Science and the Humanities: A New Level of Symbiosis

A culture of new dimensions is emerging from the interaction of the arts and humanities with science.

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Science and the humanities had their beginnings during the same era of Western cultural growth. The remarkable intellectual achievements of the Renaissance that contained the seeds of modern science were accompanied by lasting achievements in the arts. In certain individuals—Leonardo da Vinci, Albrecht Dürer, Andrea del Verrocchio, and Sandro Botticelli—talents for the arts and science were mutually supporting, and the great masterpieces of these artists could hardly have been created in the absence of this duality of interests. An interest in mathematics was often the channel of interaction. Both Leonardo and Dürer were ardent students of perspective and proportion. The fruitfulness of their studies along these lines has had a lasting influence down to the most recent generations of painters and sculptors. Cubism and other varieties of abstract art were implicit in the goals of these Renaissance figures.

The situation for both the artist and the humanist has, of course, changed in a most thoroughgoing way with the developments that have occurred since the Renaissance. During the intervening centuries there have been varying degrees of interaction between science and the arts and humanities. At times science and technology have seemed to threaten the value systems of those working in the arts and humanities. In particular, the growing body of scientific knowledge has, by changing man's view of reality, modified in an irreversible fashion the earlier boundaries of the imagination and its limits of freedom.

Prolonged contact with the methodology of science also has fundamentally altered the methodologies employed by humanist scholars in their studies. Most significant of all, science has been held responsible by many for serving as a prism through which the light of an older, unified world picture, however dim, was divided into a myriad of interestingly detailed and colored, but discrete, fractions of reality.

Today there are encouraging indications—still modest perhaps, but plainly evident—of a growing rapprochement between science and the humanities and arts. There has been the development of varied and intensive philosophical speculation on the part of several of the more eminent modern scientists and mathematicians—Niels Bohr, Planck, Heisenberg, Schrödinger, Oppenheimer, and Norbert Wiener, to name a few (*1*). It seems likely that, as more is learned about the fine structure of matter in relation to biological processes and, at the other end of the scale, about the relations between nuclear processes and events in the far reaches of the universe, there may be renewed efforts to achieve a philosophical integration of science. Even though we accept at their commonsense value Conant's warnings against premature attempts to build a new cosmology, the temptation to make such efforts will be increasingly hard to resist (*1*).

On the matter-of-fact, pragmatic level, there is a multitude of evidence illustrating the growing partnership between science and the humanities. The new tools and methods placed at the disposal of humanistic studies by the physical sciences alone is impressive, as a few examples will serve to make clear.

History and the Proton Magnetometer

To begin with archeology and Greek history, we recall that the word *sybaritic* in our language is used to describe the ultimate in luxury and wealth. It refers to the actual way of life in the Greek colony of Sybaris in southern Italy, probably the wealthiest city of the world in the 6th century before Christ. Naturally such a city would gain the jealousy and envy of its greedy neighbors. Sybaris had to defend itself against its neighbors in numerous battles. Nevertheless, the people of Sybaris continued to be delighted by the luxuries and playthings of their affluent society—in times of peace they even taught the horses they used in battle how to dance to music. We are told that their neighbors from Crotona finally overcame them in a battle in 510 B.C., using a unique secret weapon. These unfriendly neighbors brought out a band that played the very pieces of music to which the horses had been trained, and, as the Sybaritic horses began to dance, their helpless riders were slain by the soldiers of Crotona. The city of Sybaris was then razed, and the river Crati was diverted over its ruins. Only traces of the old city could be found by Herodotus less than 100 years later, and by modern times these few signs of the location and extent of ancient Sybaris had disappeared.

A scholar searching for such ruins today can be more hopeful than earlier archeologists. There are new and powerful tools available with which to investigate what lies beneath the surface of the earth (*2*). We now know that the tiny nucleus of the hydrogen atom is at once a kind of spinning gyroscope and a tiny magnet. It is possible to use these properties of the nucleus to build a highly sensitive device for measuring local magnetism to 1 part in 100.000. An ancient tomb deep under the ground, or a fireplace or buried wall, subtly disturbs the earth's natural magnetic field, and the experienced physicist-archeologist can use this information to help locate these buried articles of unique value. An international group of scientists from the United States and Italy has been using this and other techniques to investigate the ancient valley of the Crati river. In just a few days' time they outlined half a mile of one of the ancient walls of the city of Sybaris. The sensitivity

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of the method may be judged by the fact that most of the wall was buried beneath about 3 meters of the accumulated silt of the centuries.

Radioactive Dating Techniques

Another example of science's contribution to history and art through archeology is the use of radioactive carbon-14 dating methods to give us an entirely new dimension of accuracy, in cases where there previously had been little more than guesswork (*3*).

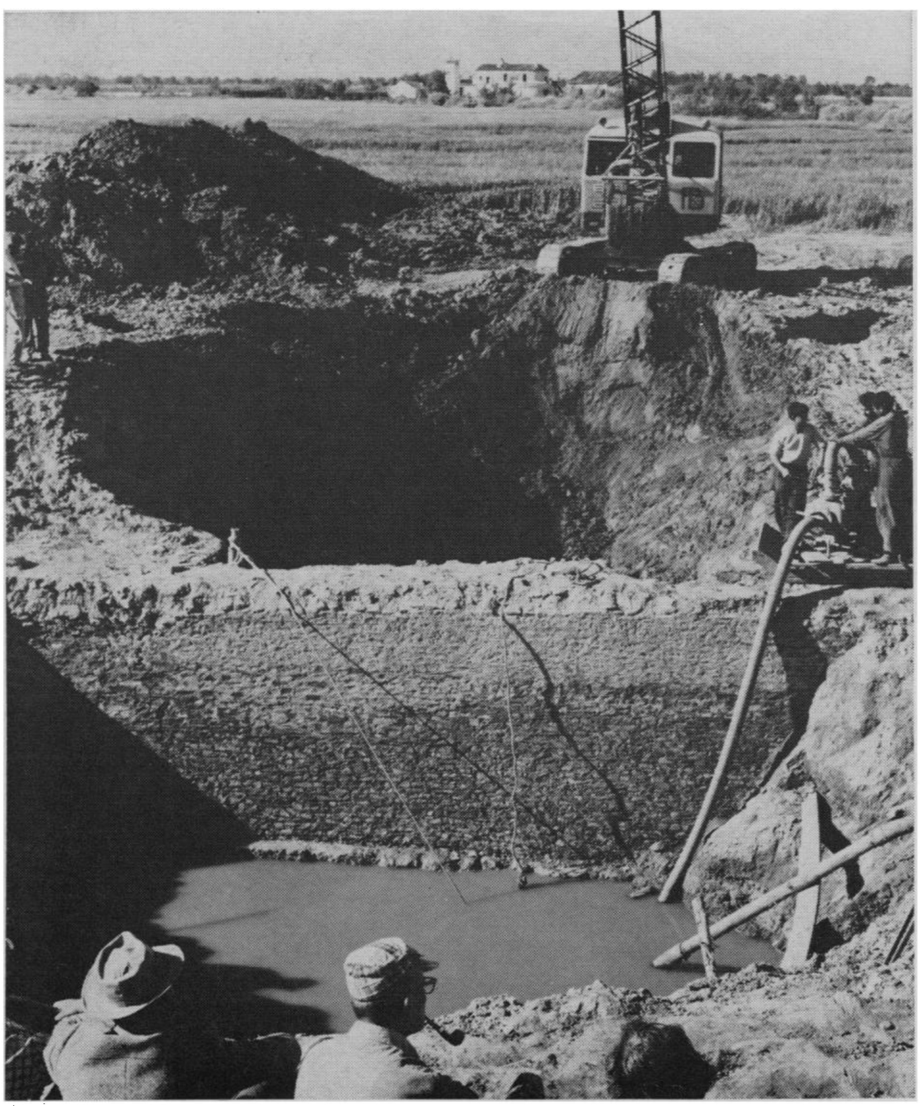
By using these methods it is possible for scientists to assign fairly accurate dates to the products of man's early activities—to charcoal from his fires, pieces of leather from his sandals, even pieces of linen from the wrappings of the Dead Sea scrolls.

By means of these methods we have now learned that the great monuments at Stonehenge in England were erected some 3500 years ago. Geologists have been able, also, to give us a new insight into the magnitude of this ancient engineering problem, because they have been able to identify the rock of which the monuments were made. The nearest deposit of this rock is in Wales, 180 miles away. Some of the individual stones raised at Stonehenge weigh as much as 28 tons, and moving them would not be easy even with modern power machinery.

Hammurabi, a king of ancient Babylon, was probably the first ruler to publish the laws of his country and assign definite punishments for those who broke them. The Code of Hammurabi was carved on great stone slabs erected in every city and village of the land. By carbon-14 dating of a house erected during his reign, we know now that Hammurabi ascended his throne in about 1750 B.C., and we can tell the approximate dates of many other events of Babylonian history.

In another study we have learned that Jericho may be one of the oldest cities in the world. Parts of the deep ruins of this city date from the period 8000–6000 B.C., when the Ice Age had not yet ended in much of Northern Europe.

Dating by radioactivity is reasonably well known by now, and it has helped the historian by clarifying many old and puzzling questions. It has given us a new yardstick for measuring how fast and how far man has come in his ascent from the swamps and the caves of his remote ancestors. L. S. B. Leakey recently found the remains of a man-like creature in the Olduvai gorge in Tanganyika, East Africa (*4*). Though primitive, this anthropoid had already learned the fundamental art of making crude tools of flint. Leakey estimated, from paleontological evidence, that his new find, designated *Zinjanthropus*, had lived about 600,000 years ago. However, two University of California scientists, Curtis and Everndon, using potassium-argon dating techniques, examined the volcanic tuff in which the bones were found and arrived at an age of 1,750,000 years for *Zinjanthropus* (*5*). Using the same methods, they dated a more recent Leakey discovery, the ape-like *Kenyapithecus wickeri*, as 14,000,000 years old. It is humbling to realize that the span of recorded history is only about one-thousandth of the entire length of time that man as a tool-using creature has walked the earth.



Excavation of part of the wall that surrounded ancient Sybaris, a city destroyed by the soldiers of Crotona in 510 B.C. A half mile of the wall was recently uncovered by scientists from the United States and Italy. A water pump is at right and a dragline excavator in the background.

Activation Analysis as a Debunker

Studies in the arts also have benefited from many of the new applications of science. In neutron activation, neutrons from an atomic reactor are used to make minute traces of some materials sufficiently radioactive so that we can recognize their presence and measure their quantity, even when the quantity is too small to be seen with the most powerful microscope. Recently, scientists at the Brookhaven National Laboratory, a laboratory operated by the Associated Universities, Inc., for the Atomic Energy Commission, have been using this new and powerful method (called activation analysis) in studying the chemical composition of ancient pottery from the Mediterranean and from South and Central America (*6*). The great advantage of this method for the archeologist is that it is nondestructive, preserving the original form and beauty of the artifact. Interesting examples of ancient fraud have been revealed by research with activation analysis. Pieces of pottery made in the ancient city of Arezzo, Italy, were popular in the Roman Empire because of the high quality of their workmanship. The potters marked their ware in much the same way that manufacturers trademark their goods today. By means of neutron activation analysis, it has been possible to show that many pieces of "genuine Arezzo pottery" must have been fashioned elsewhere and given a spurious trademark, since the chemical composition of the clay is sufficiently distinct to prove they were *not* made in Arezzo.

Scientists at Brookhaven National Laboratory now are exposing old paintings briefly to neutron bombardment from a nuclear reactor (*7*). This treatment makes the mineral pigments in the paints slightly radioactive, without destroying or harming the painting in any way. When a high-speed x-ray film is placed next to the painting, the radioactive atoms take their own photograph, even though they may be hidden deep under several layers of paint. In this way scientists are working with art experts to get interesting and unique new information on the painting techniques used by the old masters. This method may possibly be used also to detect forgeries.

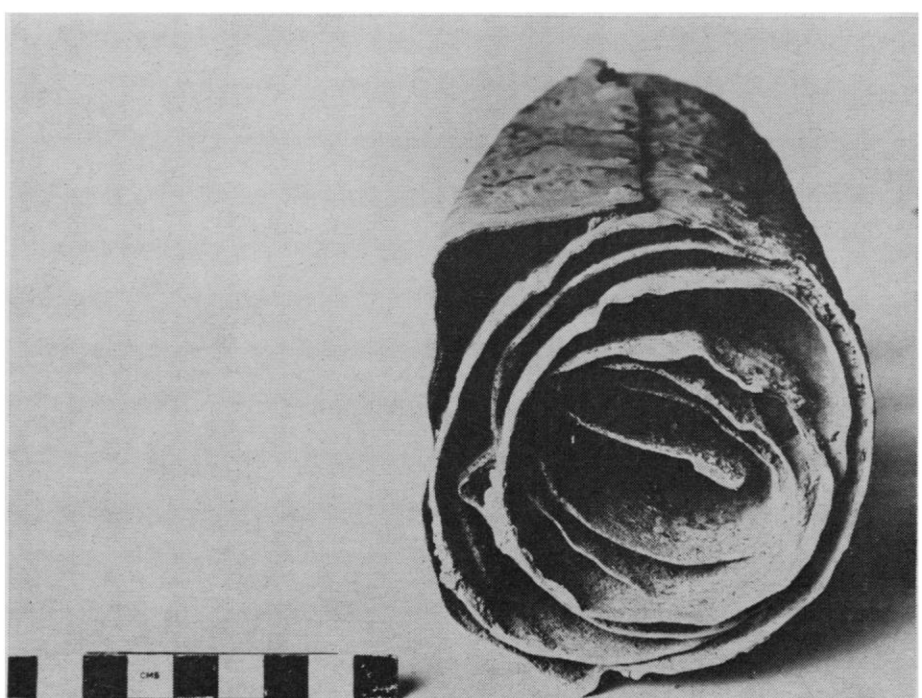
Aqualungs and Spin Resonance

There are hundreds of other ways in which the methods of chemistry, physics, biology, and even astronomy are used to study our cultural and historical origins. The aqualung, for example, a simple device invented by Jacques Cousteau, has opened an entire new world of underwater exploration and has, among its other contributions to underwater discovery, let us study the patterns of ancient trade routes in the Mediterranean.

The aqualung was utilized in a special way in a piece of scientific detective work that probed back to the days of Aristotle. In the ancient Mediterranean Sea there was a little mollusk called the murex. The Phoenicians of Tyre and Sidon were skilled at extracting a tiny colored gland from this mollusk and using it to dye wool; this was the famous Tyrian purple, so precious that only emperors, nobles, and the very wealthy could afford clothing dyed with it. In 1908, Paul Friedlaender, a well-known Austrian chemist, studied some 12,000 specimens of a closely related snail; some of his specimens were from waters off the French Riviera (*8*). He puzzled out the molecular structure of the purple extract from these snails and found that it was identical with another molecule which had been prepared synthetically by German chemists.

But there was still a question: was the substance obtained by the ancient Phoenicians from mollusks at the eastern end of the Mediterranean really the same as that in mollusks from off the coast of France? This question excited the curiosity of a group of scientists at the American University of Beirut in Lebanon, among them F. and M. Bruin and F. W. Heineken. Recently students of this group excavated the ancient shell heaps left by the dyestuff manufacturers, then went

(Left) Ancient Roman coins of bronze, in the condition in which they were found during an excavation. (Right) The ancient Roman coins shown at left after restoration by electrolytic reduction. The figures and lettering on the coins are clearly defined.



One of the Dead Sea scrolls (No. 2), showing the corroded condition of the documents. The broken riveted joint runs across the top of the scroll.

A page from the *Summa Theologica*. [From *IBM Journal of Research and Development*, with permission]

out in the nearby Mediterranean with diving equipment and brought back living specimens of the same mollusk, which experts had thought was extinct.

F. and M. Bruin and Heineken, after studying the literature, repeated the experiments of Friedlaender and others and produced a tiny amount of the dye (*9*). They were able to prove, by electron-spin-resonance spectroscopy, that the molecular patterns of the German synthetic dye and of the eastern Mediterranean purple were identical. In place of the 12,000 snails Friedlaender had used in his analysis, Bruin and Heineken needed only two or three, so sensitive are our newer methods of chemical and physical analysis. The laboratory manuals given as references in the publication, last year, of the research on Tyrian purple were books by Aristoteles (*10*) and G. Plinius (*11*); few scientists today can find 2300 years of precedent on which to base their work!

Relief from the Tedius Chores of Scholarship

In the application of computer technology, many new developments are contributing to growth of the humanities and the arts. There may seem to be little, if any, connection between theology and the intricacies of the modern high-speed electronic computer. Yet the capabilities of the computer are beginning to contribute to this complex and subtle field of thought. The complete works of St. Thomas Aquinas include approximately 13 million words. Specialists in this field would, of course, find a complete concordance or index to the words in all his books of great value, whether for making a detailed study of the way this philosopher thought and wrote or for determining how his views may have been influenced by others of his time and before. To complete such a concordance by hand in the traditional way would require the work of 50 scholars over a period of some 40 years. The program now under way at a library in Italy, which involves putting all the words in the *Summa Theologica* of St. Thomas Aquinas on some 1.6 million punched cards for machine processing, can be completed with the expenditure of only one-fourth the time and effort required by the old method (*12*).

A similar program to study the words of the famous Dead Sea scrolls is under way. In this instance, a special card punch had to be devised to punch the cards from right to left, since this is the way the scrolls were written (*12*).

These examples point to an increasing unity and coherence of knowledge and knowledge-seeking. There is a continuum that extends from theories of the origin of the universe, through theories of the rise of life on earth and the later evolution and history of man, to the emergence of such abstruse fields as high-energy particle theory. With each new step in our progress the evidence grows that there is no knowledge or true understanding which is isolated from the total fabric.

New Technical Resources for the Arts

While increase in our basic knowledge is essential to our future development, almost as important for the growth of our culture in this age of exploding populations, massive organizations, and mass media are the direct effects of science and technology on communication and the arts. It is hardly too much to say that the growth of electronic communications has turned the world into one neighborhood or, at most, a few large neighborhoods, thus enormously extending and complicating every man's environment. This influence that works, in one direction, toward leveling and wiping out cultural differences, at the same time has the overall effect of greatly enriching the major world cultures in content and structure.

The technologies of the fine and applied arts are themselves undergoing significant revolutions. Drama is now, for the average man, the drama of the motion picture, radio, and television. The repertoire of music available to him through the same media and through the perfection of high-fidelity recording and reproduction equipment is of unbelievable richness and quality compared with what some of us may remember from the days of Walter Damrosch.

The change, however, is not simply a difference of medium and availability, for the arts themselves are affected by new techniques and processes. The composer working in the modern technological environment has resources far exceeding the traditional orchestral instrumentation of Western music (*13*). He can quite easily command any sound he chooses and transform it in a myriad ways to his purpose through electronic means. Working with a computer, he can explore the widest possible range of structures and patterns, experimental and traditional. He can try out his compositions, listening to them as he goes along.

The engineer and the architect find their technical resources similarly enhanced (*14*). In construction, for instance, where the structure and geometry are already defined, it is possible to let the computer establish the internal stresses that result from application of a set of external loads. A problem of this kind is involved in the intricate patterning of flush rivets in an aircraft wing. With each new stress analysis, the computer arrives at a new modification of rivet sizes and spacings, and it repeats this process until a "best design" is achieved. Thus the computer's repeated approximations replace an activity that before this was dependent on the designers intuition or his cut-and-try methods.

Such design work does not have to be a "give-the-machine-its-instructions-and-let-it-go" kind of activity. There may be a very much less constrained and more exciting situation than this—one in which the computer becomes a responsive instrument working with the designer in the progressive completion of his design. The designer sits in front of an oscilloscope screen with a set of buttons and controls within reach on either side. He sketches with a light-pen (a hand-held photocell) while the computer follows his motions over the screen and fills in a series of points on its own surface. Simultaneously the computer's program and controls revise and reshape the design in various ways, according to a choice of constraints the designer may wish to impose.

Structure and form alike are capable of controlled treatment by the use of "coincidence matrices," so that the computer is able to deal with a wide range of problems. These may vary from architectural treatments to the design of electrical networks and their shaping into finished items, such as another computer. While in many design processes the art may be advanced to such a point that the designers will design the designing system which in turn designs the actual objects, the most challenging activities in this field may continue to be those where man and computer work together as a system of augmented capability.

A Higher Level of Integration

The challenge of our new capabilities, with science and the arts and humanities merging their powers, is such that few would be brave enough to predict the nature of the culture and economy that may emerge within the next generation or two. At least a few conclusions are fairly obvious at this stage of events. Man has, by the use of his natural attributes—and especially by the searching of his restless intelligence—vastly increased the distance that separates him from the lesser forms of life. He has found ways to amplify his senses, including sight and hearing, and, with a variety of instruments and techniques, has added kinds of perception that were missing from his original endowment. With the development of computers he is extending the range and usefulness of his intelligence, freeing it for still greater challenges.

The texture and content of modern culture are being shaped by, and are responding in many diverse ways to, the influence of science and technology—ways that must inevitably alter the relationships between science and the arts and humanities. By multiplying the choices available to mankind and by creating choices where none existed before, science has opened up new realms for the assumption of responsibility. The cultivation of equable and cooperative relationships among those of us who follow science and those dedicated to the humanities and the arts can be of great significance in developing the values required for the wise ordering of our lives as we continue to assume the new responsibilities we have earned.

References and Notes

1. Among the philosophical works of the scientists mentioned are Niels Bohr's *Atomic Physics and Human Knowledge*, Heisenberg's *Physics and Philosophy*, Erwin Schrödinger's *What is Life?*, Max Planck's *A Scientific Autobiography*, Norbert Wiener's *The Human Use of Human Beings*, and James Conant's *Modern Science and Modern Man*.
2. R. E. Linington, *Quaderni Geofis. Appl.* **22**, 68 (1961).
3. M. J. Aitken, *Physics and Archaeology* (Interscience, New York, 1961).
4. L. S. B. Leakey, *Natl. Geographic* **118**, 420 (1960); **120**, 564 (1961); **123**, 132 (1963).
5. G. H. Curtis, *ibid.* **120**, 590 (1961).
6. E. V. Sayre, A. Murrenhoff, C. F. Weick, Brookhaven Natl. Lab. unpublished Rept. BNL 508 (T-122) (1958).
7. E. V. Sayre, unpublished work.
8. P. Friedlaender, *Monatsh. Chem.* **28**, 991 (1907); **30**, 247 (1909).
9. F. Bruin, F. W. Heineken, M. Bruin, *J. Org. Chem.* **28**, 562 (1963).
10. Aristoteles, *Historia Animalium*, book 4.
11. G. Plinius (Pliny the Elder), *Historiae Naturalis*, book 9, chapters 60–64.
12. P. Tasman, *IBM J. Res. Develop.* **1**, 239 (1957).
13. M. V. Matthews, *Science* **142**, 553 (1963).
14. B. Langefors, *Intern. Sci. Technol.* **26**, 90 (1964).