chosen to illustrate one central theme: that, irrespective of how accomplished and experienced an art historian may become in recognising style visually, certain features of the forger's skill must necessarily cause severe headaches.

(i) *Terracotas of the Renaissance period* offer an interesting problem for a couple of distinct reasons. Workshop techniques of manufacture typified by the works of the della Robbia family such as the *Pieta* allow anomalies in style to be attributed to either imitative attempts in recent times or the hand of an apprentice whose efforts slightly distort the characteristic family style. Also there was a phase of definite encouragement of high quality imitation from 1850 onwards. Indeed, the Doccia factory was awarded gold medals in 1851 and 1855 for its ability to simulate della Robbia tin-glazing techniques, a treatment of the terracottas originally intended to harden them sufficiently to face outdoor exposure, so offering a cheap alternative to use of the more fashionable marble. The passing of over a century and the blurring of documentation of the sources of imitations of this type may well have allowed many pieces to receive false attribution in present times.

(ii) *Ceramics of the T'ang Dynasty in China* (Ad 618-906) first attained popularity in the western world during the second decade of this century. A large proportion of these wares were unearthed quite by chance as railway construction carved through the ancient tombs in the Chinese countryside. However, at the same time several kiln sites were found that gave much insight into the technology of the T'ang artisans, particularly aspects of the use of piece-moulding methods. Several original casting moulds were taken up and some were re-used to produce impeccable forgeries. The idea would cover a very wide spectrum of unglazed T'ang Dynasty wares such as groups of musicians, zodiac figures of mythical significance, groups of warriors and other animal types, like camels and oxen.

Porcelain problematical

A recent development in the TL method has been its application to Chinese stone-wares and porcelains. Here only partial success has been achieved as the clay used for these wares was usually much purer than the more common earthenware ceramics: only limited amounts of crystalline impurities were added before firing. Occasionally even authentic wares give no natural TL, nor do they respond to laboratory radiation. The TL method is then simply not usable.

One important example is worthy of note however — a phosphate-splashed bottle. This high-fired grey stoneware piece received much acclaim at the Oriental Ceramic Society Exhibition of T'ang Dynasty Art in 1955, but has recently been questioned by experts in America. The TL authentication of the bottle has offered a rapid solution to this academic controversy.

Dating of Bronzes

Specific reference was made to minerals that possessed the property of TL energy storage. Indeed this property is limited to such substances — metals (bronze, silver and gold) and other materials of archaeological importance, like wood, do not have the same capacity and so TL analysis cannot be applied to them, in a direct sense. However, many ancient civilizations employed a technique of bronze manufacture that involved casting the metal about a sand or clay core. Then TL analysis becomes feasible, not on the metal itself but upon this supporting, fired ceramic-like material inside.

In China this technique of construction began in the Late Shang period (circa 1100 BC) and is particularly common in the Chou period (1027-222 BC) that followed. It is of interest to note that the documented era of imitation of early Chinese bronzes is the Sung Dynasty (AD 960-1279) when academic interest in that material flourished. The intervening 900 years or so, coming forward to the present day, is quite long enough to allow development of good patination indistinguishable from that on much earlier pieces.

Dating is practical on bronzes from Africa (particularly of the Benin period) and has already found useful application in material from Java, Cambodia, Nepal, India and Thailand, where, unfortunately, there are growing signs of a flourishing industry in production of imitation wares.

In conclusion, attention should be drawn to the fact that TL dating is an absolute method, not dependent upon reference standards and requiring no data on technology of the past to solve authenticity

problems. As such it may be fairly claimed as one of the most powerful tools in archaeological and art historical research now available.

Further reading

See *Archaeometry*, volumes 11 onwards (bulletin of the Oxford Research Laboratory for Archaeology and History of Art).

Two monographs by the author are due to be published in 1973 by Merrow Press, England.

Table: TL dating of sherds from Baginton, England (Roman Fort, AD 70).

Sherd reference	Water uptake (% of dry weight)	Dose-rate internal (rad yr ⁻¹)	Dose-rate environ- mental (rad yr ⁻¹)	Accum. dose (rad*)	TL age (years)
d2	12.5	0.306	0.080	750	1940
d4	10.2	0.060	0.080	287	2110

* The doses are expressed in rad, equivalent to an absorbed energy of 100 ergs/g.

This article is reprinted from *Spectrum*, No. 108, 1973.

EDITOR'S NOTE

Caret is directed at the high-school teachers and students, and we would like to keep it so **with your help**. One of my many headaches as editor is to know what do and would appeal most to my readers. I have been fortunate, in this new office, to have many useful criticisms and suggestions from the Editorial Board, and we at L.U. are beginning to introduce some changes, e.g. shorter articles, more frequent issues, Editor's Mix with word games, definitions, etc. I cannot help feeling that much more can be done yet. In the Science Faculty, particularly near Science Fair time, we often have requests from students for help with their projects. In **Caret** we would like to feature a Question Box in the hope that the answers would prove useful to a wider spectrum of readers, particularly those from out of town. So why don't you — and that means YOU TOO — **write to us**, send in your queries, **WRITE!** It is of course always gratifying to receive letters like that from Mr. Dunnell, but that of Miss McBride is equally welcome. As in the past issues of **Caret** we are again

appealing to you to let us know how you feel about **Caret**. Feelings, likes and dislikes do change. So, even if you have written before, **do write again soon!**

Another headache that many editors have is to find persons willing to write articles. In this respect I have been fortunate to inherit a number of articles from the previous editor, Dr. J. Hart. I thank him for them, the crossword puzzles and for his help. But I am counting on YOU for future articles, and I thank you in advance for them. I also thank the contributors in this issue of **Caret**, all those who have helped to produce it, those who attended the Editorial Board meeting, and Mr. S.T. Spivak for his work on the crosswords.

True or False?

ammeter: a device for measuring the elevation of the sun through 90 degrees, from sunrise to noon.

cataract: a waterfall

genome: fictitious character commonly found under mushrooms

If you do not agree with those definitions, send in YOUR version.

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