Michigan Philosophy News

for friends, alumni, and alumnae of the Department of Philosophy, The University of Michigan, Ann Arbor ***Fall, 1988***

Dear Friends of the Department:

This past year has been one of change in the Department. In the winter, compelling personal reasons led Allan Gibbard to resign as Chair. This was a big loss for us, as he had already begun to accomplish great things. In addition to devising a creative scheme to support senior faculty research which mirrors our "minisabbaticals" for junior faculty, he played an important role in a thorough review of the graduate program that is likely to issue in substantial reform this next fall. Those of you who know Allan will appreciate that through his example of intelligence, humanity, and mutual respect he has helped to make the Department a good place to be. We all look forward to his continued presence among us as colleague and friend.

We also suffered another loss this past year when Kit Fine decided to accept a position at UCLA. It is, of course, a sign of the strength of our faculty that they are so avidly pursued by other departments, but that does not make these losses any easier to bear. At the same time, we have been able to keep faculty in the face of enticing offers, including some this past year. And we expect to be making some distinguished appointments of our own in the near future. So although Kit Fine and Jaegwon Kim, who took up a position at Brown University this past year, will continue to be missed, we expect to gain strength in the year to come.

The good news is that we have two excellent recent additions to the faculty. Crispin Wright joins us this fall, and Elizabeth Anderson joined us this past year. Wright is a distinguished philosopher whose work in philosophy of language, philosophy of mathematics, and metaphysics has attracted international attention. He is quickly establishing a position among the first rank in the philosophical world, both by virtue of his scholarship on Frege and Wittgenstein, and as a leading defender of the anti-realist program in metaphysics. We are fortunate to have him. Anderson is a promising moral and political philosopher and philosopher of social science. Her thesis, which won a dissertation prize at Harvard, concerns fundamental questions about the nature of value, especially as these arise in economics and debates about social policy.

There is another piece of good news that you will want to know about, and that is that Bill Frankena came through triple bypass surgery with flying colors a couple of months ago and is well on the way to being his old self again. Those of us in moral philosophy can't wait for him to get back to the "ethics lunch". Our other emeriti, Dick Brandt and Art Burks, both continue to be active researchers and to contribute to philosophical discussion in the Department. Art published a book with his wife Alice this past spring on the making of the first computer: *The First Electronic Computer: The Atanasoff Story.* We are fortunate to be able to share with you some of his recent thinking on minds and machines later in this issue.

Your response to our second *Michigan Philosophy News* was extremely gratifying, as was your response to the appeal we sent later. The major use to which we put your gifts is to help buy books to keep the Tanner Philosophical Library up to date. Sometimes we get large gifts that enable us to do extraordinary things for the Library. Last year, for example, we were able to use funds from a recent endowment from Obert Tanner to buy a series of reprintings of the major works of Hume scholarship of the last two centuries, many of which have long been out of print. But it is a never ending struggle just to keep the Library's collection of journals and books reasonably current, as well as to fill in obvious holes. We are extremely indebted to you for your help here; the Tanner Library continues to be an invaluable resource for us.

As you may have read in last year's *MPN*, a substantial gift from Malcolm Denise funded the Denise Endowment for Philosophy, which helps to pay research expenses for junior faculty. This past year Dr. Denise made another generous contribution to the fund which will increase what we can do. This is an area in which we could hope to do much more. It would be very nice, to take an example, if we could supplement the relatively modest travel expenses the

College can provide so that junior faculty would be better able to attend professional meetings.

Last year saw as full a schedule as we have had in recent memory of visiting speakers and philosophical events. We had a Nelson Philosopher-in-Residence for a week in each semester. Brian Loar of USC was with us in the fall and Sydney Shoemaker of Cornell came in the winter. Both weeks focussed on the philosophy of mind. To give you an idea of what went on, the title of Loar's public lecture was "The Content You Find in Your Head," and Shoemaker's, "Qualities and Qualia: What's in the Mind?". Both weeks included two further seminars and lots of informal discussion, filling our heads with the philosophy of mind.

This year's Tanner Lecturer was Albert O. Hirschman of the Center for Advanced Study at Princeton. Hirschman is known for his unique perspective on economic and political phenomena, and on the history of their study, by virtue of his erudition in economics and the history of ideas, and his sharp eye for social detail. This year's Lecture, on the rhetoric of the "perverse effect" in reactionary social and political criticism in the modern period was vintage Hirschman, and was followed by a fascinating symposium on the Lecture featuring Stephen Holmes (University of Chicago), Charles Tilley (The New School), and John Diggins (University of California, Irvine).

The spring colloquium, on the topic of emotions and art, was also a philosophical feast. Patricia Greenspan (University of Maryland) presented a paper on emotion, on which Daniel Farrell (Ohio State) commented. Malcolm Budd (University College, London) read a paper on the aesthetics of music to which Annette Baier (University of Pittsburgh) responded. And Richard Wolheim (University of California, Berkeley) spoke on attributing emotions to nature, on which David Hills, a frequent visitor in our own department, provided commentary.

In addition to these major events we had a full schedule of visiting speakers throughout the rest of the year. These included Calvin Normore (University of Toronto), Barbara Herman (USC), Thomas Scanlon (Harvard), Robert Stalnaker (Cornell) and Richard Schacht (University of Illinois). Philosophy thrives on the stimulation of new ideas, so these talks by visiting philosophers, as well as our major events, are part of our life line. They begin lines of thought and conversations that continue to resonate in the Department, often months, sometimes years, afterwards.

Both our graduate and undergraduate programs saw substantial changes this past year. I will mention those in the graduate program below. At the undergraduate level, we did some fine tuning of what has turned out to be an extremely successful concentration. Since the last major restructuring of the concentration, which significantly enhanced, and more coherently ordered requirements, the concentration has grown by leaps and bounds, and has attracted many of the best students in the College. This year we strengthened the logic requirement, and we decided to require at least one 400 level course for concentrators. As you may remember, the 400 level has relatively small courses for both advanced undergraduates and graduate students. This change will insure one intensive philosophical experience for all concentrators and make likelier a critical mass of undergraduates in 400 level courses. Finally, we reformed the honors concentration to require an honors seminar to be taken before writing the honors thesis.

The Undergraduate Philosophy Club was very active again this year. In addition to meetings, and lunches with faculty members, the Club helped to sponsor a lecture by the only philosophy major among the candidates for the presidency this past year: Gary Hart.

As new Chair I have had occasion, as you might imagine, to survey the future of the Department, in the context of Michigan's distinguished past and of our present situation. We unquestionably face serious challenges, but I sense that we also have tremendous opportunities to strengthen the Department in many ways.

For example, the review of the graduate program I mentioned above gave rise to an imaginative and far-ranging proposal of reform that will lead to a more coherent program geared to ease students through the difficult transition from course work to dissertation. The proposal is complex, and will be debated in detail this fall before any action is taken, but the faculty has already voiced its approval of the basic principles, and we can all look forward to substantial improvements in the graduate program. For the hard work and imaginative thinking that went into the proposal we are much indebted to our student representatives, Eileen John and Chris Ahn, to Louis Loeb, William Taschek, and especially, for guiding the whole process with a masterful hand, Peter Railton. And, of course, we are indebted to Allan Gibbard for the initial impetus, as well as for his substantive contributions.

On a related matter, those of you who went through the graduate program in earlier years will appreciate the large amount of teaching our graduate students have traditionally been asked to do. We have been able to whittle away at this problem over the past years, and while none of us are fully satisfied with where we have gotten, it is clear we have improved things. Regents Fellowships, which a substantial number of our entering students now win, provide teaching relief in the first year, and reduced teaching in the second and third years. Through a complex arrangement of stipends to supplement teaching assistantships, we have also been able to make a small, but significant change in how much teaching a TA must do in order to survive economically. Also, first year teaching assistants are now really teaching apprentices and are not required to lead their own discussion sections. The future will, I think, provide us with new opportunities to improve the situation even more, as well as, I fear, new challenges to the present arrangements. But all in all, the trends are in the right direction.

Readers of *MPN* will know that the Department's life has been greatly enhanced in recent years by the use of funds from the bequest of James B. And Grace J. Nelson. These funds have enabled us to establish the Nelson Philosopher-in-Residence and Nelson Visiting Philosopher programs, as well as to underwrite our very full speakers program. Other large gifts, like the Denise Endowment for Philosophy and Obert Tanner's continuing stewardship of the Tanner Philosophical Library, have had a substantial impact also, as has the encouraging number of smaller gifts. Here again, the trends are all in the right direction, and we hope to be able to do much more in the future. For example, major new gifts could enable us to improve stipends and fellowships for our graduate students, thereby further reducing the heavy teaching burden we have to place upon them. One area where fellowship support is badly needed, but where the Department has been unable to make much of a contribution in the past, is during the summer months. As things now stand, many of our students are forced to disrupt their studies. If we can raise funds to provide even minimal support for graduate students, it will have a substantial impact on the graduate program.

Since coming to Michigan four years ago, I have been struck by the high quality of the undergraduate program, and of the students we are able to attract into the concentration and into philosophy courses generally. This is not a coincidence; we have done much to improve the concentration in the last several years, and we continue to think about how we can improve things even more. We have also been lucky, I think, to get particularly enthusiastic students. There is every reason to believe that the undergraduate program will continue to be a very bright spot for the Department.

I mentioned above that we will be making new faculty appointments in the coming years. I am very encouraged here by the commitment of the College to enable us to make distinguished senior appointments. As I am sure you appreciate, it is difficult to make appointments at this level, and we are very fortunate to have the College's support. In the end, however, our greatest resource is our present faculty. We have a very strong, but also a very young faculty, many of whom have just recently been coming into their own on the national scene. Moreover, we have what we all agree to be the finest junior faculty around, two of whom we were able to keep this past year despite quite attractive offers from other universities. When it comes to national stature, one has to feel that time is on our side.

Needless to say, I'm excited about the prospects for Michigan philosophy. But I can be only because I am so vividly aware of what readers of *MPN* have done to help make Michigan great in the past and how much promise all of our efforts hold for the future. I look forward to working with all of you in the coming years to fulfill the promise of this our joint venture.

Stephen L. Darwall

Chair

Robots and Minds

According to Lucretius, basic existence consists of atoms and the void, or space. Atoms are hard, too small to see. They move about in empty space but are otherwise unchangeable.

If all things are compounds of material atoms, so are persons and their minds. A *mind* is a *system* of atoms: small, smooth, fast-moving atoms--that explains why we think faster than our bodies can act.

Lucretius' theory of mind illustrates one of the concepts I will make much use of in this article: that of one system being *reduced* to another underlying, encompassing system; for Lucretius is claiming that the mental realm can be reduced to the material realm. Take whatever thought, feeling, or desire you are conscious of at this moment. Corresponding to it is some particular property, state, or motion of your smooth atoms, and whenever your smooth atoms behave just that way, you will have that particular thought, feeling, or desire.

You will immediately note a difficulty here. The statement "I am thinking of an ice cream cone" is not about the motions of smooth atoms in my body, but about an ice cream cone, so how can this claimed reduction work at all? Nor does it resolve this difficulty to use a more modern version of Lucretius' materialism and talk about electrical signals being transmitted through neurons, or hormones circulating through the body, instead of Lucretius' fast-moving smooth atoms moving through a structure of hooked atoms. The contents of introspective or phenomenological reports on mental activities are very different in kind from the contents of scientific reports on neural activities. That's the basic point.

We can't fully address this question until later, but we can reduce the paradox of it by analyzing a successful example of a reduction of one system to another. This example is the kinetic theory of gases of James Clerk Maxwell and Ludwig Boltzmann.

Let me apologize in advance for being a bit technical. But the idea of reducing one system to a more basic, underlying system is fundamental to metaphysics. The modern materialist says not only that mind is reducible to physiology, but physiology is reducible to evolutionary biology, biology to chemistry, chemistry to physics, and--he keeps going--physics to astronomy--ultimately we all came from the big bang. All sciences, the materialist says, can be arranged in this kind of hierarchical structure of many levels, each science dependent on the ones below it.

Ideas of reduction and hierarchical structure are also basic to computers. Even a simple computer has its architecture, a basic organization of memory, arithmetic unit, control, and input-output. Each of these is made up of, and can be reduced to, its building blocks. One can proceed in this way down through several levels of hardware to the basic logical atoms: the logical switches of AND, OR, and NOT, and the primitive memory cells. These in turn are realized by, or reduced to, various kinds of physical hardware--mechanical parts originally, then electromechanical relays, then vacuum tubes, and now the solid state equivalent of the vacuum tube, the transistor.

The kinetic theory of gases constitutes a model reduction. Consider a gas held in a container. The gas is a system with mass and temperature, exerting pressure on its container. The ideal gas law states that these three measurable quantities are related in a simple way: pressure x volume = constant x temperature. Thus a gas is a system with various properties (pressure, volume, temperature) related by a certain law, the gas law.

But the gas is *also* a bunch of particles, septillions of them, each with its weight, position, and velocity, and these particles are governed by *their* laws, the laws of mechanics, which tell how they move and bump against one another and the walls of the container.

The simplest analogy to this dual nature of the gas is a forest and its trees, the forest being made of trees as the gas is made of particles. As the old saying goes, sometimes we cannot see the forest for the trees. But in the kinetic theory of gases we look at both the forest and the trees, both the gas as a unitary system and the gas as a system of many particles, for reduction involves a relation between these two systems. Moreover, we must look also at the laws of each system, for though these are different, Maxwell and Boltzmann were able to reduce the law of the gas-system to the laws of the particle-system. That is, Maxwell and Boltzmann deduced the law "pressure x volume = constant x temperature" from the laws of mechanics governing the individual particles.

Let me now analogize this example of a reduction to Lucretius' claimed reduction of mind to body. A gas can be viewed as two distinct but intertwined systems: the gas as a whole with a few properties and a simple law, and the gas as a complex system of very many particles, each governed by the mechanical laws of motion and interaction. But these two systems are really two aspects of the same system, so from another point of view there is only one system, not two. Note that we can make a similar remark about mind and body: you have a mind and you have a body; these are *two* distinct systems, and yet you are *one* person.

With this gas paradigm as a guide we can see what a reduction of mind to body would look like, if, indeed, there is one. The properties of your mental and emotional experiences would somehow be defined in terms of the properties of your bodily structure and the operation of your neurons, hormones, etc. Then the laws governing your experiences would be derived from the laws governing your body.

If this analogy to the gas example is valid, we can immediately draw one conclusion about the relation of your mind to your body: namely, that the system called your mind is very much simpler than the system called your body. This conclusion seems plausible to me, chiefly on the ground that rational thought appeared late in the evolutionary process.

I'll now introduce a technical term: "embedding." The relation of reduction just explained for gases and Lucretius' account of mind will come up again, in connection with consciousness, so some technical terms will be useful. Referring to the gas example, let us call the gas as a whole an *embedded subsystem* of the gas as a system of many particles and the system of particles the *underlying system.* To reduce one system to another is to embed that system in the other. In my terminology, Lucretius claimed that the mind is an embedded subsystem of the body as an underlying system.

We have just noted that an embedded subsystem is a simplification of the underlying system, and indeed that is why we usually deal with embedded subsystems rather than their underlying systems. We can write down a complete description of the gas of the gas law, but we couldn't possibly write out a description of the gas of a trillion particles. If we could write out this last description, it would imply the description of the gas of the gas law. Thus in a technical sense the description of an embedded subsystem contains very much less information than a description of its underlying system, so that the relation of embedding is a part-whole relation of a rather abstract, logical, or informational kind.

In using any analogy one should attend to differences as well as similarities, and there are, of course, big differences between a gas and a person. The most obvious is the big difference in complexity--a person is a much more complicated system than a gas. We will consider a significant, related difference in a moment, but there is an important similarity between our gas example and the relation of mind to body that we need to discuss first.

You will recall our casting doubt on Lucretius' claimed reduction of mind to matter by observing that a statement about a thought is not a statement about the underlying system. The sentence "I am thinking about an ice cream cone" is not about smooth atoms in my body. So how can my mind be a collection of atoms, no matter how smooth and fast moving?

But the kinetic theory of gases shows that this is not a valid objection to the claimed reduction of mind to matter. For the properties of the gas as a whole (pressure, volume, temperature) are very different from the properties of its atomic constituents (mass, position, velocity), and yet are reducible to them. More generally, the properties of an embedded subsystem are very different form the properties of the underlying system in which it is embedded.

So the fact that the sentence "I am thinking about an ice cream cone" is not about smooth atoms in my body does not refute Lucretius' reduction of mind to matter, after all.

That said, let us proceed to the enormous differences between a gas and a person, differences which are all-important to us. Historically speaking, these differences are essentially those of the whole span of the evolutionary process, which can be traced back to a primeval explosion that led gradually over billions of years to the formation of atoms, molecules, big molecules, self-reproducing molecules, single-celled organisms, multicelled organisms, organisms with organs, and on down through biological evolution to man.

Aristotle defined man to be a rational animal, and as long as we don't forget the animal part of the definition that's a good definition. So the essential question about reducing mind to matter becomes the question of reducing rationality to the functioning of matter.

Now the laws of mind resemble logical rules and computer programs much more than they resemble the laws of the physical and biological sciences. Hence the first step toward reducing rationality to material functioning is to give a *computer* account of rationality.

When I say that logical rules and computer programs are useful for understanding mind, I mean to take an appropriately broad view of what logic is. As the philosopher Charles Peirce urged 100 years ago, logic should include a study of inquiry and rules for discovery and problem-solving; it should include inductive or probabilistic logic and learning theory; and, indeed, logic should be expanded to cover all symbol usage and information processing.

The modern computer has added another branch or topic to logic--that of logical structure or organization. At the lowest level the computer designer interconnects hardware atoms that perform the logical functions of switching and memory. From these logical atoms he compounds registers, adders, counters, multipliers, address switches, memory cells, etc., to get the next higher level. These registers, adders, etc., in turn are combined into a memory which can store data and instructions, a control which can interpret these instructions, and an arithmetic-logic unit which can execute them.

The logic of computer hardware is fundamental to the reductionist claims I will make. A brief historical account of logic and hardware may be helpful. About 100 years ago, one of Charles Peirce's students built a wooden logic machine, a machine that could evaluate arguments involving AND, OR, and NOT. In 1886 Peirce wrote to his student, suggesting that he make the machine out of electromagnetic telegraph relays. By connecting the contacts of two relays in series one would have logical AND, since current would flow through these contacts only if the first relay AND the second relay are *both* operated. Peirce's student worked out a circuit program for his logic machine and then dropped the matter.

In about 1940 an undergraduate at the University of Chicago, Walter Pitts, saw how to apply symbolic logic to neuron functioning, and a psychiatrist named Warren McCulloch helped him do it. The result was a better logical system, one that encompassed the storing of information as well as the switching and routing of information. In 1945 von Neumann adapted the McCulloch-Pitts logic to vacuum tubes, which have a somewhat different logic than do relays. Von Neumann then employed it to work out much of the logical design of the first stored-program computer.

Von Neumann's logic of switches and memory elements, with various improvements and modifications, gradually entered the mainstream of computer design and is now a standard subject. Engineers talk about AND-gates, OR-gates, NOT-gates, etc. As computers have become more complex, and consequently harder to design, much of the design of gate arrays or switching circuits for a new computer is now worked out by an old computer.

Archimedes is reported to have said: Give me a long enough lever and a fulcrum on which to pivot it, and I'll move the whole earth. The equivalent computer statement is: Give me enough switches and memory elements and I'll make a computer as powerful as you want.

To reduce mind to matter I would proceed by attempting to reduce mind to logical rules (in Peirce's broad sense) expressible as computer programs. If this can be done, we will have explained mind as computer or robot functioning. We already know how to build a computer out of hardware, and hence how to reduce computer functioning to physics.

I will approach the question "Can a robot have a mind?" by modifying Pythagoras' view that "all is number." The modifications are of two sorts. First, we must recognize with Plato that mathematics can express or describe only the form of nature, not its content. Mathematics is abstract, whereas nature is concrete, consisting of things and events existing in space and happening in time, and being governed by laws and rules of various kinds.

Second, we must extend the Greek view of the content of mathematics to get the modern view. The Pythagoreans viewed numbers as geometrical patterns. For example, nine is a square number. The main weakness of the Greek view was that it limited the application of mathematics to static situations and fixed structures. This is at least in part why Plato assigned more reality to the ideas and forms of mathematics than to the changing things of nature, what he called the flux.

Since Greek times mathematics has extended its content to deal with dynamic phenomena, with things of the flux. Paths of moving objects can be described by algebraic equations. Differential equations can be solved to derive these paths from information about velocities and starting positions. When these differential equations have no solution in terms of known algebraic and geometric forms, computers can be used to solve particular cases.

By his metaphysical principle "all is number" Pythagoras meant that each thing has *its* number. He applied that principle to each human--every person has his number. We are all familiar with the expression "I'll get your number," which implies that when you *get* a person's number you will understand that person and can control him or her. I've been told that this everyday expression "I'll get your number" has come down to us from the Pythagoreans.

Pythagoras had no way of finding a person's number--he concluded there must be one because of his metaphysics. Modern genetics and physiology and (I'll argue) computer analogies to man show in principle how to find a person's number, and what it would be like. Let me expand on this briefly, and, in view of limitations in space, over-simply.

Your Pythagorean number is a big integer, and hence a very long string of digits. Alphabetic and other symbols can be coded as digits, so any description or message can be coded as a string of digits.

The first section of your Pythagorean number will express your genetic program--your inheritance--your legacy from your parents, with some random mixing to determine what traits you get from each parent. This section of your number is unchanging through life.

The second section of your Pythagorean number will describe the rest of you: your body, beginning from the fertilized egg on down through old age, including your nervous system and all the information in your brain. This section of your number is constantly changing, though certain features of it are invariant, corresponding to your basic, unchanging characteristics. This part of your Pythagorean number results from the interaction of your inheritance with your environment and culture.

If your Pythagorean number is put into a form whereby small sections of it, that is, strings of digits, correspond to basic traits, your characteristics can be compared with those of your relatives, unrelated people, and various animals in the evolutionary scale. The hereditary part of your number will resemble closely that of your close relatives, not so closely the numbers of your distant relatives.

Thus your Pythagorean number, properly interpreted, tells a lot about you, as Pythagoras thought it would.

Similar remarks can be made concerning the environmental-cultural section of human numbers.

Now if there is such a Pythagorean number, such a precise specification of each of us, then in principle we could convert it into an equivalent digital computer or robot, equivalent in all respects except for the materials and what that difference necessarily entails. This is the claim I'll develop and argue for, with a possible qualification.

My thesis is: A FINITE AUTOMATON CAN PERFORM ALL NATURAL HUMAN FUNCTIONS.

A digital computer is a finite automaton. The core of a computer is its internal computing system, which stores and processes information, including its own instructions. A computer also has input-output equipment, which communicates between the internal computing system and the outside world, *its* environment.

To compare a computer with a human, we need to make its input-output equipment more like that of a human. Imagine television cameras for eyes, microphones for ears, and sensory devices for odors, tastes, temperatures, etc. As motor outputs, the machine has mechanical arms whose hands and fingers can manipulate objects, and it has wheels and motors for locomotion. The input devices are integral with the output: a television camera may have a servo-mechanism and feedback circuit which enables it to follow a moving object, and the fingers of an artificial hand can sense pressure and texture. Thus my thesis might better be stated as: For each of us, there is (in principle, at least) a robot which will perform the same natural functions. For convenience I'll call this the "man = robot thesis."

But what about the difference between hardware and soft flesh? There are certain human functions which depend upon the natural properties of body and flesh, and a machine can't perform those functions. How could a human interact with a machine in a loving way? It is true that Hoffman falls in love with Olympia, a mechanical robot, in Jacques Offenbach's opera *The Tales of Hoffman*. But that is only an opera.

The problem here is one of second-order effects. Consider the automatic sweetheart of elementary philosophy. She's an automaton that looks like and acts like an ideal girl. She's beautiful, she's intelligent, she's charming, and she's affectionate. Suppose a young man can ignore her hardware construction. He may still reason: She's an automaton, she's not human, she doesn't feel. Can she really love me?

This move converts an external or behavioral question into an internal question--the problem of what goes on inside a person's body. This issue is not part of my man = robot thesis for I'm not claiming at the moment that the robot will function internally like a person--though I will take up internal questions later.

The best way to handle the difference between the robot's hard flesh and the human's soft flesh is to provide adequate context for one's *gedanken* or thought experiment. Let us, then, imagine that on some distant planet there is a robot civilization, duplicating our civilization in all essential behavioral respects. These robots can produce progeny and evolve. Let us imagine further that this robot civilization has the same cultures that are found on earth. Perhaps this resulted from our actually establishing a self-reproducing robot colony in outer space.

Let's turn now to the evidences for the man = robot thesis, the claim that in principle there could be a robot society of the kind just described. One could devote a semester's course to the evidence, so I can hardly do more than classify the arguments.

I'll begin with an intuitive computer argument. Once you understand the stored-program computer and the nature of the computations it can make, you may develop the intuition that all human functions can be programmed.

Whatever can be done with a program can also be done by equivalent hardware, and whatever can be done by hardware can be done with a program, provided there is a minimum of hardware to execute programs. Let me begin with hardware.

I have recounted the history of the application of the logic of AND, OR, NOT, etc., to relays and vacuum tubes. With these one can make a logical piano--the keyboard operates the logical switch, which in turn operates some output-sound generators, or perhaps a bank of lights. Each pattern of input--pushing certain keys down--will cause a definite pattern of output, a definite light pattern. Now the essence of switching theory is this: for any specification which states for each possible keyboard pattern the light pattern it produces, there is a logical piano that will perform in that manner.

Note that this logical piano is perfect and deterministic, because each particular input keyboard pattern always causes the same unique output light pattern. Two important objections have been raised to the claim that man operates on the basis of such perfect, deterministic switching circuitry. The first is the perfection objection--man is error prone, a logical piano makes no mistakes. The second is the free-will objection: man is free, a logical piano is deterministic, and free-will is incompatible with determinism.

Both are good objections. The answer to the first is to use a probabilistic switch, one which does make errors. This is not hard to do in practice, since actual switching devices all make errors. The free-will question is an ancient one, and much more difficult. However, I regard it as more a question of social psychology and moral philosophy than a question of individual psychology. I will not discuss it here.

The main weakness of a logical piano is that it has no memory. But there are computer memory elements, so let's make a memory and incorporate it into the piano. In this logical piano with memory, each time the player strikes a chord the resultant output light pattern depends not only on the keyboard pattern but also on the past history of playing. This logical piano with memory is called a finite automaton. By changing the input and output devices in various ways, we can convert it into a hand-held calculator, a big digital computer, or a robot.

There is an apparent gap between human minds, on the one hand, and automata constructed of switches and memory elements, on the other hand. Looking at automata as I have defined them, some people have noted that they have certain characteristics which seem to be different in kind from the characteristics of human thought. Computer switches and memory elements are precisely logical, analytic, authentic, and operate in a simple all-or-none fashion. But human thought is holistic, indefinite, confused, and intuitive in nature. Hence, it has been argued, the operations of the human mind could not even in principle be carried out by a finite automaton.

I accept both premises of this argument, as I must, since I'm using intuition to defend my man = robot thesis. To see that the conclusion does not follow we need to recall what I have said about reductions. The properties of an embedded sub-system, such as an ideal gas, are very different from, though reducible to, the properties of the underlying system, properties of the individual particles constituting the gas. Gas pressure and temperature are very different from particle mass and velocity, yet reducible to them. Similarly, your thought of an ice cream cone is very different form the correlated electrical signals in your brain.

These comments only refute an argument--they do not establish a positive case. But our procedure for establishing a positive case is clear: to introduce the level of programming between the level of hardware and the level of holistic, indefinite, confused, intuitive thought. This is the basis of my intuitive argument for the man = robot thesis. Once you understand the power of a computer program and reflect on the nature of thought processes from Peirce's broad logical viewpoint, you may come to feel intuitively that all human functions can be programmed.

My second class of arguments for the man = robot thesis consists of direct attempts to write programs or develop hardware that will perform intelligent functions. Perhaps motivated by the intuition I have just described--the intuition of the power of the program--people have devoted much effort to writing programs to perform human functions that require considerable intelligence: pattern recognition, language translation, logic proofs, and game playing. These efforts generally go under the name of artificial intelligence. There have been many successes and many failure; much has been learned from both.

A machine recognizes printed or written letters by noting the essential features of a letter--where it branches, bends, etc. There are good optical scanners than can read type, but nothing that can read my handwriting. I don't want to downgrade the difficulty of pattern recognition--as my typist and my students know very well, it takes considerable intelligence to read poor handwriting. But clearly a robot that could perform all human functions could read all human handwriting, including mine.

The United States government spent millions of dollars on mechanical translation, emphasizing translation from Russian to English for intelligence agencies. Considerable research was done on grammar and the resolution of ambiguity by context. But the translations produced were never more than--as they said--95 percent successful. A common joke concerned an expression translated into another language and back again, both translations being done by machine programs. The idiom "out of sight, out of mind," was put into a machine, translated into another language, and retranslated, coming back as "absence causes insanity!"

One hears no more of mechanical translation. Something was learned from the effort--that our present knowledge of language is not deep enough to reduce language to precise rules. But ordinary language philosophers could have told the government that for less than a million dollars.

There has been more success with game playing. Arthur Samuel, not an expert player, wrote a program for checker playing, embedded a learning algorithm in it, and had it learn by playing copies of itself. Though Samuels' program began as a poor player, it gradually improved its play in this manner until it became a good player. Chess is much more complicated than checkers, and there has been correspondingly less progress. Nevertheless, after 40 years of concentrated effort, chess programs are now up to the master level. These programs certainly perform intelligent human functions.

Will such a chess program ever be world champion, or will this approach eventually end up like present approaches to pattern recognition and mechanical translation--plateauing at 95 percent perfection? More importantly, will we acquire deep knowledge about human intelligence from writing chess programs? The problem here is similar to that in computer simulation: how to make interesting generalizations from special cases.

The artificial intelligence approach is essentially to replace psychology and physiology by engineering. I think this approach can carry us only so far, and that we need to look at fundamentals, natural intelligence, and how the human performs his functions. Machines and humans differ considerably in their basic computational mechanisms, and so one should expect significant differences in how they can best execute the same task. But 40 years of the direct approach of writing programs does establish the same conclusion that evolutionary theory teaches, namely, that human intelligence is very complex, and that we would do well to study how nature learned to do it.

This brings me to the third class of arguments for the man = robot thesis: results from biological science. The marvel here is the development of molecular genetics in the last 35 years, explaining the replication of DNA, decoding genetic programs, and more recently, applications to genetic engineering. All these successes are so much before the public that there is no need to review them here.

I'll make one general point supportive of the man = robot thesis. These advances in molecular biology have always revealed mechanisms that can be translated into computer terms, as computer simulations and as, in principle at least, computer hardware.

This is even true of self-reproduction. James Watson and Francis Crick showed how DNA could copy itself about 35 years ago. At the same time, and independently, von Neumann showed how to design a self-reproducing robot.

Let me make a radical shift in my approach. Up to now I've been approaching man from the outside: how he behaves. The claim that a robot can perform all human functions is an external one, the claim that there could be robots in a community of robots behaving like each of us.

This claim allows the robots to operate inwardly very differently from us, though I did suggest that the internal mechanisms of a well-designed robot would be somewhat similar to our internal mechanisms. But looking inside a robot as an engineer does, or inside a human as a physiologist or molecular biologist does, is also to take the external point of view, looking naturalistically at how the elementary computing elements of the system operate and how they are organized.

Philosophy has also developed a radically different point of view for studying man, the internal, self-reflective, introspective, phenomenological point of view. This approach began with Socrates' dictum "Know thyself" and the concept of the soul. It became central to philosophy after Descartes began what is called modern philosophy with his reflection "I think, therefore I am." The approach from inside the mind out has continued on down through phenomenalism, Kant, personal idealism, phenomenology, and existentialism.

Using the external point of view, we can see that when evolution reaches the level of complexity of minds using language, gaining knowledge of both mathematics and nature, and reflecting on their own experiences and thoughts, the internal point of view comes into existence.

Thinkers taking the internal point of view have typically held that mind is not reducible to matter, and have pointed to various mental capabilities they think are not reducible. These are: first, intentional goal-directedness or explicit goal-seeking; and second, consciousness, including self-consciousness. I'll take the second of these capabilities and consider the extent to which a robot might in principle be built and programmed to have it. Space does not permit discussion of the first.

Before explaining my theory of consciousness I need to distinguish two aspects of consciousness, which I will call "functional consciousness" and "immediate experience."

Consider an instance of pain. Suppose one's toe is injured. This is on the physiological side. On the experiential side, one feels a sharp pain in the toe, sees that the toe is bleeding, and puts a bandage on it. It seems to me that this experience of pain has two aspects: the felt pain as such, an immediate feeling of pain; and the experienced functional connection from pain as stimulus to the immediate experience of repair action as response.

My next example is taken from Karel Capek's 1921 play *R.U.R.* (*Rossum's Universal Robots*). The heroine Helena Glory was upset by the fact that the robots had no self-interest. A robot did only what it was told. It had no desire to accomplish anything, or even to continue operating. Thus a robot didn't care when it was told that it was to be dissected and then put in the stamping mill so the materials of which it was composed could be reused. Horrified by this, Helena persuaded the chief psychologist Dr. Gall to change a "physiological correlate" so the robots would have goals and would look after their own welfare. As an ultimate consequence they revolted. Goal-seeking and the will to live, are functional. Whether the modified robots had the immediate feelings which accompany the exercise of these functions in humans is a question Capek does not address.

I will now sketch a theory of functional consciousness, in two stages. The nature of immediate experience is an important problem too, but I only have space for a few remarks about it at the end.

Stage I: Designing a robot to perform the functions associated with pain, sense experience, and the will-to-live. The functional aspect of conscious pain may be illustrated by the experience of lepers. Leprosy damages the nerves which carry signals from the periphery to the central nervous system. A leper may injure his toe, and because he feels no pain is not aware of it. Consequently, he does nothing to repair and protect it, and it ultimately deteriorates and falls off.

It has been known for a long time, both practically and theoretically, how to make computers that detect and correct their own errors and malfunctions. A robot could have circuits which detected the state of its appendages and sent reports to the central processor, some central control unit responsible for reliability, or to various regional units with this function. The responsible unit would decide on a method of correction and supervise its implementation: switching-in an alternative circuit, transferring the job to another appendage, or even manually replacing the damaged part.

The functional aspect of sense experience lies in the organism's ability to use the information thus gathered from the environment and to respond appropriately to it. To be successful this ability must relate sense reports to one another and to thoughts and possible actions in various ways, and the sense reports must be of the proper generality to make these interrelations useful. This is the problem of pattern recognition which will, I think, be solved some day.

The will-to-live was lacking in Rossum's universal robots as they were originally manufactured, but was present after Dr. Gall changed a "physiological correlate." What did he do? Presumably he gave the robots desires by designing them so they would pursue various goals, including self-preservation. To deal with the problem of conflicting goals, Dr. Gall might have assigned weights or relative priorities to the different goals and organized the robot so that the amount of effort it devoted to a goal was influenced by the weight assigned to that goal.

The foregoing shows in a general way how to construct a robot that would perform the internal functions associated with pain, color experiences, and desires. This general design procedure could be applied to other types of conscious experience as well. On that basis I advance the following general claim: A ROBOT COULD BE BUILT WHICH COULD PERFORM THE FUNCTIONAL ASPECT OF EVERY SPECIFIC TYPE OF CONSCIOUS HUMAN EXPERIENCE.

Stage II: Designing a robot with conscious unity. It does not follow, of course, that this universal robot would be conscious. Our robotic depictions of pain, color experiences, and desires, contained nothing of consciousness in them. The universal robot would only have more of the same, and hence would be no nearer to being conscious. Moreover, a collection of specific functions would not have the unity of consciousness. Clearly, something essential has been left out. There must be some feature of consciousness or some particular way in which a human carries out its conscious functions that has so far been omitted from our robot account. We need to investigate what it is.

To fully comprehend a concept one must understand its relations to associated concepts and to incompatible concepts as well. Our words "conscious," "aware," "awake," "consciousness" are closely associated, while all are to be contrasted with "asleep," "unconscious," "comatose," and "the unconscious." A person may be awake (conscious), asleep, unconscious, or comatose. Consciousness is functioning in the first case but not in the case of sleep, or being unconscious, which differ in the difficulty with which consciousness may be restored.

We are now closer to understanding why a robot which can perform all the specific functions of human conscious experience and is, for good measure, intentional as well, might not be conscious. It might not have a single conscious subsystem carrying out all of these functions, a system which can be turned on (awake) and off (asleep). Our descriptions of the robot described no such subsystem, and did not employ the distinction between waking and sleeping.

We need therefore to analyze the higher order functional role played by consciousness. Why do humans perform certain functions consciously, and hence only when they are awake? Is this the best way for robots to perform these functions? More generally, why are animals conscious, why are they sometimes awake and sometimes asleep, and should robots be designed similarly?

Before proceeding to this final task one basic fact about the size or complexity of consciousness needs to be established. Consciousness is only a small "part" of the person, in the following sense. Consider the whole person, body and mind, as a system, and compare its complexity with that of the subsystem of consciousness. One cannot give a precise description of a present state of consciousness or the conscious rules governing its transitions. But it seems intuitively clear that an approximate description of these would be very much shorter than a correspondingly approximate description of the whole person. This intuition is confirmed by psychological measurements of the capacity of short-term memory, that is, the amount of information that is in consciousness at one time. Short-term memory can hold about ten items, while long-term memory can store many thousands. Assuming a parallelism between mental and bodily activity, the neural subsystem involved in consciousness is small compared to the whole body.

Now I turn to the question of whether the robots in that far-off robot civilization postulated earlier are conscious.

A survey of the examples of functional consciousness analyzed earlier shows that they have a common property. All are ways in which the organism controls itself and what it does, and does so in "real time," that is, in time with the tempo of changes in the environment and the actions of other organisms. Functional pain and color experiences involve short-term control, while intentionality is a computational procedure for long-term control. This observation, combined with earlier comments, suggests our theory of human consciousness. CONSCIOUSNESS IS A REAL-TIME CONTROL SYSTEM OF RELATIVELY SMALL INFORMATION PROCESSING CAPACITY, THAT EXERTS SHORT-TERM CONTROL OF THE PERSON AND IS CAPABLE OF LONG-TERM, INTENTIONAL CONTROL.

Consciousness developed in earlier animals. Charles Peirce enunciated a continuity principle about evolution. This is the principle that evolution is gradual. By this principle, there is no sharp line dividing the preconscious from the conscious. Let us focus on the early mammals. Our theory explains the value of consciousness to them. Consciousness is a simple system for real-time control of their immediate interactions with the environment. But why should it be turned on for only part of the day-night cycle and turned off for the rest? Why does the state of being awake alternate with sleep?

Given the large differences between day and night, organs adapted to one would generally be different from organs adapted to the other. For example, an eye good mainly in daylight would be different from an eye good mainly at night, and one good in both environments would be more complex than either. Hence at some stage evolution would produce organisms that performed differently during the day and the night, in particular, that were active during one of these periods and inactive during the other. For example, a mammal might feed, procreate, etc., during the day and do little at night. (Compare hibernation.)

The explanation of sleep I like best is that it reduces a mammal's vulnerability to predators during the inactive period. During this period the mammal would naturally hide to reduce its danger, perhaps in a hole, and predators would be searching for it. When a predator came near the mammal's best strategy might be to remain immobile and not respond at all. Sleep accomplishes this. As Carl Sagan expresses it: "Animals who are too stupid to be quiet on their own initiative are, during periods of high risk, immobilized by the implacable arm of sleep." (*The Dragons of Eden*, p. 131)

We have said that an intelligent robot could be conscious. But would that be an efficient design, and if so, should the robot's consciousness be very much like human consciousness or quite different? These are organizational design questions, the answers to which depend very much on the nature of the technology used and the design process. And these are very different in the cases of the robot and the human.

Human consciousness was constructed by a gradual evolutionary design process, beginning with primitive forms of consciousness, and if it could be redesigned *ab initio* there might very well be a much better design. Equally important, the sizes and speeds of hardware components are very different from those of biological components. Since human consciousness is a real-time control system of small capacity, these hardware-fleshware differences are relevant to how much information a robot consciousness should process (how large its short-term or cache memory should be) and how a robot consciousness should relate to the rest of the robot. Perhaps a good robot design would make its short-term memory very large and would devote much more computation to long-range planning than a human does. Note that these issues belong to the general subject of computer control, computer organization, and system management.

I have sketched a theory of human consciousness: its nature, its origin, and its function. The theory is computer based, consciousness being approached in terms of the organization of the human mind and body. Viewed from the perspective of computer architecture, human consciousness is a particular kind of computer control system, a relatively simple real-time control which, when the system is awake, directs short-term activities and plans longer-term activities.

As Plato said in the *Phaedo* : "When the soul and the body are together, nature orders the one to be subject and to be ruled, and the other to rule and be master."

We argued earlier that a robot could be built to perform the functional aspect of every specific type of conscious human activity, and raised the question of whether a robot might not be constructed so as to have a single conscious system that carries out all human conscious functions. The preceding analysis makes this plausible. I believe that someday it will be practical to build a robot capable of performing all natural human functions and to organize the control system of that robot in such a manner that the robot will be conscious.

Earlier, I postulated a robot colony in far-off space that duplicates our civilization in all essential respects. Imagine that for each of you there is a double in that robot colony who behaves just like you. It is your Doppelganger, as in German folklore, except that it is not a ghostly double, but a real robot double.

By the result just established, each of these robots could be conscious in the functional sense of consciousness. Furthermore, I think that the most efficient design of a robot to perform your functions will make your robot conscious. So, imagine that your double *is* conscious.

Since your double can perform *all* your functions it can use language. Hence it can become self-conscious and take the internal point of view, reflecting on its own experiences. When it does this it will notice that it operates by means of conditional rules: if this pain, then that response; if this sensation, then that action. Thus your robot double will come to realize that it is functionally conscious.

The next question is: Does your robot double also have immediate experiences? There must be some entities or events that are connected by the robot's functional conditionals, some qualitative items playing the role of sensations, feelings of pain, and experiences of actions. These entities cannot be hardware events, for a robot is no more aware of its hardware constituents than you are of your neurons.

To me the most plausible answer is that your robot double, if it existed, would have immediate experiences. By hypothesis, the robot would be functioning like you, so the only significant difference would concern the materials--hardware versus flesh--and I don't think that is a relevant difference.

You now have my theory of consciousness. For me, at least, it explains many things. However, it does leave a problem, which is best stated in terms of my earlier analysis of reductions.

Recall the idea of one system being reduced to or embedded in another, underlying system. The example was that of an ideal gas being embedded in a gas of a trillion particles. The embedding or reduction involved two steps:

(1) The properties of the gas as a whole (pressure, temperature) were defined in terms of the properties of the individual gas particles (mass, velocity).

(2) The law of the ideal gas (pressure x volume = temperature x constant) was then derived from the laws of motion of the individual gas particles.

My theory of consciousness is that consciousness is an embedded subsystem of the person or equivalent robot, a control subsystem governing the person or robot during its waking hours. In this case the derivation of the laws of the embedded subsystem from the laws of the underlying system works well: The human functions of the robot are programmed, and we know how to reduce programs or software to hardware---build a computer to execute that software. But how are the properties of immediate experience to be reduced to the properties of physical events?

Let me conclude with an imaginary conversation between your robot double and my robot double in that far off robot colony. Your robot asks mine: "I understand your theory of consciousness very well as far as it goes, but how do you reduce the properties of immediate experiences (felt pains, color appearances, etc.) to physical properties?"

My robot would say "I don't know the answer to that question."

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Arthur W. Burks holds a B.A. in Mathematics from DePauw University, and an M.A. and Ph.D. in Philosophy from the University of Michigan. Professor Burks served as Instructor and Research Engineer at the Moore School of Electrical Engineering, the University of Pennsylvania, from 1941 to 1946. During the last half of this period, he worked on the design of the first general-purpose electronic computer, the ENIAC. During portions of 1946 through 1948, Professor Burks served as Consultant at the Institute for Advanced Study, Princeton, New Jersey, where he worked with John von Neumann in developing the design of the Institute's computer. After serving part-time as Instructor of Philosophy at Swarthmore College, Professor Burks joined the faculty of the Department of Philosophy at Michigan in 1946. Beginning in 1967, he was concurrently Professor of Computer and Communication Sciences, serving as the first Chairman of that Department from 1967 to 1971. He has been Professor Emeritus of Philosophy, and of Electrical Engineering and Computer Science, since 1986. Professor Burks was a member of the University of Michigan Society of Fellows from 1975 through 1979, and Chair of the Society from 1975 through 1978. At Michigan, he received the Distinguished Faculty Achievement Award, and was appointed as both the Russel Lecturer, and the LSA Distinguished Senior Faculty Lecturer. In addition to his pioneering research in computer science, Professor Burks has made notable contributions on causation, induction, probability, and dispositions. His *Chance, Cause, Reason--An Inquiry into the Nature of Scientific Evidence* (Chicago, 1977) is a systematic exposition of his views in the philosophy of science. He has also written extensively on the philosophy of Peirce. Professor Burks is a former Guggenheim Fellow, American Council of Learned Societies Fellow, and National Endowment for the Humanities Fellow. He has served as President of the Charles S. Peirce Society, the American Philosophical Association, Western Division, and the Philosophy of Science Association.

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