tion takes place (*13*), but it is very weak, and this weakness seems difficult to reconcile with the idea of the presence of barriers. It appears that much more experimental and theoretical work must be done before the properties of even the simplest amorphous nonmetallic materials are completely understood.

Ovshinski (*14*) found a particularly useful transport effect in chalcogenide glasses and applied it to the design of a new device called the Ovonic switch. The device consists of an amorphous film between two electrodes. It has a high resistance at voltages below a certain threshold voltage. If the threshold voltage is surpassed, the resistance drops by several orders of magnitude. The transition time is exceedingly rapid (less than 150 picoseconds), and the effect is completely reversible. It was found empirically that amorphous materials are far better for this purpose than crystalline materials. Owing to the simplicity of production, the insensitivity to radiations, and characteristics useful for many applications (*15*), the Ovonic switch may find an important position among modern semiconducting devices. Ovshinski observed other unexpected effects in chalcogenide glasses, which may be used in the design of devices; for example, with some materials a device constructed along the lines of the Ovonic switch can remain in the blocking state or the conductivity state for a very long time and can be switched from one state to the other by an electric pulse. The nature of these effects is only partially understood.

Summary

A possible approach to the understanding of electronic properties of amorphous materials is to compare them with the corresponding crystalline materials, whose properties have been well explained. This approach has been exploited in the simple case of amorphous germanium, and I have indicated how the observed optical properties can be used to obtain information on the changes of electronic states, and what complications arise when we try to understand the transport properties.

References

1. A. F. Ioffe and A. R. Regel, *Progr. Semiconductors* **4**, 237 (1960).
2. A. Gubanov, *Quantum Theory of Amorphous Conductors* (Consultants Bureau, New York, 1965).
3. By *linear combination* I mean a sum of wave functions (in this case Bloch functions) with appropriate numerical factors. By interference effects the resulting wave function may be confined to a certain volume rather than extend over the whole crystal as the Bloch function does. Following a theorem of quantum theory, an arbitrarily selected wave function can be described by a linear combination of Bloch functions. This is the departure point for theoretical considerations given in the next two sections of this article.
4. N. F. Mott, *Advance. Phys.* **16**, 49 (1967).
5. N. E. Cusack, *Rep. Progr. Phys.* **26**, 361 (1963).
6. J. Tauc, A. Abrahám, L. Pajasová, R. Grigorovici, A. Vancu, *Proceedings, Conference on the Physics of Noncrystalline Solids* (North-Holland, Delft, 1964), p. 606.
7. J. Tauc, R. Grigorovici, A. Vancu, *Phys. Stat. Solidi* **15**, 627 (1966).
8. J. Tauc, R. Grigorovici, A. Vancu, *J. Phys. Soc. Japan* **21**, suppl., 123 (1967).
9. B. T. Kolomiets, *Phys. Stat. Solidi* **7**, 359 (1964); *ibid.*, p. 713.
10. R. Grigorovici, N. Croitoru, A. Dévényi, *ibid.* **16**, K143 (1966).
11. L. Banyai, in *Proceedings International Conference on the Physics of Semiconductors Paris, 1964* (Dunod, Paris, 1964), p. 417.
12. J. Stuke, *Phys. Stat. Solidi* **6**, 441 (1964).
13. A. H. Clark, *Phys. Rev.* **154**, 750 (1967).
14. S. R. Ovshinsky, U.S. patent No. 3,721,591, 6 Sept. 1966.
15. J. D. Mackenzie, *Electronics.* **39**, No. 19, 129 (1966); G. Sideris, *ibid.*, p. 191; J. A. Perschy, *ibid.* **40**, 74 (1967).
16. H. Richter and O. Fürst, *Z. Naturforschg.* **6a**, 38 (1951).

NEWS AND COMMENT

The Synthesis of DNA: How They Spread the Good News

1. Public Relations Aspects

Several months ago a research group, headed by Arthur Kornberg of Stanford University, concluded that it had succeeded in a long-standing quest—the in vitro synthesis of biologically active deoxyribonucleic acid (DNA). Kornberg and his colleagues, Robert L. Sinsheimer of California Institute of Technology, and Mehran Goulian, a Stanford postdoctoral fellow now on the University of Chicago faculty, prepared a report of their findings. In September the report was submitted to the *Proceedings of the National Academy of Sciences* (PNAS) by Kornberg, who is a Nobel laureate and a member of the Academy. Publication was scheduled for the December issue, which would normally have come out around the third week of this month. But because of production delays connected with PNAS's end-of-the-year index, the issue is not expected to go to press until early January.

That the work of the Kornberg group would eventually attract great attention within the scientific community was assured by the significance of the findings, Kornberg's reputation, and the prestigious place of publication. How it might fare in the outside world was an altogether separate question; for, despite the belief that the public ought to care about basic research and, therefore, does, it can scarcely be said that the man in the street has his transistor tuned for the latest word from the workshops of DNA research. Nevertheless, before news of the Kornberg report had an opportunity to become visible through the normal channels of scientific communication it had become front-page news, on 15 December, throughout the nation. In accompaniment to this news, two traditionally reticent government agencies, the National Institutes of Health and the National Science Foundation, publicly announced that they had shared the costs of Kornberg's work. And, on the eve of the appearance of the newspaper stories, no less a figure than the President of the United States had a last-minute insertion made in a speech to laud the Kornberg group for having "unlocked a fundamental secret of life." Speaking at the Smithsonian Institution on the occasion of the 200th anniversary of the *Encyclopaedia Britannica*, President Johnson advised his audience to look to the newspapers the next day for "one of the most important stories you ever read." On 17 December the New York *Times*, having had a few days to ruminate on the implications of the Kornberg report, informed its readers that the 21st century may be known as the "age of DNA," and, it went on to note that "some experts feel it is conceivable that man will be able to make an exact duplicate of a genius, such as an Einstein, with DNA."

It must, of course, be recognized that the press and the public are increasingly attentive to what is going on in the nation's basic research laboratories, but the flood of attention accorded Kornberg's delvings into the esoteric regions of subcellular biology is an event that, in some respects, is no less extraordinary than the scientific substance of his work. (An assessment of the scientific aspects follows this article.) And the genesis of this event is worth examining in some detail, for it tells a good deal about science and politics in the nation today.

Any speculation that Kornberg is a personal-publicity hound must be written off at once as altogether unjustified; those who know him well, or even slightly, share the impression that he is a reserved scholar, deeply absorbed in his work and, though widely honored, not addicted to the games that some researchers endlessly play in the quest for professional or public recognition. Nevertheless, over the previous year or so Kornberg had become considerably concerned about one public aspect of basic research—namely, the adequacy of public financial support and, closely linked to this, the public's understanding of what it receives in return for its support. It is worth noting, though, that whatever the money situation may be in various parts of the scientific community, Kornberg's own work has been, and remains, generously supported; over the past 7 years, NIH has granted him approximately $1.7 million, and at present, he also has a 3-year $111,000 grant from NSF.

But concern about the volume and durability of federal support for basic research is today endemic throughout the scientific community, and as the time approached for publication of the DNA paper, Kornberg decided that it would help the cause of science if the work were publicized generally. Accordingly, he brought the report to the attention of the news bureau of the Stanford University School of Medicine, where he is professor and executive head of the department of biochemistry. "I think this was the first time," Kornberg said in a telephone interview with *Science*, "that I told our news bureau about an article that we had sent off. I thought it had significant public interest. I felt this work could be more easily interpreted for the public than some other things we have done. Lately, I have become aware of the need for science to be better understood by the public, and I've had the feeling that we haven't always exploited our opportunities for gathering public support."

Arthur Kornberg (right), with Mehran Goulian, last week at a press conference announcing the synthesis of biologically active DNA.

The School of Medicine news bureau, assuming that PNAS would be out around mid-December, immediately took steps to bring the paper to the attention of the press. A carefully worded press release was mailed out on 11 December for release on 15 December, the date set for a press conference. And, on 13 December, for the benefit of those who could not attend the press conference, Kornberg recorded an interview with Spyros Andreopolous, of the news bureau. In this interview he described the research and assessed its potential for therapeutic purposes, stating, for example, "We expect that it should be feasible now to synthesize modified forms of the polyoma viral DNA and determine how it alters its cancer-producing germs. . . . It may be possible then to attach a particular gene to a harmless viral DNA and use this virus as a vehicle for delivering this gene to the cells of a patient. In this way, a person may be cured of a hereditary defect" He also used the occasion of the news bureau interview to express his concern about the adequacy of federal support for science. Acknowledging the generous support of past years, he went on to observe, "Today we need more facilities here at Stanford as well as elsewhere. . . . Unfortunately, the appropriation bills just passed by Congress cut back the research and training programs of the NIH and the NSF. I believe that it was the Vietnam war which forced this situation. The American people should know that we are sacrificing our future health in diverting our resources to the war in Vietnam." The news bureau, however, did not include these Vietnam-related remarks in the published transcript of the interview, on the grounds that the interview was intended to deal only with scientific and medical matters.

The scene now shifted to Washington, where NIH had been routinely informed of the forthcoming press conference and PNAS publication. With the news release in the hands of various science writers, but with a few days still remaining before the 15 December release date, NIH received a number of inquiries from reporters seeking additional information. It is not clear at what point NIH decided to get in on the publicity, but on 12 December science writers around the country received a statement in which NIH Director James A. Shannon lauded Kornberg's research. NSF simply issued a copy of the Stanford press release. At approximately the same time, many science writers received preprints of the PNAS article, which, in their experience, was not a routine event. Shannon's statement was remarkable if for no other reason than that, in a dozen years as head of NIH, he had never before on his own initiative made a public statement on a particular piece of research. In his statement he said that work of the Kornberg group "in effect adds up to a handsome reward for the American people as a result of their investment in basic health research through federal agencies." Shannon went on to say, "it seems well to make this point at this time because the end products of basic biomedical research, although highly essential to progress in clinical medicine, are seldom so clearly visible in terms of potential health applications as that of Dr. Kornerg and his associates."

Now, in searching for origins of Shannon's decision to get into the picture, as well as origins of the eventual involvement of President Johnson, it is worth noting that last year the Senate Appropriations Committee paternalistically chastised NIH for failing to publicize the federal role in health research (*Science*, 28 October 1966). Last week, in an interview with *Science*, Shannon stated that this admonition was in his mind when he decided to make his statement and to bring the forthcoming public announcement of Kornberg's work to the attention of the upper echelons of the Department of Health, Education, and Welfare. When word was delivered to HEW, it was with the suggestion that the White House, which is always in quest of good news for presidential addresses, might like to take note of the event. As one person close to NIH put it, "HEW is always anxious to align the President in support of basic research. We are attempting to oppose the forces in the country that are looking for a quick return on every buck spent for basic research."

HEW conveyed news of the forthcoming report to one of the President's special assistants, and a speech writer, drawing assistance from HEW and the Office of Science and Technology, quickly drew up a few paragraphs for inclusion in the President's Smithsonian speech on 14 December. In that speech Johnson said that the work of Kornberg and his colleagues "opens a wide door to new discoveries in fighting disease and building healthier lives for mankind. It could be the first step toward the future control of certain types of cancer." He also took special note of the fact that NIH and NSF were the sources of financial support for Kornberg's research. The next day, news of the research was on front pages and TV screens throughout the country.

Associates of Kornberg said that he was astonished by the scale of public attention given the report, and that he was not a little concerned by the news media's general focus on him to the neglect of his associates. Kornberg remarked to *Science* that he thinks and hopes basic research will benefit from the publicity. He also said that, from the clippings and TV reports he has seen, he is quite impressed with the quality of scientific reporting for the general public.

And that concludes the story of how the synthesis of biologically active DNA became a major news story throughout the land.—D. S. GREENBERG

In vitro Synthesis of DNA: A Perspective on Research

2. The Scientific Aspects

To those who have followed the dramatic recent progress of research into the chemical processes of heredity, the in vitro synthesis of biologically active DNA will seem less a spectacular breakthrough than a logical extension of the discoveries of the past decade. For example, the new experiments should be viewed in the context of the analogous synthesis of infectious ribonucleic acid (RNA) in test tubes 2 years ago, by Sol Spiegelman and his co-workers at the University of Illinois. The newly reported work is nevertheless of more general interest, because RNA genomes occur in a restricted group of specialized viruses, while most known viruses and living organisms have DNA genomes.

The study of the biological synthesis of DNA at the molecular level was initiated by Kornberg with his discovery of the enzyme DNA polymerase over a decade ago. For this discovery and the work that followed he was awarded a Nobel prize in 1959. Indeed, almost everything now known about the mechanism of DNA synthesis is contained in the series of brilliant and elegant experiments published by Kornberg and his colleagues. The current report is another in the series. These papers deal with the purification and properties of the DNA polymerase as well as with the properties of the DNA produced in the enzymatic reaction. In the reaction catalyzed by the polymerase, a DNA molecule isolated from natural organisms is used as a template: four deoxyribonucleotides (adenylic, guanylic, cytidylic, and thymidylic acids) are the monomeric units which are polymerized. Polymer synthesis is such that the sequence of the four monomers in the newly synthesized chains is the complement of the sequence in the template. Complementarity is here defined by the well-known Watson-Crick nucleotide pairs.

The available chemical techniques are incapable of indicating the exact fidelity of complementary copying. A DNA chain may contain 10,000 or more monomer units. One way to prove fidelity is to synthesize a DNA with a measurable biological activity—an activity which is dependent on a complete and unaltered chain. That is precisely what has now been accomplished by Goulian, Kornberg, and Sinsheimer. In these experiments, summarized in the accompanying diagram, the template copied by purified DNA polymerase was DNA from the bacterial virus ϕX174. Sinsheimer discovered this unusual virus, and it has been the center of attention in his laboratory for 10 years. The understanding of the properties of the virus and the technology developed specifically for it by the group in Pasadena were essential to the success of the latest experiment. The genome of this virus is unique: it contains 5500 nucleotide residues and only a single strand of DNA; it is not a double-stranded helical structure of the