RADIOTRONICS

IN THIS ISSUE

COVER:

The A.W.A. stand at the Science in the Development of Australia Exhibition.

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Science in the Development of Australia Exhibition

From the 14th to the 19th of August this year, the Science Teachers' Association of N.S.W. staged an exhibition at the Sydney Showground, "Science in the Development of Australia". Amalgamated Wireless Australasia Limited and Amalgamated Wireless Valve Co. Pty. Ltd. are proud to have been associated with the Science Teachers' Association of N.S.W. in this exhibition, by providing a stand which included items ranging from a semiconductor testing unit to closed circuit television and two-way radio.

This exhibition is the second of its kind to be held in Australia, the first being organised by the Science Teachers' Association of Victoria which was held in Melbourne last year. As was the case in Melbourne, AWV sponsored a competition in which the students were asked to construct a symmetrical multivibrator or "flip-flop" circuit using two transistors and a circuit which were supplied free of charge. The name given to the competition was "Operation Multiflash".

The results of this interesting competition, together with a description of the entries, are discussed in detail in another chapter of this magazine.

An exterior view of the stand

A section of the crowd on the stand

The AWA-AWV stand was a most interesting exhibit, the feature of which was the S.C.A.T.E. (Semi-Conductor Automatic Test Equipment) test unit. This unit aroused a host of interest and was controlled by a skilled operator from the AWV works at Rydalmere. The purpose of the unit was to test transistors and separate them into their correct families. As each transistor was tested the result of the test was shown on a large board behind the operator (see illustration this page).

A.W.V. General Manager, Mr. Dick Lambie, talking to the "SCATE" operator

In keeping with the theme of the exhibition of having exhibits that could be operated by students, a number of experiments were displayed on semiconductors. These experiments were taken from a book recently published by AWV ("Semiconductors & Transistors", by Dr. L. W. Davies and H. R. Wilshire) in which a series of experiments are described on the physical properties of semi-conducting materials and of techniques such as modulation, transmission and reception which find everyday application in electronic communications. These experiments were extremely popular and the questions asked by the students kept the instructors on their toes. A Ledex dialling unit which could be operated by the students was also on display.

The A.W.A. Radio Museum

The closed circuit television was in operation continuously and it was a common sight to see large groups of students (and parents) clustered around the set. The receiving set was the latest "Tudor" model, designed exclusively for schools and education purposes by AWA.

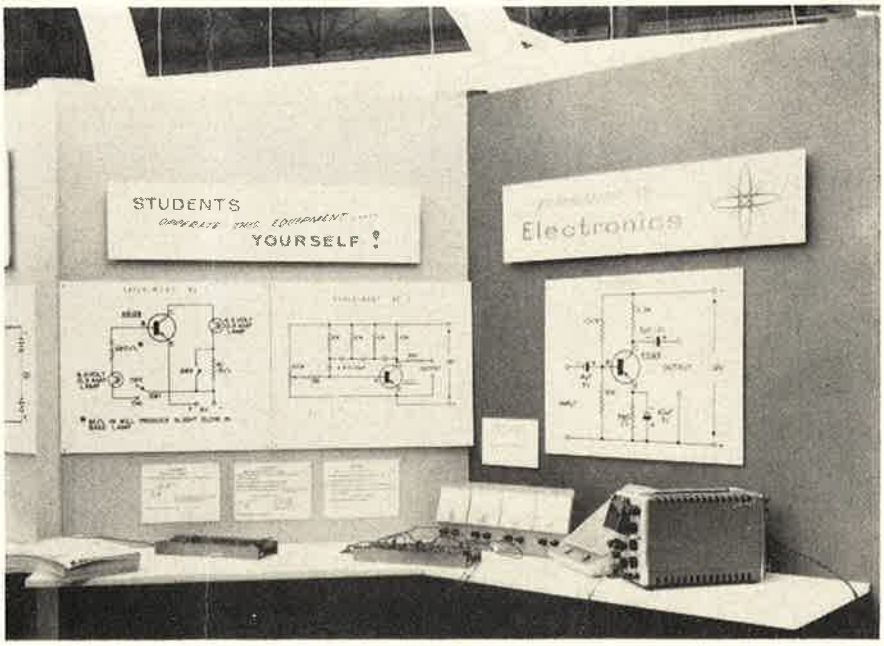
A 30-minute colour film was shown at regular intervals titled "453 steps". This film explained in detail the manufacture of transistors from the raw material to the finished product.

Four old radios were displayed with their modern counterpart in a corner of the stand called the radio museum. On the opposite side was a display case showing examples of the early receiving valves. These two displays demonstrated the tremendous advancement that has been made in the industry in a few short years.

Judging by the amount of people that visited our stand and the entries received in the competition, the exhibition was a huge success and we offer our congratulations to the Science Teachers' Association of N.S.W. for a job well done.

This exhibition provided a welcome opportunity for us to put into practice our policy of encouraging technical education and advancement of all kinds. By offering this assistance we feel we are helping Australia to find the scientists and engineers that are going to be needed so urgently by this country in the years of development that lie ahead.

The Tudor Model television set



Experiments taken from "Semiconductors and Transistors" by H. R. Wilshire and L. W. Davis

Operation Multiflash

At a recent education exhibition at the Sydney Showground, a competition was staged by Amalgamated Wireless Valve Co. Pty. Ltd., similar to that held last year in Victoria. In this case our thanks are due for advice and co-operation to the Science Teachers' Association of N.S.W. The fine exhibition was a great success, and so was the competition staged by AWV. A large number of entries to the competition were received, and a great deal of time was gladly given by the panel charged with the judging of the entries to ensure that every entry was carefully examined, read and evaluated.

As in the case of the competition held last year in Victoria, a simple circuit was published, and the necessary transistors were given to intending competitors by AWV. The competitors were asked to make up the circuit in any way that occurred to them, to write a description of the operation of the circuit, and to prepare also a short note on "What Transistors Are Doing Today". The competition was primarily intended for secondary school students.

We take this opportunity to thank all who assisted in the planning and preparation of the competition, and of course all those students who took part and gave us all so much pleasure with such a large number of highly skilled and well informed entries. There is a great field open both now and in the years to come for electronics; doubtless many of those who submitted entries to this competition are destined to play an important and rewarding part in the electronics world of the next generation.

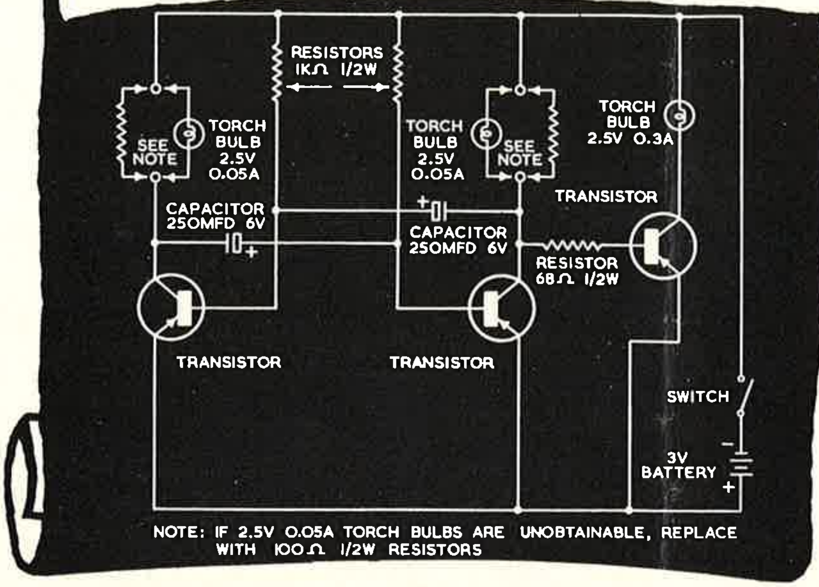
The winning model displays excellent presentation.

JUDGING THE ENTRIES

The judging of the entries to this competition was both a pleasure and an onerous task, a pleasure because the quality of the entries and the ingenuity shown by the entrants was so stimulating, an onerous task because the very qualities which made the assignment interesting also made it difficult. The generally high quality of all the entries made one wish that a prize could be awarded to each entrant, as they had all obviously put a great effort into the project. However, competitions being what they are, it fell to us to find one entry that we felt had merit just that little bit over and above the others.

Without wishing to moralise, one hears so much these days to the detriment of young people, who after all, are going to be running the world for us in a few years' time. To witness a competition like this is a great education for the "oldies" and "squares", because it shows that whilst minor

OPERATION MULTIFLASH



CONDITIONS

(1) Construct the unit (consideration will be given to neatness and layout).

(2) Describe briefly the operation of the circuit.

(3) Write 200 words on the subject "What Transistors are Doing Today". Submit your completed project, your description of its operation and your essay clearly marked with your name, school and home address to:

Amalgamated Wireless Valve Co. Pty. Ltd.,
348 Victoria Road,
Rydalmere, N.S.W.
"Operation Multiflash".

values may change from one generation to the other, the essential properties are still present beneath the surface. From another aspect, it was interesting to see quite a few entries from the young ladies. It would be derogatory for us to be surprised at this, because of course just about every profession and occupation is open to women today, and there is no reason why the girls should not be just as interested in electronics as the boys. From what we have seen, they can give the boys very close competition at any time.

JUDGING FACTORS

It is most unusual in any competition to discuss the basis on which the winning entry was found. The reason for doing so here is that the remarks may assist the progress of those who came close to winning in particular, and of all the others in a more general way. It must, however, be clearly understood that this is not inviting letters or telephone calls on the subject, as no discussion can be entered into regarding individual entries.

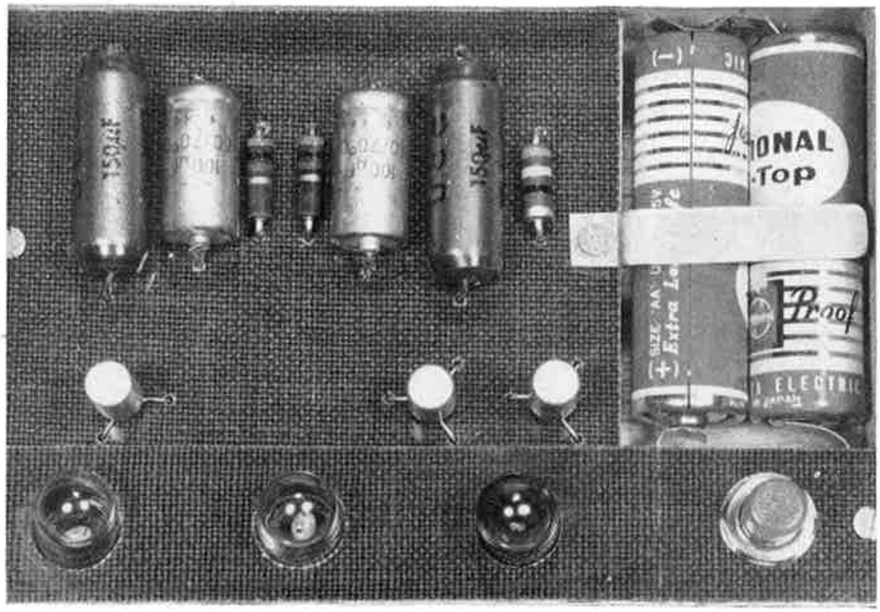
Every entry was carefully examined because we were fully aware of the time and trouble that had gone into them. Every entry evinced merit. The models themselves were re-examined on the basis of workmanship, layout, operation and ingenuity. Some of the models had suffered slight damage in transit, usually a lead fallen off or something minor; these were put into going order. Batteries were supplied for testing where the model did not include a battery. The written entries were examined mainly on the basis of originality and facility of expression, and the accuracy and quality of the technical description of the operation of the circuit.

This then was the basic outline of what was done, and it was no mean task to try to evaluate the points of quality of every entry. The final assessment was a cumulation of favourable factors.

GENERAL REMARKS

A judgment based solely on the models or solely on the written portions of the entries would have been comparatively easy, or at least one is inclined to think so. In fact we found many cases where excellent workmanship was displayed, but it was supported by poorer expression and an imperfect understanding of the operational principles of the circuit, and of course, the converse was also found. We also found models which displayed considerable ingenuity but in which the workmanship was of a lower standard. There was at least one entry which was excellent in workmanship and ingenuity, and the written portion of the entry was certainly among the three best-presented in the competition; however, the description of the circuit operation displayed a serious misconception and so lost marks.

As a general assessment of the entries, most entrants showed a reasonable grasp of the operating fundamentals of the circuit, whilst the conception and layout of the models, and the ingenuity shown in them, was almost invariably of a high standard. The one single factor that lost most marks was workmanship. It is realised that quality of workmanship is to some extent a matter of practice and experience, and due allowance was made for this. However, it is felt that a conscious effort must always be made to-



Workmanship and design of the winning entry meet a high standard.

wards good quality work, especially in such details as good soldered joints. The art of good soldering is essential, not only to the production of high-grade work in the first place, but to the production of work-pieces which will continue to give satisfactory service over a long period of time. Many of the soldered joints we saw, whilst they make good contact at the moment, will almost certainly include dry and brittle joints within a few months.

As a further word on soldering, and in particular when using matrix board pins, it is a mistake to run a common wire through several pins and then hope to make a good soldered joint when further component leads are soldered into each pin. These pins are of high quality and are a boon to the constructor, but one would be well advised not to take the soldering for granted. One must work "according to the book", separately tinning each pin and each lead before attempting to join them together. To push several leads into the cleft of a pin and then expect to make one good soldered joint in one operation is expecting too much. The poor joints that are likely to result are in the category of operator fault rather than component fault.

THE WINNER

The winning entry selected by the judging panel was that submitted by Mr. Barry Mitchell, pupil of the Port Hacking High School. Congratulations to Barry, and to his parents and his science teacher. The model submitted by Barry displayed a high standard of workmanship, the layout and presentation were excellent, and a considerable degree of thought and ingenuity was in evidence. The written portion of the entry was of a high standard, and is reproduced in its entirety in the accompanying pages. The written portion of the entry can speak for itself, but some description and evaluation of the model may be helpful as a pointer to others.

The presentation of the model was very good. It was built into a small wooden box with a hinged lid secured by a clasp. As the accompanying close-up photograph shows, the main portion of the circuit was built on a bakelised fabric panel into which holes had been drilled to accept the leads of the various components, the components being mounted flat on the upper surface of the panel. The wiring behind the panel was of the conventional type, and the panel was held off the bottom of the box by two small battens. A compartment left at the side of the main panel contains two "penlite" type batteries, held in place with a brass clip, and engaging brass contacts screwed to the walls of the box.

The three lights and a press-to-operate switch are mounted on and through a further small bakelised fabric panel running the full width of the box across the front. The main lamp being switched was distinguished by being coloured blue, the two lamps in the collector circuits of the flip-flop stage being clear. A very ingenious home-made triple lampholder was made by Barry to hold the three lamps, consisting of a strip of brass pierced with three holes to accept and retain the three lamps, together with separate contact strips for the second pole of each lamp, the whole being screwed to the inside of the box at appropriate points to complete the assembly; a very interesting low-cost multiple lamp holder.

This model, besides being the winner, or perhaps because it is the winner, serves as a fine example of the sort of thing that must be looked for in industry as well as in competition. The full impact of the model cannot be felt through the medium of words, but inspection reveals that it scores highly in all the essential categories of workmanship, presentation, ingenuity and originality. Barry wins for this fine effort an equally fine piece of design and workmanship, an AWA Radiola radio receiver which we hope will bring him many hours of enjoyment, and give some small further incentive to an undoubted talent.

OTHER NOTABLE ENTRIES

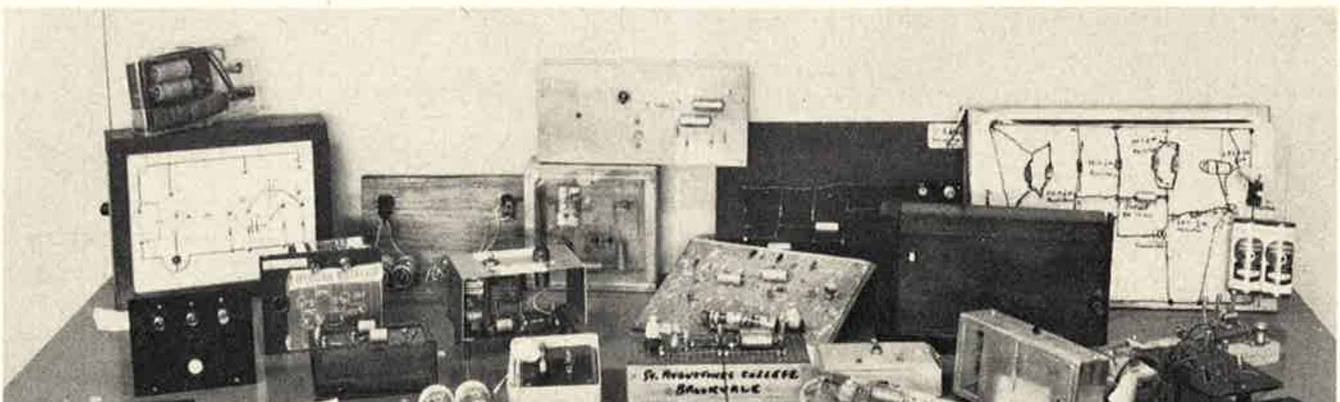
Whilst one of the acompanying photographs shows a selection of the entries received for the competition, a further photograph shows a selection of ten entries, including the winning entry, being examined by Mr. B. Simpson of the AWA Patents Department, who was one of the judging panel members. These entries, apart of course from the winner, were selected for further discussion in these pages. They are all models of high quality, and further represent a good cross section of the varied approaches to the problem. A few remarks will be made on each of these models.

The first model (rear row, left) was doubly interesting. It is not only a good model, but was one of several submitted by the girls, showing that the boys no longer have a monopoly on this sort of thing. The girls, as they would have wished, were treated from the judging point of view on precisely the same basis as the boys, and all their entries were of a high standard. The one selected here was submitted by Miss M. Dufficy, of Bethlehem College, Ashfield. The main frame consists of a piece of light-gauge aluminium bent into a "U" shape with a flange at each end, and provided with small feet. The circuit was constructed on a piece of matrix board using the special pins provided for use with the board. The whole formed a very neat model, the only possible improvement being the method of retaining the batteries.

The next model for comment (rear row, right) was submitted by Mr. D. Garnsey, of St. Ignatius' College, Riverview. The basic construction used here was very similar to that of the last entry, but, as the photograph will show, completely different proportions were used. Access to a pop-rivetting tool helped to make this entry a neat one, and a cardboard box was used to protect the assembly. There appears to have been a slight drift in the mechanical tolerances used, resulting in slight deformation of the finished assembly; overcoming problems of this type is only a matter of practice. This entry was interesting in that a printed circuit was used, one of many used in the models submitted.

By the way, these entries selected for further discussion as being good examples of models and techniques are not presented in order of merit, but merely in the order in which they appear in our photograph. The fact that they are of a high grade allows us to use them to point out considerations that may be helpful not only to the skilled competitors who made them, but to others whose skill has not yet attained such a high level.

The next entry for comment is shown at the left hand side of the middle row, and was sent in by Mr. R. Posener, of The Forest High School. This model was made on a sheet of matrix board, but this time eyelets were used for the connection points, and slots were cut



The standard of the models was worthy of commendation.

B. J. Simpson (A.W.A. Patents Department) examines some of the models submitted.

for the connecting lugs for the three lamp holders and the switch. Robert apparently managed to obtain some low-current bulbs for the flip-flop collector circuits, and cleverly adapted them into miniature screw bases of discarded torch bulbs. A very competent model in which the only conceivable improvement would have been a slightly more positive securing of the on/off switch.

A completely different entry came from Mr. K. Kondziolka, of the Macquarie Boys' High School. This entry is shown in the centre of the photograph, and was constructed in an aluminium box with a window to view the lamps and a removable panel to gain access to the batteries. Inside we found an exceptionally good printed circuit board with integral lamp holders. Whilst most amateur constructors are content to solder the printed circuit only at the points where components have to be contacted, a procedure which is quite acceptable, the whole of the PC board in this entry had been soldered for extra strength and protection, and in fact looked just like the professional assemblies that are made in the factories using dip-soldering methods.

In the middle row, right hand side of the photograph is the model sent in by Mr. R. Eve, of St. Augustine's College, Brookvale. Mr. Eve used matrix board and the special pins to construct a well laid out and well executed model in which the quality of the soldering was well above par for the competition. A wooden plinth held the matrix board and also provided the necessary stowage space for the batteries.

Coming now to the front row of the photograph, at the left hand side is seen the entry submitted by Mr. G. Collins, of Northmead High School. Mr. Collins also used matrix board, but in a generally smaller model which was also very neatly constructed and well laid out. The assembly was completed with four short brass rods forming feet. Many of the models followed a layout very similar to the layout of the circuit diagram. Whilst this is often a good idea, it is by no means mandatory, and the layout in this model showed an interesting breakaway from that idea. There is just one small point we could make here, and that is that it is generally customary in this type of small assembly using matrix pins or similar items to arrange the soldered joints of a component such as a resistor on the same side of the board as the component itself. The reason for this is obvious, and is the opposite of the general rule for printed circuit work where the soldering is generally done on the side opposite the components. Points of this kind were given little weight in the judging as it was realised that few of the competitors could be expected to be familiar with industry preferences.

Sydney Boys' High School is represented by the entry of Mr. C. Welch, seen in the centre front of the photograph. This entry received very favourable comment for, among other aspects, the originality of the construction. The housing consists of a blank household-type switch plate mounted on a plastic mounting block. The switch is mounted through one side. The indicator lamp red bezel is mounted in the centre of the top, and the three transistors passed through closely-fitting holes in the top and cemented into place. The interior circuitry is made up on a small section of matrix board, and the whole is a very creditable performance.

The last but by no means the least of the entries to be commented on is that seen at the right-hand front of the photograph, submitted by Mr. G. Johnston of Cronulla High School. Here a small section of bakelised paper board was used, pierced with holes to take the component leads, and very neatly wired behind the board. A holder for two "penlite" batteries was made of some acrylic material and affixed to the board. Attention to detail was shown by the fact that two small brackets to hold the lamp and the switch had been painted. A further point of interest not so often seen in amateur constructions was the fact that the resistors and capacitors were mounted with their major axes normal to the board to conserve space, the second lead being bent over and run down the side of the component and so through the board also.

The foregoing comments are all directed towards the models submitted and not towards the written portions of the entries. We have reproduced in full the winning entry, and would have wished to do the same with several other written entries which are very good. Unfortunately lack of space precludes a large effort along these lines, so we have had to compromise. We have made up a composite essay on "What Transistors Are Doing Today", using portions of several entries, with acknowledgements. This exercise, in addition to the publication in full of the winning entry will, we hope, serve to show the quality of thought of some of those who will be guiding our affairs within the next few years. The eight competitors mentioned above have been awarded consolation prizes of a copy of "Radiotron Designer's Handbook" and a subscription to "Radiotronics".

WHAT TRANSISTORS ARE DOING TODAY

"Today transistors are revolutionising the world. The transistor is one of the most outstanding achievements of the century. Used everywhere from minute audio amplifiers to the enormous data processing systems in the space tracking stations, there is no segment of the electronic field in which the transistor cannot be used." (D. Garnsey). "It is possible to construct complete transistor control systems in the form of small solid blocks, with all of the components embedded in square slabs of resin, which will easily withstand the shock of launching or re-entering the earth's atmosphere." (R. Eve). AWV engineers add the comment here that the introduction of integrated circuits has carried the art a long step further in the reduction of size and weight, and ultimately it is hoped in the matter of circuit cost. "The impact transistorisation has had on industry and scientific research can best be seen in the evolution of computers. Modern computers, while being much more complex and having a much larger information storage capacity, are smaller than the earlier valve computers." (W. Bleeker).

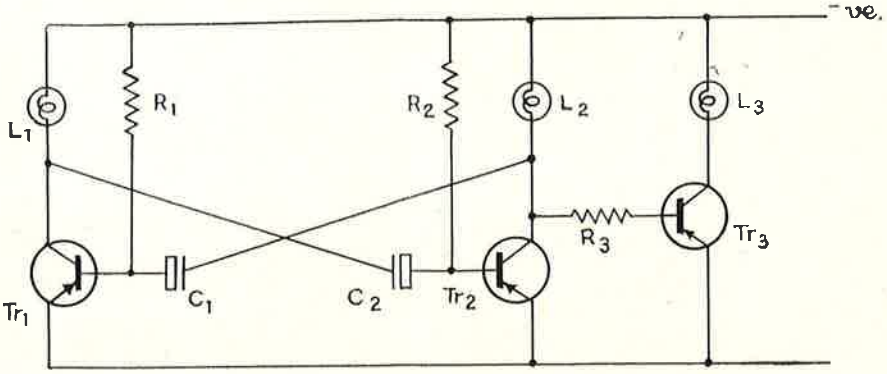
"A typical application for transistors is in hearing aids, for, because of their small size, they permit miniaturisation of electronic equipment and can also be used where fragile bulky tubes are impractical. They also reduce the weight and cost of battery replacements." (M. Dufficy). "There is less chance of a transistor failing than a valve and transistors can thus be used in places where a failure may be very costly and take days to locate." (R. Posener). AWV engineers comment here that great reliability can be obtained from valves by careful design, and by the use of premium quality valves where the type of service indicates their use. Apparatus of great complexity is generally provided with testing and metering means that allow a fault to be localised within a very short time; fault clearance will then usually consist of replacing a complete sub-assembly from spares held at the station.

"Although playing an extremely important part in the domestic sphere, one of the most notable uses of transistors is in space research. Gemini V and the Mariner projects illustrated very significantly the role of communications in space travel, and their development to the present high standard has been due to the transistorisation of equipment." (C. Welch). "Transistors are helping man to progress in research connected with medicine, space exploration, electronics and industry. Due to their ruggedness, small consumption of electricity and minute size, transistors have revolutionised the field of electronics." (G. Collins). "The most important application which takes advantage of the transistor's reliability is for inclusion in the human body, to control various operations unable to be continued by the body, such as cardiac pulse simulators (pacemakers), kidney activation, and so on." (G. Johnston).

The foregoing extracts serve to show the general tenor of the written portions of the entries. All of the competitors seemed well aware of the general advantages of transistors and the ways in which they are being used. The emphasis placed on various applications is largely of course dictated by the interests of the individual. As a general critique of the written entries one can offer very little except perhaps two points. Firstly, as one may expect, the field of applications as known to those outside the industry must of necessity be a year or so out of date. For example, several entrants mentioned the high-frequency limitation on transistors and talked of applications in low and medium frequency fields; whilst this may have had some justification a few years ago, it is not quite the position today, except that we can hardly expect transistors to move immediately into fields occupied by specialist valves, particularly those like the magnetron and klystron, which have integral resonant circuits. Outside these areas, frequency and power limitations have been a matter of logical development and are succumbing to the forward trend of knowledge. The second point of criticism is on purely technical grounds. Several entrants displayed a very good general understanding of the use and operation of transistors, at least from a practical point of view, but were hazy on the precise mechanism of operation. Unfortunately there are several types of books available today that endeavour to by-pass the physical properties of semiconductors, but as any secondary school pupil will already have discovered for himself, it is difficult to go very far without a competent grasp of the fundamentals.

THE WINNING ENTRY

Mr. Barry Mitchell



In the circuit Tr_1 and Tr_2 form a multivibrator stage and Tr_3 a switch which cuts off at every positive pulse appearing in the collector of Tr_2. When the circuit is in operation it can be seen that L_1 lights first, followed a fraction of a second later by L_3. These two extinguish and L_2 lights.

When C_2 is charged there is a positive signal at the base of Tr_2, thus it is cut off. The base of Tr_1 is negatively biased by 1 K Ω Resistor (R_1). Transistor 1 is then conducting and L_1 lights. Because Tr_2 is cut off, C_1 starts to charge through L_2 and the emitter-base junction of the transistor. With Tr_1 still conducting the positive current at the collector neutralises the negatively charged plate of condenser 2. The charge on the positive plate then leaks away through R_2 until the base of Tr_2 is negatively biased through R_2. Tr_2 conducts and lights L_2, and begins to neutralise C_1. This cycle is then repeated.

In the former state when Tr_2 was cut off the base of Tr_3 was negatively biased through R_3 and L_2 so that the transistor conducts and L_3 lights. It was aforementioned that L_1 lights a fraction of a second before L_3. This is due to the fact that at first some of the current is used to charge C_1. When the condenser is sufficiently charged the current flows through R_3 to the base of the third transistor. This small time interval is in fact the time taken to partially charge the condenser.

Barry Mitchell,
7 Merriman Street,
Blakehurst.
Port Hacking High School.

"What Transistors are Doing Today"

In June, 1948, The Bell Telephone Laboratory announced their invention of the transistor. At this early stage the transistor could not compete with the thermionic valve, but it was revolutionary and held great potential for the future. Its functions as an oscillator detector and amplifier were immediately apparent, but it was not till later that various other applications were found.

The transistor is being used extensively in industry today. Computer operation is facilitated by means of high speed switching transistors; burglar alarms can be made compact and reliable and take advantage of the photoelectric properties of transistors.

They also have many entertainment values in the home, in radios, tape recorders and novelties for which their small size is ideally suited. Although many of these functions were formerly carried out by valves, the transistor is showing a superiority where power requirements and size are of major consideration. Such a situation can be seen in space exploration, where it is necessary to dispense with high tension supplies whenever possible.

In its short life-time the transistor has developed into an item which can be ranked with the most useful inventions of our time.

Barry Mitchell,
7 Merriman Street,
Blakehurst.
Port Hacking High School.

Life Beyond the Atmosphere

ORIGINS, DETECTION, AND SUPPORT

This paper discusses the existence and detection of life forms in the universe (with emphasis on our planetary system), and the support of life in manned space travel. It is shown that while we have several good ideas as to the origin of life, much sophisticated research awaits before we arrive even at a good set of hypotheses of how life occurred. Likewise, while we can detect many forms of life chemically, much more sophisticated sensors are needed for space missions to help decide whether a certain observed phenomenon may constitute "life". Finally, although we have demonstrated short-term life-support outside the atmosphere, the present crude automatic control of a few gases and fluids will have to be refined greatly before we can, for example, establish a colony on the Moon. The advanced electronics for each of these pursuits offers engineers one of the greatest practical challenges of an already challenging technology.

DR. A. G. HOLMES-SIEDLE
Physical Research Groups
Astro-Electronics Division,
DEP, Princeton, N.J.

The usual artist's impression of the solar system shows a bright, colourful, crowded panorama of planets revolving about the Sun, against a backdrop filled with comets and star-clusters; but, by no fault of his own, the artist is giving a false impression. For the most part, the solar system is a very empty place, and very inhospitable to humans.

Artists' pictures, of necessity, show the solar system as more crowded than it really is. This is for the simple reason that, if the artist were true to his scale, and then drew the solar system on a 6-inch sheet, the Sun (to scale) would be a dot smaller than a period, and the Earth would be completely invisible as a dot one millionth of an inch across. To visualize these relations at a more familiar level, let us imagine the Sun as a very large balloon on the White House porch: then the Earth would be a softball on the Capitol terrace. The planet Venus would be another softball halfway down Pennsylvania Avenue and Mercury would be a pinhead on the pavement outside the White House. Pluto, the furthest planet, would be a pinhead way out past Baltimore, while the rest of the planets would turn inside Pluto and outside Earth. No other star or sizable body would exist in the rest of the Americas.

Our discussion here is on two questions which arise out of the emptiness and inhospitality of the universe. First: *How long can we support our own lives effectively outside the atmosphere?* Second: *Is any other planetary body anywhere as effective as Earth in providing a "greenhouse" for life?* Thus, it is useful first to recognize the universe for what it is — a dark, barren place on a scale which dwarfs humanity, very *sparsely* dotted with matter, some of it incandescing with nuclear reactions at several million degrees (in stars) — mostly a void occupied by a very thin "dust". These fragments of matter are commonly no larger than a grain of sand and frequently no larger than the atom and may be moving at several miles per second. Thus, the islands where life could possibly support itself are very few and are widely scattered.

HABITABILITY

If we wish to gauge which of these larger bodies might be habitable, we must remember how radiation from light and heat decrease with distance. Pluto would see the Sun as a distant star with no warming effect; air on this planet would be cold enough to liquefy. In fact, the only planets above freezing point would be those which, on our "Washington scale", lie in the downtown area, while those planets much nearer than the Capitol would probably be hotter than the boiling point of water.

Only planets large enough to retain, by gravity, their thin skin of gas (0.005 in. thick on our "softball" Earth), would be protected from the powerful particle radiation which needs considerable metal shielding to stop it. Thus, even in the "comfortable" zone, many sterile pieces of rock must exist, of which the Moon is probably one.

The above perspective may lead us to be surprised that we are here at all; but it may also help us to decide where to look for signs of life. For example, we would clearly not spend much of our search effort on Pluto or on Mercury. We would, for the above and several other reasons, concentrate on Venus and Mars, our neighbours in the "comfortable" downtown area. The perspective may also give engineers and physicists some feel for the problems they face in detecting and supporting life forms in this barren environment.

LIFE SUPPORT

When we take a man outside the atmosphere, we must reproduce as many of its functions as we can. We find that, quite apart from giving us air to breathe, the atmosphere serves us in many ways:

(1) It provides a cooling or a warming system, whichever is needed, to even out extremes of temperature; in other words, it is a transport and damping system for heat, cold and moisture.

(2) It absorbs the harmful ultraviolet light from the Sun and the fast atomic particles from space, only letting through a little of each.

(3) It acts as a "meteor bumper", burning up the showers of dust and larger stones which cross our path at thousands of miles per hour.

(4) It acts as a diffuser, softening the Sun's light by scattering it; hence, we see a blue and not a black sky and have "twilight" after sunset.

(5) The even distribution of moisture allows the formation of a firm soil which produces plants which, in turn, produce oxygen and food to keep animals alive; the soil also acts as a disposal system for the husks, bones, hair or horns of dead animals or of the wastes which our bodies reject from food.

Any manned spacecraft, or Moon base, is mainly a device which reproduces these functions, possibly ignoring the diffusion of light as unnecessary, and, up to now, replacing the oxygen-producing function by tanks of oxygen, while wastes are, at present, stored. However, for a very long flight, or a long-stay base on the Moon, it will be very uneconomical to import all oxygen, while the waste problem could become serious. Thus, we would do well to consider creating, in our Moon base, a microcosm of the oxygen-food cycle which occurs on Earth. Some of the principles for doing this are discussed below.

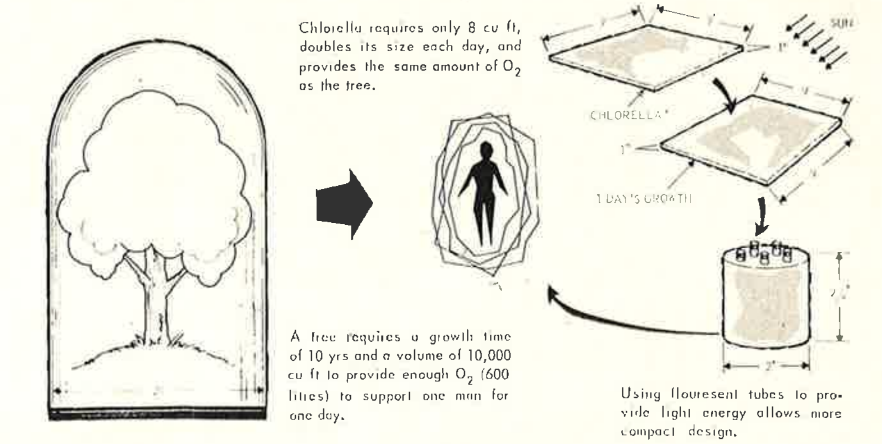


Fig. 1—A rapidly growing chlorella culture can serve a man's daily O_2 needs and is a thousand times smaller than a tree having a growth time of ten years.

The Oxygen-Food Cycle

The maintenance of our atmosphere on Earth is done solely by means of the Sun's energy. At the same time as the Sun's energy liberates oxygen from plants, it causes the plant cells to build sugars and other food substances from carbon dioxide. We ingest these foods, extract the chemical energy as "work", and our bodies release chemicals of the type which first went into the plant. If these are "ploughed back" into the soil, the process can start all over again. It would be ideal if we could instate a cyclic process like this in a Moon base. We would not have to import new atmospheric chemicals, just keep the cyclic, or "regenerative", process under control, using the Sun as driving force. The automatic control of such a process could fascinate generations of electronic engineers.

As a basis for this cyclic process, therefore, our Moon base must contain plant life; however, we cannot use all the immense variety of plants that do the work on Earth, so we must choose one or two hardy and adaptable ones to do the whole job. The problem is—which to choose? We might choose the tree on the basis that it is a hardy, powerful plant. It is, but it is not adaptable. Fig. 1 shows the volume of tree needed to keep one man supplied with oxygen; also, trees develop very slowly. For each man, a tree would have to be planted about ten years before he came to the Moon. And what to do with all the spare timber? It could not be used for construction; if it caught fire, it would suffocate the whole Moon base. This all shows how the Earth system has the advantage of good waste disposal, a long, stable cycle, and a reservoir estimated at 10^{11} tons of oxygen (about 200 years' supply).

Chlorella Plants as Food

It can soon be seen that, to give flexibility to our Moon base, we want to choose a plant which packs closely, produces little inedible waste, tastes good, and is adaptable to "flow" production rather than "batch" handling. The best organism so far found is the minute, simple seaweed or "green slime" species, the algae. These are what we see in a fishbowl which has stood for some time. In the bowl, they are doing what we want them to do on the Moon: they are growing rapidly, using the body wastes and carbon dioxide of the fish plus daylight to produce oxygen and more of themselves. The Chance-Vought Company has actually kept two mice, "Mousetronauts" as they called them, alive for over two months on oxygen photosynthesized from chlorella, one of the hardier, free-floating algae. Other companies claim to have kept a man alive for several days with a similar system. Fig. 1 shows, conceptually, how the volume of chlorella culture needed to serve one man is about a thousand times smaller than that occupied by a tree. Furthermore, using stored sunlight (e.g., electricity, to light fluorescent tubes) as the energy source, a one-man supply of this plant can possibly be packaged in a container the size of a waste basket.

The chlorella plants double their weight every day, contain most of the necessary vitamins and proteins, and are entirely edible. Here is the "crop" of food that we need; unfortunately, it is not very palatable. After all, who would want to live exclusively on green slime? Dr. Alain Bombard tried to cross the Atlantic living only on the

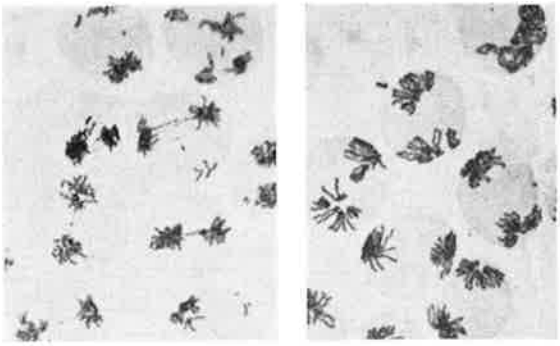


Fig. 2—One of the effects of radiation on living tissue. The dark bundles are chromosomes—cell units which control the rate and direction of tissue growth. In healthy cells (left-hand photograph) the bundles pull apart into two lots just before the cells divide, one lot going to each "daughter" cell. In cells which have been given a dose of X-rays (right-hand photograph) the bundles do not divide cleanly and the cells may die or produce abnormal "daughters".

surface plankton, a mixture of similar types of organisms. He soon found he would rather starve. Hungry mice, given dried chlorella, sweep it aside and use it as bedding. It can, however, be used to fortify other foods, and "chlorella cookies" containing up to 20% chlorella are edible. On the whole, though, it would be better if we could find, as on Earth, an animal or a fish which would thrive on these useful little plants and then provide us with better fare.

This approach, however, brings more problems. Most animals have a fair proportion of bone, gut, hide, or hair which we just cannot eat — one third in the case of cattle — and we at once have a real rubbish problem. We must seek an animal which is all edible. The slug is one of the few nearly so and it *is* eaten in parts of the world, as slug jam; but perhaps we might prefer to forgo this treat and use a compromise like shrimp, the edible insects, or, perhaps, just mushrooms. I am sure there are still many bright suggestions in this plant-animal combination game which have not yet come to light and the author is tempted to propose a prize for the best combination suggested. The Boeing Company suggested the Tilapia fish, a South American species which enjoys algae, is hardy, tasty and breeds fast.

In a Moon base, we may find it an advantage not to rely on the Sun for photosynthetic regeneration. Nuclear power could supply artificial light for underground photosynthetic cells, solving the problem of supporting these cells for the two-week Lunar night.

Protection Against Particle Radiation and Meteoric Damage

The next most important function of the Earth's atmosphere is to act as a shield for space particle radiation. The Sun and other stars emit streams of charged atomic nuclei, some of which will penetrate inches of lead. All high-energy particle radiation can cause damage to living cells, either causing death of the cell or causing a break or change in the chromosomes so that daughters of that cell are somehow different, or "mutated". Fig. 2 shows how a dose of radiation has disorganized the right hand group of cells. They are not dividing cleanly like the unirradiated cells on the left and may either die or reproduce irregularly. The results of several intense efforts in predicting solar flares, and the "storm" of particles which reaches the Earth shortly after, have given us some hope that inhabitants of a Moon base will have enough warning to get underground, or behind thick shields, before the storm arrives.

Protection against meteoroid damage is one of the most difficult atmospheric functions to simulate. It is possible to build structural shielding to ward off the heavy rain of sand-size particles but, apart from building entirely underground, there is little one can reasonably do to stop the very occasional brick- or boulder-sized meteoroid, which may arrive at a speed greater than 30,000 feet per second, from penetrating surface shelter. We have to rely on their relative rarity and the laws of chance.

Psychological Factors

By no means the least important factor which may limit our activities in space is the psychological factor. We probably do not realize how much we rely on familiar sounds, light, textures, and companionship to keep us on an even keel. We must not underestimate what loneliness, harsh light, odd food and danger may do even to the most determined man. It may be this factor which will limit extensive space travel to a few trained astronauts rather than a commuting throng.

ORIGINS OF LIFE

In the previous description, life appears to require a protective atmosphere; we will now consider how, if this atmosphere is provided on a planetary body, living forms could arise from the raw materials of its surface and in what forms they might arise.

Basic Life Requirements

It is not easy to define life, but it is generally agreed that at least three things are indispensable: (1) a liquid solvent, like water or ammonia; (2) a system of polymers to provide structure and (3) polymers having the ability to *reproduce* themselves out of raw materials. It seems fairly certain that the polymers making up the living system must be carbon-based, since carbon appears to be by far the most efficient in producing extended "backbones" where organic carbon chains of two to six units are linked to one another by oxygen, phosphorus, or nitrogen bridges, such as are shown in Fig. 3. The "backbone" commonly has other chemical groupings as useful appendages, adapted to doing the necessary chemical work for the polymer (hence they are called "functional groups"). The main classes of polymer used in Earth-based life are the proteins (such as muscle, fibre, bone, or albumen) and polymeric sugars (such as cellulose, starch, or DNA, the last being the basic heredity carrier).

Polymers and Temperature Effects

In order to construct a system of polymers which reproduce themselves, it can be deduced that the polymers must be complex; moreover, they must be laid out in a very specific spatial pattern. The patterns must persist both within each individual polymer molecule and in the relation of one molecule to the neighbouring molecule. How the polymers may achieve suitable spatial orientations to one another is dealt with later. Here we will deal with one important conclusion of the above—thermal stability. For a protein or polysaccharide to maintain its delicate, internal "secondary" structure, it must stay within a certain fairly narrow temperature range. Virtually no enzyme will stand boiling, and even egg white, a simple protein, loses its secondary structure, or "denatures", on boiling (or even by whirling round the head in a nylon stocking). We can say that the heating literally shakes the secondary structure to pieces. This condition sets the upper temperature limits for carbon-based living forms at *well below 100° C.*

On the other hand, if we cool down any chemical mixture sufficiently, we can virtually stop all chemical reaction. By Arrhenius' Law, chemical reactions slow by about a factor of two for every ten degrees fall in temperature. Because of this effect, we can store many biological materials (such as food, spermatozoa, or bacterial cultures) for years in the deep-freeze without their changing appreciably, either functionally or chemically. The need for a minimum reaction rate for active life to proceed places the lower temperature limit *above the freezing point (0° C.).*

Livable Zones—Ecospheres

The mature conclusion is that if, as seems likely, life can only exist by employing sensitively positioned arrays of carbon-oxygen and carbon-nitrogen chains in an ionizing solvent such as water, then advanced forms of life can only exist in a narrow range of temperature between about 10° C. and 60° C. This means that life around our Sun can only exist on the Earth and possibly on Mars and Venus. Although the MARINER flight has given weight to the conclusion that the surface of Venus is well above boiling point, balloon experiments have pointed to much lesser temperatures.

Around other stars, there will also exist narrow livable zones, or *ecospheres,* although these are only of reasonable size and stability in the medium-temperature stars like the Sun (F, G and K type). Though it is impossible to be sure, it is probable that stars like the Sun (smaller than type F5) also have planets around them. The nearest of these is Tau Ceti, which is about 5×10^{12} miles away. At the speed of our present interplanetary spacecraft, it would take about ten million years to get there. Therefore, there is no point in considering such stars for a search at present.

On the other hand, it is worth recalling that there are about 10^{20} stars which fall into the above categories and so, if as some biologists think, life is a phenomenon which is likely to arise whenever chance sets the conditions right, this number of "chances" is quite a high one. Thus, we might find life around other stars once we have vehicles which will get us around the galaxy in reasonable times. But, if we discover Mars and Venus to be sterile (a very likely possibility), we can resign ourselves to our own company for some time. It will still, of course, be of interest to discover whether Mars is *colonizable.* If world population grows, the possibility of some temperate real estate on Mars may become very attractive.

It is not too difficult to deduce, as above, from the results of simple biological experiments, what conditions are required for life to survive. It is still not within the scope of our knowledge to reconstruct, in detail, how life arose on Earth. Intensive biochemical analysis, even of the simplest known living organisms, does not yet provide a clear answer.

Self-Reproducing Polymers

The simplest self-reproducing system—the virus—is well known to us by its effects. Viruses consist of little but the necessary self-reproducing polymer, DNA (deoxyribonucleic acid) usually isolated as a colony of spherical or simply-shaped units. The units contain no cell wall or other retaining structure. Hence, unless conditions are exactly right, they cannot, like other simple cellular organisms, collect their own raw material, settle back and then build it up into new replicas of themselves. One splash of water, and the colony is dispersed into individual molecules. Because of this, they only survive and multiply when they find themselves in a "host" living cell. Here they act as complete

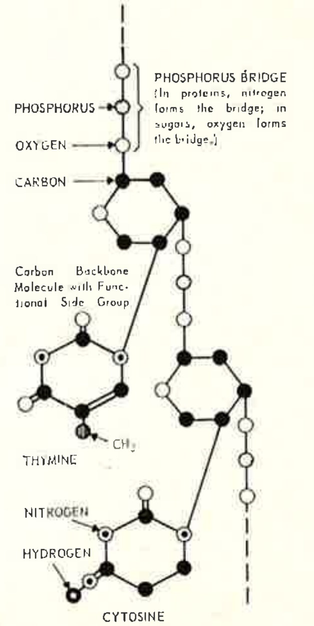


Fig. 3—Organic carbon chains linked by oxygen and phosphorus bridges. The example here is a section of the genetic polymer DNA, a nucleic acid.

parasites and apparently usurp the cell's production facilities in order to replicate more of their kind. This behaviour sounds like a by-product of biological evolution, not a likely first stage.

The account of the virus points out one of the prerequisites of life—a bag, cell wall, or other retaining structure to isolate the self-manufacturing process from the nonliving medium. It is not too difficult to propose a model of how this first step could occur in a warm, sunlit "soup" of aminoacids and sugar on the Earth's surface. As shown in Fig. 4, clay (or a crystalline mineral surface) could act as a regular structural "backbone", absorbing, as is natural with surfaces, some of the organic matter onto it in a regular array and catalyzing its further polymerization onto the surface. It has been shown that the correct conformation of nucleic acid polymer can, in fact, act as a "template" and build up on itself a string of sugar and carbon rings similar to itself, but a kind of "negative" image of the original. The negative can be expelled from the "mould" and then repeat the process, building up on *itself* an exact replica of the original nucleic acid polymer. It can be seen that, given

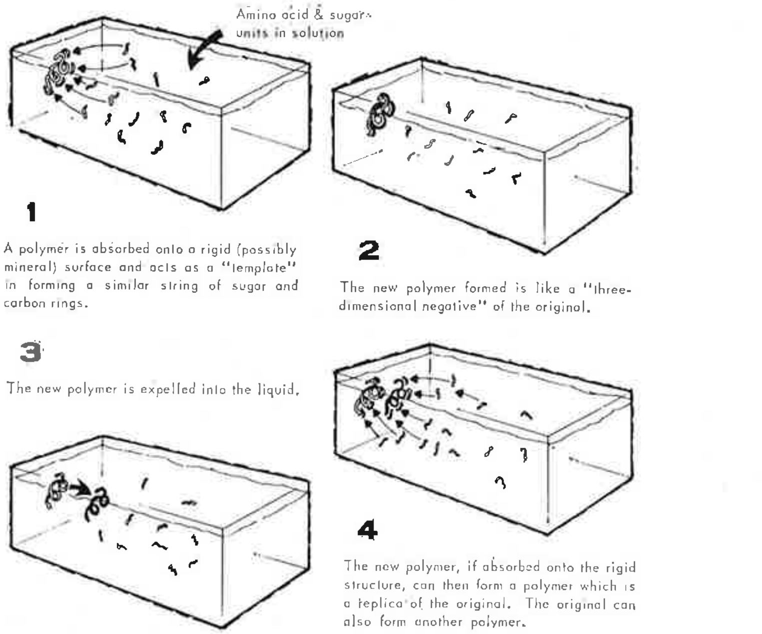


Fig. 4—Representation of self-reproduction of a nucleic acid polymer in primitive aqueous environment.

a supply of raw material, a spatially confined nucleic acid polymer system could act as a perpetual factory of replicas of itself. As a result, a blob of thickened "soup" could form. Around it, a further-polymerized, elastic coating (or crust) could form, perhaps by oxidation and the separation of fatty constituents. This could isolate the building process from the medium, allowing only some types of osmotic transport of the necessary raw materials into the "cell", but retaining the larger manufactured molecules. Fig. 5 puts this simple model in visual form.

However, we cannot say we have hereby solved the mystery of life; the "growth" of this cell is still uncontrolled. How the "cells" decide, as true living cells do, to divide and redivide, always retaining the right geometry and size is a problem no more than nibbled at by contemporary biochemistry, or *molecular biology*, as this field of study is more accurately called.

Function of Light

The kind of growth described is possible without oxygen or sunlight, if some other suitable fund of chemical energy is available. However, a biological system requires chemical energy rapidly, and the best source of rapid energy is sunlight. As organic chemists have known for some time, light, especially in the ultra-violet wavelengths, can be used to put together a wide variety of organic molecules. Fig. 6 illustrates how, with the right plant catalyst, light can produce the carbon backbones in the form of sugars by oxidizing water and reducing carbon dioxide—the gaseous by-product being oxygen. In the plant chloroplast cell, the chlorophyll molecule is arrayed in a highly organized manner which makes a highly efficient system for producing carbon chains.

Motion

For an organism to become advanced in function, one final basic attribute is required: it must be able to move parts of itself mechanically, or be *motile*. It must transduce chemical energy into mechanical energy. Very recent biochemical research has isolated the polymers involved in this process. The form of the secondary structure of a protein called actomyosin is normally long and thin; however, when a simple organic chemical called adenosine triphosphate is added, the secondary structure changes very rapidly into a bunched-up, almost spherical, form; the effect can be reversed by other chemicals. Given the right "hooks" at each end of the molecule, we could, in the laboratory, make one molecule do an unlimited amount of work by repeating this cycle indefinitely. Again, however, it is a long step from this test-tube model to the construction of a single animal muscle fibre.

Prerequisites of Life Forms

Summarizing biological evolution in a few words, we might say that from the biochemist's point of view, the prerequisites of advanced life forms are: (1) moderate temperatures; (2) an ionizing solvent; (3) self-reproducing polymers; (4) cell wall structure formation; (5) a respiratory system and (6) an available photosynthetic source of raw materials.

LIFE DETECTION

As the discussion so far indicates, our main hopes for detecting extraterrestrial life in the near future rest on Mars, although we must not completely exclude the Moon and Venus. Mars would, in any case, be the object of intensive scientific study; it is the only planet on which we can obtain a reasonably unobscured view of a cloudless surface. Dark patterns come and go on the surface of Mars, while patches looking like ice appear at the poles in winter. Much can be done to study these changes from the surface of the Earth. Telescope observations have been carried on for many years, but the obscuring effect of our own turbulent atmosphere has brought this to a limit. Very soon, balloon and satellite telescope observations will produce a much clearer view of the puzzling surface patterns now seen in a blurred fashion from Earth.

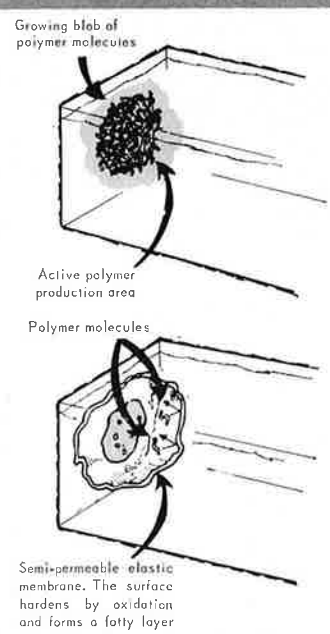


Fig. 5—Polymer molecules as an elastic membrane.

Concerted Effort and Analysis Needed

Much more detailed analysis is also possible by analyzing the spectral distribution of the reflected sunlight, from the ultraviolet wavelength into the infrared. The light reflected or transmitted by a chemical compound bears a characteristic "fingerprint" of the chemical classes present in that compound. Given a small tube of an unknown Martian material, a chemist could put it into his laboratory absorption spectrometer and identify, or at least class it, in a few minutes. What we get from Mars in Earth-bound telescopes is a less informative reflectance spectrum, further obscured by the smearing effect of the atmosphere and the low "signal-to-noise" ratio from this weak source of light. Even so, one person has observed, from the Earth, definite reflectance peaks in the 3-micron wavelength region, only obtained when the telescope was centred on a dark blue-green region near the Mars equator. Such a region is the dark, comma-like area known as Cyrtis Major. The reflectance peaks are at wavelengths characteristic of green plants, where they arise mainly from the C-OH groups in cellulose and sugars. However, a similar band is present in all alcohols; thus, this band could just as well arise from pools of pure hundred-proof spirit which, for all we know, wells from the ground on this planet! The STRATOSCOPE II balloon flight also obtained somewhat noisy spectra of Mars. These indicate that there is little oxygen or water vapour in the atmosphere—a damper on our hopes for advanced life forms there.

Mars Biological Test Laboratory

Mars will be the object of the first unmanned planetary landing, which may take place in about 1969. The major part of such a landing capsule will be a biological test laboratory containing experiments to determine the existence of life by the most advanced methods which can be employed remotely (Table I lists some of the possible tests being considered by NASA).

The practical problems of these remote laboratories are immense. If we think of the diversity of Earth life, it would be very difficult to design a machine to detect them all — elephants, flies, earthworms and germs—especially if the weight of the laboratory is limited to 100 or 200 pounds. The first machines will thus be limited to the forms of life most likely to be widespread and most easily handled — soil microorganisms. Most of the tests will be of the following type: A clear soup (or culture medium) and oxygen will be provided for the delectation of a few pinches of Martian soil. The accompanying instrumentation will be designed to detect the smallest change in the composition or appearance of the culture medium (production of turbidity, production of carbon dioxide from the oxygen, release of new phosphorus compounds, etc.).

Great Decisions to be Made

One cannot help feeling that some great issues and decisions may rest on quite fallible tests such as these, but it is very difficult to design an infallible test of this type. For a beginning, we have to be completely sure that we have sterilized our equipment so perfectly before launch that it will not carry any of its own bacteria and then detect *them* on Mars. Also, no knowledge exists of the culinary likes and dislikes of Martian organisms. Judging by Earth organisms, an error of a few fractions of a pH (acidity) unit can inhibit otherwise rapid bacterial or viral growth. Perhaps only the TV microscope or telescope will provide us with enough "feel" to recognize highly foreign forms of life. It is quite possible that all the remote instruments will remain "blind" to an existing form of life on the planet and that these forms will only be discovered when man arrives.

A manned Martian landing has its own major problem: Mars does not carry enough atmosphere to slow a heavy capsule efficiently. Probably a large amount of uneconomical rocket braking will be required; although concepts for Mars capsules capable of landing (and employing some aerodynamic braking and control) have recently been advanced.

PROGRESS IN SPACE EXPERIMENTS

Actual biological experiments in space began early in the space age with the flight of the Russian dog, Laika, in SPUTNIK II in November, 1957. Of course, many suborbital flights by small animals have preceded and followed this flight, even outside the U.S. and Russia. For example, the French have recovered a white rat, "Monsieur Hector", and several other animals from powerful liquid-fuelled rocket flights over the Sahara.

The story of the more recent successful manned orbital flights needs little further description except to note that the feared physiological effects of weightlessness, space radiation and enclosure have been reassuringly mild. No other country yet has serious plans for such expensive manned orbital experiments; although in Britain, the concept of the "Aerospace Plane" is being pursued. This concept comprises a fully-manoeuvrable winged craft similar to the X-15 but made capable of longer missions by the use of a ramjet in the atmosphere and rocket propulsion in orbit.

The earliest unmanned orbital biological experiment for the U.S. came with the launching, in the DISCOVERER XVII satellite, of a payload of living mammalian and plant-cell cultures in November, 1960. The nose-cone of the satellite was then fired downwards from orbit after two days. The capsule re-entered the atmosphere and was caught in the air. Although a moderately large solar flare occurred during the mission, depositing a radiation dose of about 30 rads of protons (about one-tenth the lethal dose for a man) in the samples, no noticeable effects of the flight were noted in the subsequent lifetimes of the cell cultures.

Several RCA projects investigating physiological telemetry have been completed. Many of the transducers used

Fig. 6—Effect of light to produce carbon backbones in the form of sugars.

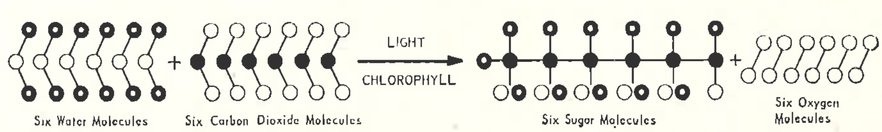


TABLE I—Current Life Detection Instrumentation

Instrument	Physical Quantity Observed	Limitations
	Life Detector Sensors Under Development by NASA	
Multivator	Fluorescence of enzymatically hydrolyzed synthetic substrate.	Substrate subject to spontaneous hydrolysis. Enzyme activity varies widely, hence response time is uncontrolled and may be the same as base-line drift.
Gulliver	Radioactive CO_2 from radioactive sugars.	Result measured from a difference in rates of spontaneous and bacterially caused decarboxylation. Base line may drift badly over the course of a long experiment, e.g., four hours. Reliable determination is needed of the radio-active background on Mars. Also, the presence of materials that will cause oxidation of the sugars by non-metabolic mechanisms may result in a false positive response.
Wolf Trap	Increase in hydrogen ion activity and turbidity from growth of bacteria.	"Universal" substrate required. Growth rate slow, and base line drift may obscure pH and/or turbidity change.
J-Bands	Spectral absorption band of dyed bacteria.	Detects equivalent of 10^7 bacteria/ml. Substrate subject to deterioration. Interference or false alarms from non-living tissue possible.
Vidicon Microscope	Displays image plane of microscope on TV.	Very wide data bandwidth needed, or automatic pattern recognition. Spurious shapes are possible.
High-Resolution TV	Observes and displays macroscopic morphology of planetary terrain and possible animals.	Transmission of TV image necessary.
Gas Chromatograph	Measure column chromatographic retention times of several dissolved compounds.	Slight variations of retention times because of environmental changes will alter analytical results. Columns require cleaning and renewal.
Mass Spectrometer	Molecular fragments of degraded sample.	Limited specificity because it measures only mass number.
MARBAC	Essentially redox potential measurement.	Limited specificity.
Ultraviolet Spectrometer	Absorption in the far ultra-violet.	Sensitivity low (about 10^6 bacteria/ml.).
Optical Rotatory Dispersion	Optical activity associated with biological materials.	Will not detect optical rotation if equal quantities of optical antipodes are present. Sensitivity low, about 10^6 bacteria/ml.
	Life Detectors Under Investigation	
Protein Pyrolyzer	NH_3 from pyrolysis of airborne particles.	Non-living substances would respond identically with biogenically formed protein or amino acids. Sensitivity good, about 10^4 bacteria would be detectable.
Partichrome Analyzer	Blue (ethyl violet stainable) particles in the microscopic size range.	Abiogenically formed organic particles should also stain. Sensitivity good, about 30 bacteria/litre of air. Specific to organic particles.
	Other Sensors Applicable to Life Detection	
Gas Chromatograph	Lipids of bacteria.	Non-living lipids would interfere. Sensitivity good, about 10^4 bacteria). Other problems similar to those described previously. Reagent may undergo changes.
Spot Scanning Microspectrophotofluorimetry	Fluorescence of stained particles.	Similar to Partichrome Analyzer. Staining more specific, directed at nucleic acids. Reagent may undergo changes.
Polarization of Fluorescence	Degree of polarized fluorescence from solutions of fluorescent dyes plus biological material.	Non-living materials may interfere. Reagent subject to changes. Sensitivity about 10^4 bacteria/ml.

in ground-base clinical telemetry require adaptation to space use, where long-term discomfort cannot be tolerated and light weight is required. To overcome these deficiencies, new sensors were investigated by the Systems Support Engineering group of the DEP Aerospace Systems Division.

The first was a blood-pressure transducer that picked up the entire pressure wave from the body surface. Present blood pressure techniques are cumbersome and awkward, using a pressure cuff and microphone to detect the high (systole) and low (diastole) points on the pressure curve. To develop a cuff-less technique, radial vascular pressure, sensed by miniature strain gauges, and changes in tissue capacitance were investigated. Another area of sensor development is with pressure and temperature measurements by means of endoradiosondes. These miniaturized, passive devices are used currently to study temperature changes and organ potentials of mammals. Other sensors have been developed for respiration rate and volume, blood-oxygen saturation, blood flow rate, deep body temperature, and cardiac function information.

Weight and size reduction in circuitry were also achieved. For example, an electrocardiograph (ECG) with a total volume of 1.5 in^3 has been developed that is capable of transmitting the ECG signal to a distant receiver. Similarly, an electroencephalograph (EEG) was developed that could be carried in the shirt pocket and will be capable of transmitting a half dozen channels.[1]

A recent project within RCA's Astro-Electronics Division (in collaboration with the Marquardt Corp.) has produced an outline design of biosatellite carrying embryo of opossums.[2] These are particularly well-adapted for the observation of development in the weightless state. Several opossum foetuses are maintained in incubation cells in the satellite while rotating optics supply pictures from each cell to a central black-and-white TV camera. Interposed filters give indications of colour changes in the foetus. The polar orbit (300 nautical miles altitude) and spacecraft configurations are chosen to keep radiation within the compartments at a low level.

CONCLUSIONS

The main aim of this article has been to demonstrate the following: While we have several good handles on the problem of the origin of life, we have a lot of sophisticated research to do before we arrive even at a good set of hypotheses of how life occurred. Likewise, while we can detect many forms chemically, we need much more sophisticated sensors to help us to decide whether a certain observed phenomenon may constitute "life". Finally, although we have demonstrated short-term life-support outside the atmosphere, our present crude automatic control of a few gases and fluids will have to be refined greatly before we can, for example, establish a colony on the Moon. The design of the advanced electronics required for each of these pursuits should offer engineers and scientists one of the greatest challenges of an already challenging technology.

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