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BY-LAWS
of the
American Society for Cybernetics
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0. Cybernetics
Cybernetics seeks to develop general theories of communication within complex systems. Its scientific content has been elaborated by many scholars, notably:
- Work on complex networks of communication has suggested the notation of organization as the prime focus of cybernetics (Warren S. McCulloch, Heinz von Foerster);
- Studies of circular flows of information, mutual causality, and the dynamics they imply have associated cybernetics with theories of control that are entirely neutral and predictive in orientation (Norbert Wiener, Magoroh Maruyama);
- Research on decision making and on information transmission together with advances in recursive theories of computation have led cybernetics to describe living organisms as adaptively changing information processors (John von Neumann);
- Philosophical analyses have identified cybernetics as the science of models, including those of self-reference (W. Ross Ashby, Anthony Wilden);
- Generalizations from ecology which sees man in interaction with his environment of physical, social, and informational contingencies have relativised the notion of mind (Gregory Bateson) and as a self-governing being (Karl W. Deutsch).

The abstract and often formal mathematical nature of its aim (W. Ross Ashby), makes cybernetics applicable to any empirical domain in which processes of communication and their numerous correlates occur. Applications of cybernetics are wide spread, notably in the computer and information sciences, in the natural and social sciences, in politics, education and management.
Beyond its scientific and transdisciplinary orientation, cybernetics has profound philosophical and religious implications.

1. Name
The name of this organization shall be the “American Society for Cybernetics,” herein referred to as the “Society.”

2. Purposes
The Society encourages:
(a) The advancement of cybernetics as a science;
(b) The development of cybernetic research methods and techniques that improve the manageability of complex systems;
(c) The systematic accretion, evaluation and exchange of cybernetic knowledge and its application across disciplinary, national and ethnic boundaries;
(d) The application of cybernetics towards improving the informational condition of man and the social use of communication and information processing technology;
(e) The practice of self-government.
3. Organs

The Society shall achieve its purpose through the following organs:

- the Membership

4. Membership

Every individual, group or institution who subscribes to the purposes of this Society, demonstrates professional and scientific conduct, and pays his membership dues may become a member. Membership must be approved or may be cancelled by the Membership Committee. A member whose membership is being reviewed shall have the right of audience.

Members are categorized in three ways:

- Regarding the nature of their participation in the Society, members are either Affiliate, Regular members, or Fellows. Only Regular members and Fellows enjoy voting privileges. With the category of Fellow, the Society recognizes individual members for their achievements and contributions to cybernetics. Fellows are appointed by the Nominating Committee of the Society.

- Regarding the services provided by the Society, members are either Institutional, Group, or Individual members. With an Institutional membership, an organization may become an Affiliate member to obtain certain specified services as a whole. With a Group membership an organization may become an Affiliate member to obtain certain specified services for their individual members.

- Regarding rate and frequency of contributions, members may pay their dues either annually or as a single contribution to the Society. Single contributions entitle institutions to become Long-Term members or individuals to become Life-Time members. Single contributions may be waived by concurrent decisions of the Nominating Committee, the Finance Committee and the Executive Board of the Society in order to recognize outstanding personalities in the field of cybernetics as Honorary members. Dues for Full members are reduced for Students but only for a period not exceeding four years and Emeritus members after at least ten years of Full membership in the Society and upon reaching sixty years of age.

Dues are proposed by the Finance Committee and set by the Executive Board.

Basic control of the Society resides with its voting members. This is manifested through the election of the officers of the Society, through the approval or disapproval of proposed amendments to these by-laws, and through the exercise of the right to petition as stipulated herein. Voting is done principally through mail ballot.

There shall be Business Meetings as often as needed, at least once every three years at each convention or upon a petition signed by fifteen percent or more of the voting members. The Executive Board shall determine the time and location and inform all members of such meetings. The President of the Society shall preside. The business to be transacted at such meetings shall include announcements of...
election results, a report on the activities of the Society, and a statement on the financial position of the Society. The Business Meeting shall also serve as a platform for reaching consensus on the formulation of policies and on the execution of plans which are normally the domain of the President and the Executive Board. The minutes of such a meeting shall be made available to the Trustees, the Ombudsman and members of the Executive Board within one week after such meeting and to all voting members within six months after such meeting.

5. Trustees

Between three and twelve individuals who are recognized for their ability to support and lend guidance to the Society shall constitute the Trustees of the Society. Trustees are elected for six year terms by the members of the Society but need not be members thereof.

The Trustees shall elect their chairman and formulate their rules of procedure, quorum and voting requirements.

Trustees shall advise the President and the Executive Board in the implementation of policy and have the right to veto decisions by the President and by the Executive Board no later than two weeks after receipt of notification of such decisions. The Executive Board may call on the members to override such a veto by simple majority vote. Such a vote shall be by secret mail ballot. Trustees may participate in meetings of the Executive Board and its committees, and in the Business Meetings of the Society.

In the case of a serious conflict among the officers or members of the Society, the Trustees may convene a special panel as a fact finding or arbitration board if they are requested to do so by one party to the conflict.

6. Executive Board and President

The Executive Board shall consist of the President as chairman, the President-Elect (when he exists), the immediate Past President, the Elected Vice-President, the Secretary, the Treasurer and may include other Vice Presidents with special responsibilities (e.g. publication) or to assure regional representation. All members of the Executive Board shall be elected from the voting members of the Society for three year terms. Change of office shall be staggered with the President-Elect to be chosen one year before the current President’s term of office expires. At presidential elections, the Elected Vice President shall be one of the candidates for the President’s office, the highest vote shall determine the President-Elect and the next highest vote shall determine the Elected Vice President. The President-Elect succeeds the President when the President’s term of office expires.

The President shall be responsible for implementing and enforcing the policies formulated by the Executive Board, shall preside as chairman at Executive Board meetings and at Business Meetings of the Membership, and represent the Society before the public.

The Executive Board shall formulate the policies of the Society and assist the President in implementing and enforcing these policies. In its deliberations, the Executive Board must rely on the Committees of the Society and may request guidance from the First Ombudsman and from the Trustees. The Executive Board shall hold regular meetings at least once each year and distribute its minutes to the Trustees and the Ombudsman within one week after such meetings.

The Executive Board shall arrange for the election of officers, the voting on proposed revisions of or additions to these By-laws, and the polling of members on particular issues to determine consensus or to override a veto by the trustees.
7. Ombudsmen

The office of the Ombudsman shall consist of two individuals who are recognized for their ability to evaluate decisions made by the Society's organs and relate them to membership interests and to the purposes of the Society. Both individuals shall be elected for three year terms by and from the members of the Society, with the First Ombudsman receiving the largest and the Second Ombudsman the next to largest number of votes. The Ombudsmen shall have free access to the meetings of the Executive Board, the meetings of the Committees and the files of the Society. They shall communicate and provide feedback to the Trustees and the Membership by any means and at any occasion deemed appropriate and shall report to the Membership whenever desired. They shall be present at all Business Meetings.

In the case of a conflict among officers or members of the Society, either ombudsman may serve as an arbiter if requested to do so by a party to the conflict.

8. Committees

Standing Committees are appointed by the Executive Board to develop proposals and prepare suggestions for decisions to be made by such Board or by the Membership. Standing committees shall include the Nominating Committee, the Membership Committee, and the Finance Committee.

Ad Hoc Committees may be established from time to time in response to emergent problems.

The Nominating Committee shall be appointed within thirty days after a new President takes office. Its task is to evaluate proposals for recognizing regular members as Fellows or others as Honorary members and to elicit nominations to all offices that will become vacant. The Nominating Committee shall nominate at least two candidates for each office except that candidates who are nominated by a signed petition of 15 or more members and all those nominated for the Ombudsman's office must be included on the ballot.

The Membership Committee shall review the membership status of the Society and decide on applications for and on cancelations of memberships.

The Finance Committee shall supervise the Treasurer, propose the budget for the Society including the dues structure and consider proposals for appointment of Honorary members by the Nominating Committee.

9. Elections and Voting

No individual shall occupy the same office for more than two consecutive terms.

Elections shall be held at regular intervals, and by secret mail ballot. Valid ballots must be received no later than 45 days after mailing the blank ballots to all voting members of the Society.

Voting on issues shall be arranged as needed, either at a Business Meeting of the Membership or through secret mail ballot. Valid ballots must be received no later than 45 days after mailing the blank ballots to all voting members of the Society.

10. Conflict Resolution

There are two formal conflict resolution bodies. Given a conflict among the officers or members of the Society, any party to the conflict may request the services of either of the two. The bodies are:

- Either of the ombudsmen may serve as an arbiter.
- A specially convened panel of trustees may serve as a fact finding board or as arbiters.

The process for using the ombudsmen is:

- Any party to the conflict requests an ombudsman's service as an arbiter.
- The ombudsman decides if he can properly accept the case.
- The ombudsman investigates the case, seeks a resolution, and if necessary prepares a report.

The process for using a panel of Trustees is the same as for using the ombudsmen, except the request for assistance goes to the Trustees. Only large scale or very serious conflicts would be taken to the Trustees.

11. By-Laws

Amendments or revisions of these by-laws may be initiated in one of two ways: (a) the Executive Board or one of its Committees may formulate proposals for amendment or revisions of these by-laws and submit them with any argument it chooses to the voting members for action; (b) the Trustees or twenty-five voting members of the Society may submit to the Executive Board proposals for amendment or revision of these by-laws. The Executive Board then shall submit these proposals together with all arguments advanced by their sponsors and its own recommendation to the voting members for action.

These by-laws, including amendments, revisions or other changes require an affirmative vote of at least two-thirds of the secret ballots received no later than 45 days after mailing the proposal and the blank ballot to all voting members of the Association.
Working groups of the April 1980 ASC Planning Conference.

From left: Barry Clemson, William Moore, Barbara Williams, Heinz Von Foerster.

From left: Robert Kaunitz, Unknown, Bill Reckmeyer, Carl Hammer, Stephen Weiner, Dave Ryan.

From left: Howard Hilton, Stephen Weiner, Mary Whittaker, Carl Hammer, Mark Ozer, Heinz Von Foerster.
The April 1980 Planning Conference of the American Society for Cybernetics

Stuart A. Umpleby
George Washington University
Washington, D.C.

After several years of little activity, the American Society for Cybernetics held a planning conference April 18-20, 1980 to decide the future of the Society. The meeting was held in the Marvin Center of The George Washington University in Washington, D.C. The Institute of Cultural Affairs, a private non-profit organization, acted as consultant to the Society in conducting this meeting. The conference employed a group process called LENS, Leadership Effectiveness and New Strategies. The conference was divided into five segments.

1. An “operating vision” consisting of goals for the Society was formulated.

2. The “obstacles” or blocks that are preventing the achievement of the goals were identified.

3. Broad “programs” or strategies to remove the blocks to achieving the vision were identified.

4. Tactics provided more detail on the programs.

5. Finally, “implementaries” which are even more detailed were drawn up. They state who is to do what, when, where and at what cost.

To develop these plans, the group divided into four teams, brainstormed for a while and then came back together to report results and to see how much overlap there was in the ideas generated. The participants received instructions for the next round and divided into teams again. The process was repeated for each of the five steps.

The purpose of this method is to insure that everyone has the opportunity to express his or her views. All suggestions are recorded. An indication of the most important ideas is provided both by seeing whether an idea is generated in more than one team and by grouping the suggestions into topic areas. Redundancy is eliminated, and added attention is given to novel ideas. Having an outside group in charge of the planning process eliminates bias and favoritism. Because the outside group is unfamiliar with whatever conflicts exist in the organization, all suggestions are dealt with fairly. Our goal was not to vote on proposals—an exercise that produces winners and losers—but rather to arrive at a group judgment on the direction in which the Society should move. LENS, and similar methods, can be thought of as an alternative to Robert’s Rules of Order as a way of holding a meeting.

The following pages present the results of the planning conference. The tables were prepared during the conference. The narrative is based on the tables. This report should not be interpreted as the last word on the future activities of the American Society for Cybernetics. Rather the conference and this report represent a beginning, a direction, and a preliminary strategy for achieving the goals stated. In one form or another, this planning activity will be repeated at regular intervals.
The Story

Preface:

Every organization has a guiding myth or story which it refers to when a major decision is required. For example, some organizations see themselves as high technology innovators creating new products. Other organizations pride themselves on being mass production specialists who modify the ideas of others and make them available to a large number of people. Usually the story is about the founders of the organization and the purposes they had in mind. The story below was written hurriedly at the end of the planning conference, but it captures some important ideas. The story, of course, will be told differently on different occasions. But it will be told frequently, both to new members and on occasions when important decisions are being made. If the story changes fundamentally, ASC will become a different kind of organization.

In the beginning was Macy, and Macy was a group of miners who with joy, inspired insight, and excitement visualized a treasure on the other side of a mountain. They began to dig and immediately discovered the field of computer technology and the power of digital logic. Still, there was the treasure on the other side of the mountain. The experiences with computer technology and the use of digital operations were so rich they caused many of the miners to lose sight of the rewards that were originally seen.

The Macy miners, in their work, tunneled almost through the mountain but did not break forth into the bright light of cybernetic and humanistic comprehension and operational function. In the words of the prophet McCulloch, "It was awful—no one could understand anyone else—people were insulted, cried and sometimes left, never to return." But the union Macy persisted and many stars were born and sent into the heavens, and these stars were called Mead, Bateson, McCulloch, Wiener, Von Neumann, Ashby, Von Foerster.

Many and varied dimensions of society and science basked in the light of these stars and built various edifices under these lights. Macy united in the form of a professional society, and in the union was much excitement and much joy. That union included large amounts of chaos, combat and confusion. As time went by interaction became diffuse. Both the joy and the combat diminished. There was only chaos and the small edifices built in various places across the cognitive and social universe.

In 1980, we embraced the chaos of many different cybernetics and committed ourselves to recapture the combat and the joy. The work evolves and where it goes not even Macy can tell. Shall it be down into chaos, darkness and extinction? Shall it be toward totalitarianism and mindless conformity? Shall it be into fuller humanity and freedom? Today the processes of interaction and human evolution are stunted, perverse and frequently anti-human. Cyberneticians, if they recapture the joy and the combat of full interaction will enhance the trend toward more desirable, more truly human ends. The bright light at the end of the tunnel—the cybernetic comprehension—reveals that the journey of man can be directed if men so choose. To facilitate this process is our role and our destiny if we so choose.

The Operating Vision

The operating vision, summarized in Table 1, presents the goals that participants expressed for the Society. The table is organized around a central concern—public understanding of how cybernetics can be used. The two principal subconcerns were applied cybernetics and public education. The conference felt that cybernetics could be applied in administrative systems, in developing appropriate information technology, in establishing policies for materials and energy use, and in operating the Society itself. Public understanding of cybernetics can be enhanced by increasing the number of educational programs in cybernetics, by producing a review of the state of the art, and by calling attention to successful applications of cybernetics. The group identified two supporting endeavors—cognitive responsibilities and societal responsibilities.

The first supporting endeavor—cognitive responsibilities—was broken down into fundamental research, knowledge access, and cybernetic society networks. It was thought that fundamental research would be most fruitful in the areas of epistemology, taxonomy, and intuitive cybernetics. Knowledge access referred to communications facilities, professional publications, information retrieval services and periodic conventions. The work of the ASC was thought of in terms of building networks—contacts with other societies in both North America and overseas, regional networks for an area including several states, and local networks on a campus or in a city.

Societal responsibilities were divided into power, social integrity, and cybernetic models. Political power referred to promoting an understanding of cybernetics among decision-makers. Financial power meant the ability to obtain support for research and curriculum development. Grass roots power meant a general public understanding of cybernetics concepts. Social integrity was the heading chosen for several related goals—emphasizing the humanitarian potential of cybernetics, reexamining the ethical aspects of conducting science, and improving the quality of articles in the field by increasing the use of review processes. More extensive use of models was also a goal expressed by the group. In particular it was thought that effort should be concentrated on modeling the brain, visual pattern recognition, and social processes.
### Table 1—The Operating Vision

<table>
<thead>
<tr>
<th>Cognitive Responsibilities</th>
<th>Public Understanding of Cybernetic Use</th>
<th>Social Responsibilities</th>
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<td>Fundamental Research</td>
<td>Applied Cybernetics</td>
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<td>Cybernetic Society Networks</td>
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<td>Intuitive Cybernetics</td>
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<td>Professional Publications</td>
<td>ASC Application</td>
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<td>Periodic Conventions</td>
<td>Local Networks</td>
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<td>Regional Networks</td>
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<tr>
<td>International Network</td>
<td>Recognize Achievements</td>
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<tr>
<td>Communications Facility</td>
<td>ASC Application</td>
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</table>

### The Obstacles

Before the goals of the ASC can be realized, it is necessary to identify and deal with the obstacles that are preventing the Society from achieving its goals. Table 2 lists the obstacles that were identified, with the most frequently mentioned appearing on the left. The largest category identified had to do with "immaturity in fundamentals and synthesis." People both inside and outside the field are unfamiliar with the fundamentals of cybernetics. It was suggested that the field suffers from imprecise vocabulary, cloudy epistemology, lack of methods for problem solving, overly simple current models, the inability to apply the standard methods of verification to cybernetics, confusion regarding the relationship between energy and information, and the lack of a mathematical foundation to produce synthesis.

The second group of obstacles was labeled "educational traditionalism." In this category were items such as insufficient educational materials, unfamiliar modeling methods, lack of information on the use of cybernetics concepts by others, disciplinary boundaries within universities, lack of an agreed upon curriculum in cybernetics, and insufficient drive or creativity in starting cybernetics courses and programs.

The third category, "undisseminated information about principles and successes" referred to the poor image of the field, the perception of cyberneticians as power grabbers, the feeling on the part of many people that cybernetics is not significant, a widespread fear of or reluctance to use technology, an existing mind set that is very different from cybernetics, the assumed complexity and hence inaccessibility of cybernetics, the reluctance of people to innovate, and the threatening nature of new ideas and new patterns of organization.

The fourth category was labeled "the Pandora's box syndrome" and reflected concerns that many people, including cyberneticians, have that cybernetics can be misused. Cybernetics can be applied for controlling a large bureaucracy, as is done in the Soviet Union. Social models are often self-fulfilling prophecies. Some cyberneticians seem to be interested in increasing power for themselves. Consequently there is some hesitancy to encourage applications of cybernetics.

The fifth category dealt with "private vs. public interests." There are proprietary problems; international communication is restricted by powerful institutions; and there is little support for modeling political processes.

The sixth category pointed at the lack of a steersman for the discipline. Goals for cybernetics are unclear. An interdisciplinary field lacks a common context. The state of the art changes rapidly. Educational needs go unrecognized. There is impatience with consensus making, and different uses of words lead to language barriers.

The seventh category called attention to poor ap-
### Table 2—The Obstacles

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<th>Undisseminated Information About Principles &amp; Successes</th>
<th>Pandora's Box Syndrome</th>
<th>Private vs. Public Interest Conflict</th>
<th>No. Steersmen</th>
<th>Poor Application Methodology</th>
<th>No Critical Mass</th>
<th>Technological Insufficiencies</th>
<th>Opposing Inclinations</th>
<th>Relevance Not Seen</th>
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<td>Self-interest</td>
<td>No Common Controversy</td>
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<td>Theoretical vs. Application Dominance</td>
<td>No Sense of Urgency</td>
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<td>No Method for Problem Solving</td>
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<td>Fuzzy Social Boundaries</td>
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<td>No Mathematical Foundation for Synthesis</td>
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<td>No Holistic Modeling of Consciousness</td>
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Application methodology. Model validation is difficult. The cost of data collection is high. There is a lack of support for modeling efforts. Cost benefit analyses only consider a set of alternatives; they do not emphasize attempts to redefine the problem.

The eighth category suggested a lack of critical mass. On most campuses there is a low density of cyberneticians, leading to too few personal contacts. There is a lack of infrastructure, and communication is difficult. Potential members are not being identified.

Technological insufficiencies were the ninth group of obstacles. Progress is limited by information overload, the high cost of technology, inappropriate technology, and underemployment of people at the grassroots.

The tenth obstacle is "opposing inclinations." Whereas some people feel that in cybernetics theory has dominated application, others maintain that some cyberneticians do not understand the theoretical questions that have stimulated the development of the field. There is an imbalance in society and science favoring empiricism over theory and both over ethics. Care should be exercised in how the issue of power is dealt with.

The eleventh category noted that the relevance of cybernetics is not widely recognized. There is a lack of a sense of urgency in developing cybernetics, and there is inertia in social institutions toward adopting new methods.
Strategic Programs

The strategic programs developed at the conference were divided into three major activities. (See Table 3.) At the center was building ASC. In order to do this, it will be necessary to cultivate the environment and cultivate the science.

Building ASC will require organizing ASC internal affairs, presumably by using cybernetics principles. A stronger organization implies an enlarged membership, improved communications, and long range planning. A unique feature of cybernetics, which should help in creating interest in the organization, would be a statement on ethics and effective methods for conducting the Society's business.

Cultivating the environment will require good communication with the public—seminars and training programs, publications directed at several different audiences, and applications relevant to social needs. Successful applications should be publicized, concepts need to be popularized, and self-reliance among cyberneticians should be encouraged. Development of cybernetics will be enhanced if there are appropriate incentives for professional development—funding for research and education and recognition for accomplishments.

Cultivating the science will require using cybernetics in the teaching of cybernetics and using appropriate educational technology. Tutorials for people in the field will help to articulate the epistemology, philosophy and methodology of cybernetics. Education in the fundamentals of the field can be promoted by codifying the basics, particularly Ashby's conceptions.

The Tactical System

Table 4 presents the tactics needed to carry out the strategic programs. It is organized somewhat like concentric circles. Credible professional standards are at the core with the subsequent rings being substantive development, public visibility and growing organization, public recognition and support, and practical societal impact. Credible professional standards will be achieved through high quality publications and conferences and through high ethical standards. The development of the field will be accomplished by assembling a looseleaf cybernetics manual, publishing seminal works, writing texts, developing courses, educational programs, cybernetics centers, and educational extension. Visibility and growth will be achieved by interacting with other societies, holding summer meetings in Maine and elsewhere, developing information for the public and launching a membership drive. To achieve public recognition and support we shall undertake projects to serve as examples, scout out potential research support, increase our activity in reviewing the research proposals of others, and establish an ASC awards program. Practical social impact will result from short term task forces, a list of projects to be undertaken, a model of ASC, and a model of the environment.
Implementaries and Accomplishments

The implementaries, which are quite detailed and short range, have been modified and updated several times since the April meeting. Consequently it is probably more important here to report what has been done. A number of important things have already been accomplished. Roger Conant has found a publisher for an ASC book series and is working on a collection of articles and class notes by Ross Ashby tentatively titled Mechanisms of Intelligence. Heinz Von Foerster is publishing a collection of his articles under the title Observing Systems. A newsletter for timely information is now being edited by Roger Conant. Al Kreger is taking steps to insure that the Society is on a sound financial footing. Phyllis Carr is planning a large membership drive. Vadim Drozin has found editors for several special issues of Cybernetics Forum. Mary Whittaker has set up an administrative system which will give ASC members low cost access to Murray Turoff's Electronic Information Exchange System. Frank Leonard and Allen Reid have distributed a questionnaire which will permit us to match up people with similar interests, inform us of what services our members want, and enable us to make better use of the members themselves as a resource. Doreen Steg and Jean Weir are arranging an awards program for the Society. With support from his university, Stuart Umpleby reported on the activities of the American Society for Cybernetics at the International Cybernetics Association meeting in Namur, Belgium, in September. Paul Henshaw has joined forces with Michael Pearson, Stuart Umpleby and others working on a glossary for the field. Howard Hilton is representing ASC in formulating plans with Jack Rose for the large meeting on cybernetics and systems research to be held in Mexico City in August 1981. Larry Richards is arranging a conference for the Society for November, 1981, in Washington, D.C.

Table 4—The Tactical System

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Conclusion and Comment

As these accomplishments indicate, the April planning meeting succeeded in generating a great deal of enthusiasm for the Society’s programs. I believe that the LENS method or similar methods for holding a meeting constitute a decision technology in much the same sense that computer simulation is a decision technology. I believe these methods should be considered part of cybernetics and be taught in universities just as computer simulation is taught. From this point of view, the April 1980 Planning Conference can be regarded as a successful example of the use of cybernetics to operate the American Society for Cybernetics.

Participants

The following ASC members participated in the planning conference: Bruce Abele, Arle Ariely, Larry Bidinian, Phyllis Carr, Barry Clemson, Roger Conant, Don Driscoll, Vadim Drozin, Leila Engman, William Gevarter, Fred Glessler, Carl Hammer, Laurence Hellprin, Paul Henshaw, Gertrude Herrmann, Howard Hilton, Dan Howland, Akira Ishikawa, Robert Kaufitz, Alienna Leonard, Frank Leonard, William Moore, Mark Ozer, William Paris, Rammohan Ragade, Bill Rockmeyer, Allen Reid, David Ryan, Doreen Steg, Leo Steg, Ellen Stolarik, Stuart Umpleby, Heinz Von Foerster, Stephen Weiner, and Mary Whittaker. The conference was ably conducted by the following members of the Institute of Cultural Affairs: Tim Crane, Wayne Elsworth, Diane Galbreath, Clarence Mann, Mike Vosler, and Barbara Williams. Correspondence and physical arrangements prior to and during the conference were handled by several George Washington University students: Bill Donnelly, Robert Kemmerer, and Sarah Vogel. Gretchen Larrabee typed and made copies of the charts during the conference.
Part I

1. Commitments to the Tenets of Science
As a practitioner in the fields of science, I respect first and foremost the orderliness of nature and the reproducibility of research results. I see science as a search for knowledge, and I see it as a kind of fraternity with implicit trust in the consistency of nature. Anything less than complete objectivity and impeccable honesty, I see as degrading the integrity of science and as acting to destroy and abolish it. Those who are less than completely objective and less than totally honest in dealing with the processes of nature, I see as automatically disqualified as scientists.

2. Commitments to the Human Position
Similarly, as a practitioner in the fields of science, I respect as paramount the dignity and worth of individual human beings. I regard the human mind—the means by which we think—as evolution's finest product and man's most precious possession. I hold that science with all its capacities to aid in comprehension and accomplishment, to have a place in human society, must contribute to the well being of the individual person and of humanity.

I see curiosity, the desire to know and understand, as one of man's strongest attributes; at the same time, I see feeling and emotion—the ability to know in a more profound way—as still more significant. I recognize information as the substance of intellect and the basis of experience and behavior in living things. I see the human mind as a processor of information and as directed by intellect comprised of sensory input and internally generated information.

I identify with the view that independent development of the human spirit and mind is an inviolable privilege. With all the force at my command, I shall oppose deceit, deception, subversion, mental debasement and character assassination. Instead, as a step in the process of becoming more human, and of making human beings still more eminent in nature's ongoing scheme, I shall as a practitioner in the fields of science, encourage the development of verifiable information in every possible way. I regard the development of knowledge as a kind of human transcendence.

3. Attributes and Qualifications as a Scientist
As a scientist, I search for truth, whatever its nature. I utilize intuition as well as evaluative techniques and I do this in social, economic and cultural fields, as well as the physical. Inasmuch as human advancement appears to rest directly on development of comprehension and understanding, I consider secrecy about the facts of nature to be undesirable, inappropriate and intolerable. As a scientist, I do not ask about good or evil—only the validity of impressions and findings; and I do not make judgments about the appropriateness of applying research results.

4. Attributes and Qualifications as a Scientist-Citizen
As a scientist, I am also a citizen; and, as such, I have obligations beyond those of being a scientist.

*The Scientist's Manifesto emerged from an Honors Student Colloquium on Science and Ethics at the University of Arizona during the spring semester 1980. The Colloquium brought forth a feeling on the part of students that the good name of science had been sullied in recent decades by the attitudes and conduct of people working in the fields of science. Using the Hippocratic Oath for Medicine as a guide, an effort was made to prepare a manifesto that makes sense to conscientious young people anticipating scientific work. Views were collected by a single person and assembled to make one document. Editing by all then resulted in the material set forth below. There was general concurrence on the tenets of science and on ethical standards, but some minor differences remain on specific points and certain inherent implications.

Thoughts at the onset were that the statement would terminate at the end of Part I, Section 5 on Guidelines. Soon it was realized, however, that a code alone did not address questions that were causing some of the greatest concern to young people. Accordingly, Part II, Sections 6 and 7 were appended to provide what appeared to be the best answers to representative questions.

Some of the questions dealt with fundamental societal matters usually not discussed. Feeling was, however, that any person true to the tenets of science—i.e., objectivity and the search for truth—cannot evade them and must take a stand if he is to discharge obligations both to science and society.

The working group was as follows: Students: Glen Broemer, Philosophy; Brian Condit, Evolution; Roy Hakes, Music; Dana Honeycutt, Physical Chemistry; Jill Legg, Biology; Tanya Maslak. Nuclear Engineering; Mark Turner, Health; Emil Stein, Medicine, and William Weigle, Space. Colloquium Leader: Paul S. Henshaw, Biophysics.
alone. In a sense, I wear two hats: a scientist's hat and a scientist-citizen's hat. As a scientist, I am committed to objectivity without regard to good or evil, but this in no way countermands my obligations as a citizen in making judgments about the development and use of information, including information resulting from scientific research.

As a scientist, I may have skills, data and analytical techniques that may make me valuable as a resource person, and because of my commitments to truth and reason, my views about facts and data may be regarded as more trustworthy, but these characteristics do not make my judgments more acceptable or in any way superior with respect to human needs and the general human interest.

As a scientist-citizen, I accept the obligation to help insure that research results are utilized for human happiness and not against it. In particular, I accept the obligation to resist the inept, inane and insane application of such results—as in the cases of untested use of DDT, mass mind control, mental subversion and generalized decimation of human life with nuclear or other kinds of weapons. In many ways, I regard my scientist-citizen's hat as more important than my scientist's hat. By the nature of things, I am a citizen first and a scientist second even though my scientific side may stand out.

5. Guidelines

Confronted thus with the seemingly inexorable emergence of research information, with the dual nature of my position as scientist and citizen, and with an accepted imperative to resist diabolical uses of research information, I shall be guided by the following principles and thoughts:

a. As a scientist, I shall seek—with objectivity—the truth about natural processes, evaluating all evidence, negative as well as positive, and I will endeavor to account for discrepancies between my findings and those of others before permitting my results to be brought to bear on public problems. Continuously, I shall struggle for better explanations and theories, and as stronger evidence becomes available, I shall adapt my thoughts and views.

b. As a scientist, I shall be rigid and unrelenting about objectivity and I shall make no judgments about the advisability or inadvisability of applying research information.

c. On the other hand, as a scientist-citizen, I will—with a sense of strong obligation—develop ideas, along with other citizens, about the application of research results. Moreover, as a scientist-citizen, I will, with a further sense of obligation, utilize any special knowledge and skills that I may have. Not only will I weigh advantages and risks, I will take into account common sense, human rights and a feeling about the nobility of man.

d. When evidence for and against a proposition appears essentially equal, I shall propose calculated risks, and be prepared to make further recommendations as more information becomes available.

e. When I see our scientific community becoming so dependent on support for research that it can no longer stand the reasons for its lust for knowledge, I shall oppose such support. Furthermore, when I see this community becoming so dependent on support that its efforts to stay alive must be devoted to even more diabolical decimation of human life, I will say that the time has come for the scientific fraternity to make a complete change in direction of movement.

Part II

6. Position on Central Questions:

Having committed myself to the search for truth and to respect for human worth, I am, as a practitioner of science, confronted with the necessity of decisions on important matters:

a. Shall I interfere with nature?—with human life, particularly human heredity? As human beings have become increasingly aware of the fragility of natural systems, especially those of the body, the environment and the biosphere, the question has arisen whether natural systems should be regarded as sacrosanct and thus untouchable by man. By his mere existence, man affects nature, but until recently not in a threatening and overpowering way. Now, with knowledge of genetic potential, with such remarkable ability to save and destroy life (and property), and with capacity to consume resources at an ever increasing rate, natural life support systems are being affected profoundly—even to the point of extinction in many instances. The question is not one of whether to affect natural processes, but rather how much and in what ways. I commit myself to considered action. My efforts will be to perform a stewardship with respect to the things of nature—to evade wanton and reckless disruptive measures and to encourage action considered reasonable according to tested conservation criteria.

b. Who shall decide? On matters like abortion, artificial insemination, cloning, euthanasia, secrecy, mind control, selection of research subjects, etc., who has final authority and on what grounds? These are questions for citizens and scientists-citizens, not scientists, although science and scientists are involved. They are questions on which, for the most part, public policy has not been determined. Without laws and without specific and concrete rules, I shall be guided by the following:
1. In cases where individual human rights are under consideration, I shall insist that decisions should be made by persons directly concerned (the mother in case of abortion; members of the family in case of euthanasia, sterilization, spare body parts, and resort to sperm banks; the investigator in case of selecting research subjects, etc.). In these kinds of cases, I shall oppose interference by governments, churches or other organized groups.

2. In situations involving public concern, as well as individual concern, as in cases like the application of DDT to crops, environmental radiation, water use and stream pollution, my behavior will be in accord with laws, when such exist, and with democratic processes; I shall be concerned with accuracy of information, public education and informed action. I will be guided by knowledge of comparative risks and merits. When there is lack of confidence in government, I shall struggle for improvement and enforcement of the laws. In situations where I become convinced that due process is shot through with corruption, inefficiency and ignorance to the point of complete ineffectiveness, I shall exercise my right as a human being to protest and rebel. On moral matters, I will be influenced strongly by the tenets of science. Commitments to truth, honesty and accuracy make a strong base of departure. I shall also be influenced by the concepts of democracy—the greatest good for the greatest number. My judgments in large measure will be determined by my own sense of right and wrong coupled with my underlying impressions of reality and fairness.

c. Shall I participate in human experimentation?—in research that will affect the welfare of other human beings? As with regard to interference with nature, there are both good and evil aspects. Some experimentation with human subjects can be uplifting and beneficial, whereas other types can be painful, degrading and destructive. Since hard and fast rules appear impossible, I shall be guided by generalized concepts of human rights, and what I would expect my own feelings and wishes to be if I were in the position of the person (or persons) on whom I would propose to do tests. Altruistic motives on the part of subjects I would regard as having a proper place and deserve consideration. I see volunteers as being able to provide aid and benefits to others. Under no circumstance, however, will I knowingly act to degrade or destroy another's body, mind, spirit or will.

d. How do I deal with my own foibles—desire to have (greed), and desire to lead and influence (aggrandizement, power)? People in every walk of life, including science, have tendencies toward greed, lust and deception—and indeed toward self-deception. The problem is one of making strength superior to weakness. In science there are some advantages. Evidence is that science as a discipline is more relentless and unyielding than any other approach to human function. Science, because of what it is, because of its commitments to truth and objectivity is in no way permissive of dishonesty and deception. Those who would fudge on results or slant evidence for personal gains are in time revealed as charlatans by the research process and disqualified as scientists. More particularly, a breach with the tenets of science automatically condemns a practitioner of science both in his own eyes and the eyes of others. By dealing straight with nature, practitioners are better able to deal with their own temptations and weaknesses.

7. Position with Respect to Underlying Problems (i.e., as impelled by rational approaches):

a. Population. World population is approximately 4 billion and doubling every 30-40 years. As so very clear to the scientific mind, compounding growth cannot continue for long, and the central question is whether slowing will be by peaceful means or by starvation and decimation. I shall struggle for peaceful and humanistic means. It will not be my purpose to struggle for the maximum number of souls on earth, but rather an optimum number of people—a number for which there are prospects for a reasonable standard of living.

b. Free Enterprise. Competition and profit motives comprise powerful incentives for exploitation and growth, and in pioneer situations where resources have been essentially unlimited, the greed and aggrandisement approach can, by certain criteria, be said to have been successful. Even simple scientific analyses make it clear nevertheless that some other type of operation will be required if anything more than subsistence is to be achieved. Common sharing in the form of socialism and communism also have been only partially successful at best. Clearly, something quite different for developing and distributing wealth will be required in the future. Continuously, I shall struggle for a new and better economic design.

c. Governance. Authoritarianism is unacceptable because of its disregard of human rights. In the present period of increasing limits, technical capability and complexity, democracy, as practiced, is proving slow and inefficient. Because of waste, ineffectiveness, impersonalization, and lack of humanity, citizens are loosing confi-
d. Warfare. Force as an instrument of public policy is primitive—animalistic. Destructive power has become obliterative. Pyrrhic victories serve no useful ends. I shall struggle to make the use of force unnecessary as a method for settling factional disputes among people.

e. Armaments. Weaponry based on multiples of overkill affords little security, and an economy maintained on the basis of armaments is wantonly wasteful and grossly inconsistent with requirements for human survival. Because of these facts, I shall struggle to make the use of force unnecessary by fostering the one species-one world concept. By this means, security will not be neglected but the need for armaments will be caused to diminish and disappear.

f. Nationalism. Clearly we are one species on one planet, the resources of which are limited. Garnering segments of the earth and maintaining them under the rituals of sovereignty when our numbers have become so vast, our way of life so very complex and our destructive power so very great, is without sense or reason. Our behavior is unbeciting of a species of intellect. It is representative of reptilian or mid-brain mentality. I shall struggle for an integrated and intelligent world order that makes nationalism and the resort to war and armaments unnecessary.

g. Education. Education involves development of the mind including the development of emotional potential, objectivity, value judgments and wisdom, and thus the most superior aspect of man. Education involves the creation and dissemination of information. It has been said that power resides where information is. I regard learning as one of the more fundamental aspects of man, and teaching and research as among the most respected and most honored professions.

h. Religion. The approach of science is different from that of religion. Science holds with natural law, whereas religion holds with "divine" law as perceived by man. The laws of nature appear rigid and unyielding, whereas religious laws can change and are changed. Religion has been a strong influence on human behavior, but less impelling than science. Religion has been strong among primitive peoples. With education, science has become stronger, and at present exerts a commanding influence. Religion also exerts a commanding influence, but in quite a different way, venturing into the unknown on the basis of faith alone.

8. Compulsions of Science

With commitment to truth and objectivity, and with acceptance of the idea that nature is consistent—as appear required by the way nature operates—the positions stated in (6) and (7) above, seem impelled by what science is.

Nationalism, militarism, armaments, overkill, international power politics, exponential growth, profit motivation, etc., by rational scientific criteria are revealed as primitive—indeed, as characterized more by greed and lust than desire for human advancement; they are revealed more as animalistic than humanistic—more as mid-brain than cortical.

Human intellect is seen as a fragile, and human beings as morally adolescent. Evidence reveals that most human beings are corruptable by temptation, torture or blackmail. Animalistic mid-brain behavior is reactive and reflexive more than considered and reasoned, and it has an overabundance of ritual, patriotism, dogma, unfounded beliefs, greed and lust, much of which is in conflict with humanism and the objectivity of science. Science because of what it is will not respond to the irrational.

9. The Human Role

I see the advancement of human intellect as movement toward the achievement of larger goals, including greater comprehension, understanding and creative influence in the universe. Potential for such advancement, it is clear, came into existence as the elements of matter accumulated to form stars and planets. Final objectives and goals are not evident to me, but my participation in the process of creation affords particular personal satisfaction.
Information Dynamics

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Summary

Information dynamics deals with information, as such—information as meaning and message, not bits. It deals with hierarchical organization in systems where information processing can occur. Because of expanding knowledge of macromolecular, neural, and data processing functions, the significance of information as an entity comes more plainly into view. When considered as a force, information is more fully understood, appreciated, and recognized as a determinant in nature's ongoing scheme.

Part I. Axioms and Principles

Terms

Axioms, as used here, refers to phenomenologies that are comprehended more on the basis of observation, logic, and hypothesis than on actual proof. Principle, in contrast, refers to provable percepts.

Information, at the outset, is defined as organized facts and data; intelligence as facts and data that are organized; intellect as the power of knowing; psyche as mental capacities; mentation as thought or as information processing; mind as the means by which we think, including memory and mentative capacities; and personality (soul) as the essence of what an individual is, including knowledge, values and beliefs.

Self-organizing systems are energy-information input-processor-output units, living or non-living, that are adaptive, purposive and discretionary. They are systems in which the full scope of regulative and conceptual information processing can occur, and in which the results are brought to bear by means of controlled energy application.

On the basis of a priori considerations, the following can be said axiomatically of information as meaning and message:

1. Information seeks consistency—in entropy terms, high points of low energy. Information-seeking-consistency occurs in systems where free interplay of information can take place—systems that have capacities for memory, assimilation, integration, and selective energy distribution, including switching, channeling, and gating.

2. Information interacting with information is generative. Assimilation, as occurs in a cell, a brain, a macromolecule or a computer, creates new information—information that never existed before (answers, conclusions, concepts). The information process (mentation), by its nature, is creative—builds to new levels of comprehension and understanding.

3. Consonance tranquilizes, satisfies, relaxes. Accepting that information seeks consistency, it follows that consonance is a goal of information processing. It realizes—produces satisfaction and composure. By challenge, it also stimulates.

4. Dissonance irritates, motivates, activates. It triggers action—opposes tranquility. It can lead toward consonance, or toward greater dissonance, involving antagonisms, aggression, chaos and destruction. Direction, in some degree, can be detected and controlled.

5. Curiosity—the desire to know—is inherent in assimilation. Because information seeks consistency, mentation involves a continuous search for new information, which, as acquired, is sorted, tested for credibility, and applied or rejected.

6. The human mind, with its desire to know and its ability to integrate information, is inventive. It will create—even fabricate—images, explanations and concepts, and these may be based on imagination as well as on facts and principles.

7. Mentation—information processing as done in particular by higher forms, including man—carries with it potential for emotion (feeling), the same as for awareness, comprehension, imagination, and inventiveness; it involves an affective consciousness state with experiences of joy, sorrow, fear, hate, and the like; these also motivate, and sometimes with seemingly little relation to reason or reality.

8. Custom, habituation and ritual act to fix attitudes as mental constructs which also motivate, and by continued imprinting can become sound ideas or dogmas that have only casual relation to reality. But faith irrespective of reality, can in itself be a strong motivational influence.
9. Natural selection and survival-of-the-fittest processes operate with respect to ideas and concepts. Consonant information, because it is more consistent and rational, is more dependent and useful and tends to persist, whereas dissonant information, being low in reliability, is in time selected against and caused to disappear.

Part II. Information as such

Background

In 1949, Shannon and Weaver, accepting that electrical signals as bits can be used to convey information, presented a general theory of communication. The model employed was that of a transmission line, with an information source at one end and a message destination at the other. Included was noise as a deterrent to successful transmission. Concepts useful to engineers pertaining to transmission efficiency were developed which were helpful when dealing with load and interference. However, both Shannon and Weaver, in their separate statements, emphasized that information as meaning and message is another subject, calling attention to the fact that one bit may be “heavily loaded with meaning,” while another may contain “pure nonsense.” Information, it is clear, is the commodity of mentation and the substance out of which intellect is built.

In 1963, the Author wrote on “Information, per se,” giving characterization to information as an influence. In 1969, some preliminary ideas were set forth about information as a force, and in 1971 the evolution of information use and the emergence of intellect leading to sapiens were traced. In the period since the Shannon and Weaver presentation, analysts have in various ways come toward the question of information as a force, with its own dynamics and phenomenologies, but, for the most part, have been content to evaluate in terms of mechanisms. Accumulating knowledge and experience in biochemistry, biophysics, neurophysiology and cybernetics, however, is forcing upon us a greater comprehension of the significance of information as an operational means and as a determinant.

Information Phenomenology

At the outset, it is apparent that information, as meaning and message, is an entity apart from the means by which it is processed, the bearers by which it is transported, and the symbols by which it is represented. Quite clearly, information has its own way of functioning. In dealing with information, as such, considerations go beyond the objective to include the subjective—to the essence of thought and resulting behavior. Information, it is obvious, is dependent on physical structure and energy, but involves an additional sphere, category, or hierarchical level of action.

Information and Energy

Information, like energy, exerts an influence. It causes things to happen. It is a kind of force, and, in a particular way, a prime mover. Much of what organisms, as self-organizing systems, do every moment of every day, is initiated and directed by information—inherned information transmitted by genes and chromosomes, environmental information coming into the system by way of sense organs, and information generated within the system itself by mentation. Questions thus are raised as to the relationship of energy and information, and whether, in some special way, information and energy are interchangeable like energy and matter.

The precise meanings of these terms are sometimes elusive. We define energy as force, force as power, power as capacity to do work, and then find ourselves asking again: “What is energy?” Similarly, we speak of information as meaning, meaning as that perceived, and that perceived as resulting in meaning, and we are guilty of circular thinking. As a beginning we shall think of both energy and information as influences—as types of force, but with differences.

Carriers

Energy carriers (electrons, protons, etc.) are also information carriers. Information, as signals transported by electrons, can be modulated and applied by means of electronic circuitry and componentry—also by molecules, cells, organisms, and computers since they have comparable circuitry and componentry. Information can be processed in a free living cell like an ameba, as well as in a nervous system, including the brain. In large molecules, in a cell, in a nervous system, or a computer, information—like energy—is transmitted, transduced, sorted, stored, integrated, and, in a specific way, caused to do work by initiating the movement of electrons (or other particles) as energy carriers. In these ways, energy and information exert the same kinds of influence and are comparable.

Electrons as Means

In addition to serving as vehicles for both energy and information, electrons comprise a basis for various kinds of accomplishment, including mentation and control. By means of number and location of atomic orbits, electrons give properties to elements. By means of extended orbits—that is, by means of molecular orbitals—they cause molecules to form, build in complexity, and acquire special properties, including mentative function. Electrons
move in orbits around atoms or groups of atoms; with strong forces, they can be propelled as free moving entities, and, depending on force states, they may suspend as clouds. Electrons that are tightly bound, or that exist as free moving entities with high momentum, are less useful—or useless—for information processing even though they transmit large amounts of energy, simply because their behavior is less malleable. This situation provides for a beginning separation of information and energy.

Electrons have an electric charge opposite in sign to that of protons, and a mass much smaller; hence, when other governing forces (including chemical) are less dominant, are to a large extent controlled by protons or groups of protons in critical numbers.

In conductors, electrons under the influence of electromotive forces comprise a current by progressive transfer from one atomic nucleus to another. Current involving lower level voltages and information laden electrons can be influenced and modulated, not only by protons, but also by electronic componentry consisting of resistors, capacitors, and inductors. Currents can also be sorted, amplified, and transduced with diodes and transistors, which make use of electron excesses and deficiencies in orbital configurations. The potential for regulation and control in electronic circuits is vast.

Electrons have spin, and spin creates magnetic fields. Magnetic fields comprise energy storage, and thus (as revealed by Sakalosky, 1975) information storage and memory. Magnetic fields coalesce to form magnetic domains that provide a basis for attitudes, ideas, conclusions and concepts. Insights thus come from considering the role of electrons as energy carriers, and as means for information storage and modulation, but, in using the electron carrier approach, it is to be remembered that there are other kinds of energy carriers and other kinds of manipulative systems.

With respect to the interchangeability of energy and information, guidance comes from reference to the Second Law of Thermodynamics. Information, as has been indicated, can be created and destroyed, whereas, according to the Second Law, energy is conserved—neither created or destroyed, changing only in form. This is an additional reason for continuing to deal with energy and information as separate phenomenologies.

Cybernetic Models

Next it is useful to consider levels of information processing, and the progression leading to self-organizing systems where regulatory control and purposive behavior occur.

A spinal reflex reveals elements of reactive systems (Figure 1), be they macromolecules, electronic circuits, living forms, or systems like a type of economy or a civilization. The reflex model consists of: sensory input which provides the system with information about its environment; of processor throughput where information assimilation occurs, conclusions are reached and action initiated; and of expressor output involving especially muscles, glands, levers and joints, by means of which action is taken that may vary all the way from homeostatic control to speech and locomotion.

In Fig. 1, throughput consists of a segment of spinal cord in a nervous system. Throughput in nervous systems may also have subcategories for use as hierarchical levels of information processing, and they may consist of other segments of cord or parts of brain (Fig. 2). By means of spinal cord segments,
a millipede accomplishes the beautifully rhythmic and sequential flow of appendage movement involved in locomotion. A brain is scarcely needed. Experiments, in fact, have shown that millipede "walking" can be accomplished without a head and its brain. A reptile with specialized sense organs at the anterior end, such as eyes, ears and tongue, has a brain consisting of anterior cord enlargement. More particularly, it has a double brain with right and left hemispheres (Fig. 3). In mammals, there is a millipede-like cord and a reptile-like brain, plus a brain overlay of cortex (or neocortex). Thus, going beyond the simple input-throughput-output reflex, the other segments of the cord, the old or reptilian brain, and the new or mammalian brain, represent subcategories of throughput, and an ascending order of hierarchical communication and control.

Reptiles, like millipedes, are concerned especially with survival—food and reproduction—the immediate. Higher forms, and particularly human beings, think of, and—in some respects—look into the future; they educate, develop strategies, consider alternatives, and make choices. Human beings walk upright, displaying remarkable skills of proprioception; they communicate by means of speech; and they employ abstractions—sound, symbols, words, maps, and blueprints to represent things. The human species, because of its successes in comprehension, is able increasingly to select and determine its future.

Subdivisions of Brain

The neocortex also has specialized parts which serve as additional subcategories of throughput. There are the occipital lobes predominately concerned with binocular vision, the parietal lobes with space perception, the temporal lobes with perceptual tasks involving the senses, and the frontal lobes with abstraction, analysis, logic and interpretation. Indications are that thought processes leading to words of qualification and reason emerge especially from frontal lobe regions.

Between the old and new brains—in higher forms—and existing more as part of the new brain, is the limbic system. This is understood to be the main seat of emotions—feelings, such as love, hate, fear, and the like.

In the characterization of mental processes, it is appropriate, and seemingly necessary, to recognize three types of mentality: first, that associated with the old brain and concerned especially with self-preservation and reproduction; second, that associated with the limbic brain concerned in particular with inner reactiveness (feeling), and third, that associated with the new brain and concerned mostly with sense and reason.

Hierarchies of Mentative Function

Starting with the spinal reflex as perhaps the simplest of throughput control systems, the next level of complexity is one having feedback, which provides balance or maintains direction with respect to some destination or goal (Fig. 4). Next is a system with memory and recall, which is like a tape recorder. When there is opportunity for thought, mentation or information processing, the system's function is like that of computers where sums and comparisons are made, and conclusions reached. It also is like that of organisms with sensory input and adaptive responses. When the information processing is done without nerves or brain, it is pervasive and dispersive; when it is mainly by reflex processes, the system functions like a millipede with very little brain; when the mentative process is motivated mainly by objectives of self-preservation and reproduction, it is characteristic of reptiles with

Fig. 3. Hierarchical levels of nervous system control as revealed by animal types: (1) millipede with little more than a double nerve trunk; (2) reptile with a nerve trunk and double bulbous enlargement at the forward end; (3) mammal (human) with a new brain (cortex or neocortex) overlying the reptilian brain.

Fig. 4. Block diagram of an adaptive, purposive and discretionary (self organizing) system. Memory, recall and thought (mentation) correlate with specific molecules of cells and tissues. Consciousness, emotionality, instinct, intuition, reason and free will are transconstitutive. They do not correlate with specific organ parts. They appear when information processing has reached a stage of complexity and specialization that causes them to exist.
a primitive or old brain; and when the system or organism is capable of up-right walking and speech, and motivated in considerable degree by curiosity, it functions like human beings with a thick cortex and strong frontal lobes.

The increasing complexity of function just mentioned correlates with tissues, organs, and structure—but consider the capacity identifiable as awareness or consciousness. Consciousness appears to be a characteristic of all animal organisms (possibly all plant organisms, as well, depending on definitions), and it is fundamental; but, it does not correlate with any particular tissue or organ of the brain. There are also the important features of emotion, instinct and intuition, and, in human beings, reason and free will, none of which correlate in any specific way with tissues or organs. Such features can be classed as transconstitutive—those that emerge when mentative processes reach a level of complexity that enables assimilative function.

Transportability of Mentative Function

Significantly, the locations of brain function, such as those just identified, can be removed. By conditioning, “handedness” can be transferred from one side to the other, and, in case of severe brain injury, the function of the two hemispheres has been observed to be taken over by one with reasonable effectiveness. Related evidence is that information signals picked up by eyes from the printed page, by ears from spoken words, and by finger tips from braille, travel along different nerve pathways to quite different parts of the brain, yet the cognitive impressions come out to be the same. This is substantiation that information as meaning and message is an entity unto itself and not invariably associated with specific cells of the nervous system. As will become more evident, information processing is a feature of all cells.

Pervasive and Progressive Mentation

Communication and control, as done by neural tissues, are both accomplished by digital impulse conduction. But, there is another, and perhaps more fundamental method—one that is analogue in character, and one that is readily appreciated by considering operational behavior in a single-celled organism like a paramecium. Dealing with this second type of information processing gives insight into two important features: one, the nature of mentation as such; and the other, where mentation occurs.

Under the microscope, one can observe at the surface of a paramecium the flowing wave-like motion of cilia as the creature propels itself in a fluidic medium. Also, when the organism collides with an immovable object, one can see that the directional beating of cilia is “reversed,” that the organism backs away a bit, and then turns right or left in a meaningful manner. Clearly, there is information input, throughput and output (sensing, processing and expressing), yet there is no brain and there are no nerves. Clearly also, the informational stimuli reaching the base of each cilium on a moment to moment basis is different, because of timing and guidance needs. There is, therefore, pervasive and progressive mentation—the message changing adaptively as it moves from point to point in protoplasm. Mentation in organisms is not only not limited to nerve and brain cells; it occurs generally in protoplasm. Healing, differentiation, etc., give much evidence of protoplasmic communication—intra and extra cellular.

Molecular Information Processing

Because of nuclear, orbital, electrical and other forces, all atoms and molecules store energy; and, as noted, when there is opportunity for modulation of energy fields by information carriers, there is opportunity for information processing. When a system functions like a simple reflex, it is simply reactive; when it acquires feedback, it gains purpose and objectivity; when it has energy storage capacity (as all atoms and molecules appear to have in some degree), it has memory; and when it has interactive memory—as exists in self-organizing systems—it has potential for adaptive control. Most atoms and molecules are reactive, and most appear to get involved in one-way processes of decomposition or synthesis, but so far as known, only certain ones, deoxyribo- and oxyribo-nucleic acids (DNA and RNA), have capacities for adaptive and discretionary regulation.

DNA and RNA are comprised of nucleotide bases, of complementary nucleotide pairs, and of tetranucleotides resulting from the combination of any two complementary pairs (plus, of course, phosphates and pentose sugars). Tetranucleotides have been revealed by biophysical analysis (Sakalosky, 1975) as dynamic units—that is, molecular structures that store energy (information) by means of magnetic domains in the achievement of learning and memory, that accomplish stimulus initiation (as required in processes of assimilation) by thermo-electric microcurrent generation, that respond to message (genetic, incoming or generated), that operate as molecular throttles or switches to control energy distribution in response to messages as stimuli, and that communicate by means of energy (information) carriers (mainly electrons) and by resonant (electromagnetic) radiation from magnetic domains generated by the interaction of energy fields. Information processing can, and does, take place in important ways at the level of molecules, and now the process is being comprehended.
Origins
DNA and RNA, as one important information processing system, are comprised of hydrogen, carbon, nitrogen, oxygen and small amounts of phosphorus; DNA (and probably RNA under certain circumstances) is self-replicating by the processes of complementarity. This means that because of inherent properties, DNA draws constituents from its environment—sometimes as elements, and sometimes as simple and complex molecules—making more molecules like itself, which in turn perform the operative and replicative functions of DNA. It follows then that the continuity underlying life and intellect rest on the physical and chemical properties associated with the elements of nature. Life and intellect arose from the elements of the earth.

Actuation and potentiation
The uniting of nucleotide bases to form complementary nucleotide pairs, and the association of such pairs to form tetranucleotides, represents a staging process which forms actuators as devices for the achievement of replication and adaptive control, and thereby life survival processes. Similarly, the function of actuators to create magnetic domains that can "sense," "feel," and react to each other and to electrons and other information carriers represents potentiation as energy states that have a bearing on each other, thus making a basis for intellect and mind. Sequential ordering of nucleotides throughout the length of DNA molecules provides a means for holding and transmitting genetic information, but it is atomic groupings that in turn perform the operative and replicative functions of DNA. It follows then that the continuity underlying life and intellect rest on the physical and chemical properties associated with the elements of nature. Life and intellect arose from the elements of the earth.

Intellect
At the level of electrical circuits, information exists as signals, but at the level of potentiation, it exists as images and concepts, and it is at this level that information has meaning and message. It is at this level that information seeks consistency, is generative, and, as concepts, competes for survival. It is at this level that information has a dynamics of its own.

Although units are not yet available for quantifying any of these factors, the operational process is apparent and has significance. That which can be known is equal to the forces for understanding offset by the forces of deterrence. The process is similar to that defined by Ohm's Law which states that current in a circuit is equal to electromagnetic force offset by resistance as a deterrent force. In the case of information, much more can be known as ways are found to offset deterrents. More importantly, information as meaning and message, and as intelligence, is seen to operate as a kind of amplifying force—an entity that has special potential as a prime mover and acts as a terminator pulling toward higher ground in organization. Information is revealed as a negentropy factor, and one whose influence is accelerating. The progression of intellect represents vast power.

What has been said rests primarily on the perceptions that information seeks consistency, that information interacting with information is generative, and that selection occurs with respect to information as concepts. Asking why information seeks consistency, is generative, and involved in selection is like asking why a current has electromotive force, why like electrical charges repel, and why evaporation occurs. All represent fundamental forces in nature. Some understanding has been obtained of each, but so much more is to be revealed. Meanwhile, much use has been made of at least some of the forces, and it seems a certainty that much greater use will be made of information as a force in the future.

Mental disorders have been poorly attended—due especially, it appears, to lack of comprehension of the mentative process. Information dynamics, it is submitted, will open many doors.

Summary
Particular points are listed as follows:

1. That information as meaning and message is transmitted and modulated by energy carriers—especially electrons.

2. That information processing (mentation) can occur in a variety of systems, including molecules, cells, organisms, and computers.

3. That some degree of memory (as energy storage) is associated with all atoms and molecules, but that information processing at mole-
cular levels occurs only when there is adequate carrier mobility and flexibility of action.

4. The adaptive, purposive, and discretionary information processing occurs only in systems, such as DNA and RNA tetrannucleotides, where free play of low energy processes can occur.

5. That information as meaning and message has a dynamic of its own, involving interactions between organizational and disorganizational forces.

6. That information as meaning and message is a negentropy feature and a determiner that moves organizational developments toward higher levels of order, function, and control.

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Some Economic Parallels To Equilibrium Thermodynamics*

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Abstract

"Ecodynamics" is an economic theory that parallels the physical science of equilibrium thermodynamics. It is constructed by finding economic analogues of H = total heat, E = internal energy, W = mechanical work, T = absolute temperature and the first two laws of thermodynamics. Defining E = "capital" in a sense that is different from and much more comprehensive than that in which it is usually employed, we obtain a first law of ecodynamics that parallels the physical law of the conservation of energy, which is expressible in terms of E = capital (an economic state function), W = labor and H = E + W = total wealth. Another innovation is in the employment of T = "value" as an intensive function of a potential nature which is radically different from the usual concepts of economic value as an extensive quantity. Then corresponding to physical entropy S which is defined in terms of E and T, we can define an economic entropy S or "ecentropy" (another economic state function) in an entirely similar manner. We can express a second law of ecodynamics that parallels the physical second law, but in an opposite sense, because wealth, capital or labor, tends to move or flow spontaneously to where its value is greater, resulting in diminished ecentropy or increasing "negentropy." There are, of course, many situations where ecentropy will also tend to increase spontaneously, as in the physical world. However, the overall global tendency is for a vastly preponderant decrease in ecentropy. Some detailed quantitative illustrations are given for both ecodynamic laws. A large practical extension of ecodynamics, which can be applied to many economic systems having coexistent "phases," is made possible by introducing variables m_i to denote various specific kinds of capital and labor and specific capital potentials \mu_i = \delta E/\delta m_i corresponding to chemical components m_i and chemical potentials \mu_i through which Gibbs vastly extended the scope and effectiveness of thermodynamics. Brief mention is made of possible parallels to the third law of thermodynamics and to non-equilibrium thermodynamics. A non-equilibrium ecodynamics would treat fluxes or flows of different forms of wealth and labor in conjunction with various specific capital potential functions.

Introduction

The role of entropy in economic processes has been featured in a recent highly original work of N. Georgescu-Roegen (1). The entropy concept which he employs is identical with that which originated in thermodynamics and is applicable to the entire physical world. Thus, in Georgescu-Roegen's application of the entropy law to the universal dissipation of energy that comes from the sun to the earth, there is no deviation from the literal physical meaning of entropy.

Even superficial perusal of that stimulating work gives rise to alternative notions concerning entropy in economics—in particular, that there might be something that is analogous to entropy but which is definable entirely in terms of fundamental economic concepts, and which differs from the various standard physical definitions that range from the historically original one in terms of heat and temperature to the more recent theoretical ones which are quite abstract. The economic concept that is suggestive of a parallel to physical entropy appears to be something that tends to decrease spontaneously, rather than to increase, even though the latter also occurs frequently. In other words, here it is something that is analogous to negative entropy or negentropy that tends to increase. Also, more than just an economic analogue of entropy or negentropy is involved if one considers a surprising parallelism between the first two fundamental laws of classical equilibrium thermodynamics and two analogous economic laws which are expressible in terms of very inclusive economic concepts.

In this presentation we employ the notation for the physical quantities such as heat content, internal energy, mechanical work, absolute temperature, entropy, etc., which has been standardized in the classic work of Lewis and Randall (2), and we shall refer to the first two laws of thermodynamics in the form given there.

*Editor's Note: The publication of this article should not be considered as an endorsement of the ideas expressed by the author; rather, it is an invitation for discussion about the limits of applicability of thermodynamic models to economics.
First Law of Ecodynamics

The first law of thermodynamics, which is that of the conservation of energy, is usually stated as follows, although the context appears to be far from universal: In any physical or chemical process, the increase in the internal energy \( E \) of a given system, is equal to \( q \), the heat absorbed from the surroundings, less \( w \), the work done by the system upon the surroundings. In the particular case when the pressure \( P \) is constant, for a change of volume \( \Delta V \), so that \( w = P \Delta V \), we have:

\[
E_B - E_A = \Delta E = q - P \Delta V = q - P(V_B - V_A) \tag{1}
\]

or:

\[
(E_B + PV_B) - (E_A + PV_A) = q \tag{1'}
\]

the subscripts \( A \) and \( B \) denoting the initial and final states respectively. Equation (1') suggests the definition \( H \equiv E + PV \) and the observation that we can measure just the changes in \( H \) or \( E \), without having to know the absolute value of either one. Since \( \Delta H = q \) when the pressure is kept constant, \( H \) is customary called the "heat content" or "enthalpy" or "total heat" of the system, even though it is not composed of just heat energy. We note here that for a body in a given determine state or condition, the internal energy \( E \) is an unchanging function of that state, or, more briefly, a "state function." This is not true of \( H \) or \( W \), both of which may vary in the passage of a body from one state to another, or in other words, \( \Delta E = E_B - E_A \) depends only upon the two states \( A \) and \( B \), however, \( \Delta H \) and \( \Delta W \) might vary in the passage between those states.

The preceding formulation of the first law of thermodynamics suggests a broad economic conservation law that is quite analogous to the conservation of energy. In place of total heat \( H \), internal energy \( E \), and mechanical work \( W = PV \), we might have these prominent forms of "economic energy": \( H \) = "total wealth," \( E \) = "capital," and \( W \) = "labor," each taken in a rather all-inclusive sense. Thus in this "ecodynamic" sense we might employ capital to include almost every tangible asset, of almost every kind, as long as it is reproducible and not human. The difference from the usual economic meanings of capital and labor would be that here \( E \) = capital would include machinery, land, wealth, materials, money, food, fuel, etc., and \( W \) = labor would include every type—physical, mental, administrative or organization labor, creative work or thought, etc. Then \( H \) = total wealth would be the sum of every type of capital and labor, and the analogue of the first law would be the ecodynamic law of conservation of wealth, which might be stated as follows: The gain in total wealth \( H \) is equal to the increase in capital or \( E \) plus the added labor or \( W \), i.e.:

\[
\Delta H = \Delta E + \Delta W \tag{2}
\]

In (2) the \( \Delta H \), \( \Delta E \), and \( \Delta W \) would correspond to the physical thermodynamic variables \( q \) or added heat, \( E_B - E_A \) and \( PV_B - PV_A \) respectively, which occur in (1) and (1').

In an analogy to the thermodynamic \( E \), the ecodynamic internal energy \( E \), or capital, would be viewed as a state function of any system, whose difference for the system in two different but completely defined states would not vary no matter how much labor and tangible or outwardly visible wealth is involved in the passage between those two states. In particular, when an economic system returns to its original state, having the same amount of capital, the algebraic sum of the amounts of all forms of wealth acquired or absorbed must be balanced by the amounts of all forms of labor performed by or withdrawn from the system. In reference to (2), the added labor \( \Delta W \) that is required would be interpreted as contributed to the system from the outside in the passage from state \( A \) to state \( B \), but as \(- \Delta W \), after transposition, it is drawn from resources within the system. Expressed otherwise, \( \Delta W \) is the price to pay for \( \Delta H - \Delta E \), the excess of the increase in total wealth over the increase in capital gain. Thus, \( \Delta E \) is a measure of a gain or loss in intrinsic wealth, being a difference in values of a true state function.

In the physical world the first law is much broader than in its original formulation (1), (1') involving only the convertibility between heat and mechanical work, since it applies to all forms of energy. In particular, energy of many different forms, including also mechanical work \( W \), can add directly to the internal energy \( E \), which implies a change in state. In the ecodynamic field this means that added \( W \) is convertible into something more specific than total wealth \( H \) since it can form capital \( E \), which is another way of implying that labor can alter an economic state function.

The interconvertibility of capital \( E \) and labor \( W \), in a purely economic sense only, has many obvious illustrations. Thus for \( W \) into \( E \), we have labor going into the building of a machine which is capital, and likewise we have the labor of thought and planning contributing toward the building of a business organization which is here considered capital. For \( E \) into \( W \), we need the capital of money to pay and adequately support a labor force, which includes the intermediate stage of the purchase of other capital such as food and other means of living in order to accomplish any work.

For two final remarks concerning this first ecodynamic law, we note that: (1) \( H \), \( E \), and \( W \) are extensive quantities with broader connotations than wealth, capital, and labor in most economic treatises; and (2) we still have not introduced a concept of "value," which will be required in the formulation of a second law of ecodynamics in which value will be given a meaning entirely dif-
different from that in practically every economic theory, namely, that of an economic potential function that influences the flow of economic energy in the form of H, E, or W.

Second Law of Ecodynamics: Value and Entropy

The simplest and oldest expression of the second law of thermodynamics is that heat will never flow from a reservoir at one temperature to another at a higher temperature unless outside work or energy is employed to effect such a transfer; i.e., heat will go spontaneously only from warmer to cooler bodies. This leads to the definition of a fundamental quantity S or "entropy," as a measure of the state of irreversibility of a system. We shall not repeat here the usual derivation of the entropy function from the second law, heat reservoirs, Carnot cycles, maximum efficiency of reversible engines, etc. These all lead to the definition of an absolute temperature scale which was defined by Kelvin so that, for two reservoirs at temperatures of \( T' \) and \( T'' \), \( T' > T'' \), where a quantity of heat \( Q' \) is removed from the reservoir at \( T' \) and the amount \(-Q''\) is received by the reservoir at \( T'' \), and where the maximum obtainable work is \( W \), which must equal \( Q' + Q'' \) by the conservation law, we have:

\[
W/Q' = (Q' + Q'') / Q' = (T' - T'') / T'
\]

from which:

\[
Q'/T' + Q''/T'' = 0
\]

leading to:

\[
\frac{\delta Q}{T} = 0
\]

for a continuous reversible cyclic process. This last equation defines the difference of entropy \( S \) for any system between two states I and II as:

\[
S_{II} - S_{I} = \Delta S = \int \frac{dQ}{T}
\]

where \( dQ \) is the infinitesimal amount of heat which is received by the system and where \( dQ/T \) is the infinitesimal increase in entropy, at every stage, along any reversible path. The exact:

\[
\Delta S = \int \frac{dQ}{T}, \text{ where } \Delta Q \text{ is the heat received from some source, when the temperature is } T. \text{ In any irreversible change } \Delta S \ge 0. \text{ Also, employing } \delta \text{ to denote an infinitesimal variation, it is shown in standard works } (3), (4), \text{ in great detail, that for any isolated system at equilibrium:}
\]

\[
(\Delta S)_E = \text{constant} \le 0
\]

(maximum entropy at constant energy), which is equivalent to the condition:

\[
(\Delta E)_S = \text{constant} \ge 0
\]

(minimum energy at constant entropy).

To find an economic analogue of an entropy concept, say "entropy," that may replace or supplement Georgescu-Roegen's entropy which is meant in just the literal physical sense, we need something that is economic in meaning and which corresponds to some way to the absolute temperature \( T \), an intensive variable having the character of a potential function. Even though the term "value" is employed in economics in an extensive sense, such as "so many dollars or cattle," "so much land," etc., we shall empty value in a purely intensive sense, like absolute temperature, so that it may be applied in a manner similar to that in which temperature measures hotness or coldness regardless of the amount of material that is involved. In this respect, value \( (T) \), where the adjective "absolute" will be understood, differs fundamentally from the extensive variables capital \( (E) \), wealth \( (H) \), and labor \( (W) \). At the outset, and just tentatively, we shall overlook the many different kinds of value, such as comparative cost or market price, rarity, intellectual, artistic, or technical value, and we shall measure value by the single variable \( T \). This is suggested by the use of the thermodynamic temperature \( T \) which may be influenced to a large extent by any number of other types of potential functions, such as chemical or electrical potential. Even without other potential functions, the simple and convenient concept of temperature is a sort of average intensive function that is composed of many factors—molecular velocity, atomic motion, radiative effects, etc. Likewise, economic value will be employed at first in a convenient overall sense, even though there may be many separate factors which can be distinguished and measured upon deeper study.

Without detracting from the role of physical entropy in the overall global economic picture, especially in the light of Georgescu-Roegen's penetrating analysis, we may introduce a second new and fundamental general economic law that capital, labor, or any combination of those two have a tendency to move from where they originate or occur to some other place where they will have more value, prompted by greater utility or demand. This also includes the cases where there is no
change in locale should the wealth, capital, or labor under consideration tend to increase in value more in its present location than anywhere else. This is directly opposite to the physical flow of heat from a higher to a lower temperature—or in other words, higher value T attracts the flow of wealth H as well as capital E and labor W, unlike higher temperature T which repels the flow of heat H. We may also note here another difference in that the physical second law involves the flow of H alone, not H, E, and W as in the ecodynamic law. Just as in thermodynamics $\Delta H/T$ measures an increase in entrop $\Delta S$, so here $-\Delta H/T$, $-\Delta E/T$ or $-\Delta W/T$ in economics is a measure of increase in negative economic entropy or $-\Delta S$, and in place of a tendency toward the spontaneous increase of entropy $\Delta S$, in economics we have a tendency toward spontaneous decrease in ecentropy or increase in negative ecentropy, i.e., "negacentropy." We can formulate a state function of negacentropy by means of a concept of ideal reversible ecodynamic processes connecting any two different economic states, such as in a situation where labor and capital are interconvertible on the slightest shift of either one or the other, a market which is almost perfectly balanced with respect to buyer and seller, or any other conceivable economic process without any waste or loss that can go either way with the slightest change in any variable factor. To maintain the parallelism with $\Delta S = \Delta H/T$ in physical thermodynamics, since $\Delta H = \Delta E + \Delta W$, there will be no real loss in generality in writing only $\Delta S = \Delta H/T$ for the increase in ecentropy with the understanding that the $\Delta H$ may be $\Delta E$ or $\Delta W$ alone.

For economic equilibrium states we should expect an analogue of equations (6) and (7), but with the inequality signs reversed, so that the conditions would be minimum ecentropy (maximum negacentropy) at constant capital, which is equivalent to maximum capital at constant ecentropy or negacentropy.

Alongside this tendency toward an increase in negacentropy, there will also operate a certain inevitable degradation of wealth or economic energy in the form of dissipation, waste, losses, devaluation of capital or labor, etc., which will cause some increase in ecentropy $\Delta H/T$. For example, very noticeable dissipation occurs whenever we have inflation, idle capital, unused machinery, obsolescence, social upheavals, and of course, the actual process of consumption or enjoyment of living, the last having been pointed out by Georgescu-Roegen in connection with physical entropy. However, the net ecentropy change over most wide areas will still be much more in the former effect of increase in negacentropy, which governs large flows, on a continental scale, of materials, labor, commerce, population flows and immigration, as well as increases in productive population in developed countries, transfer of every kind of capital, development of resources, international trade, and allocation of skills which include creativity and invention. All of this comes under the general tendency of wealth in some form of capital or labor to move to where its value is greater. In other words, the general tendency toward constantly increasing value in capital and labor, through the awareness of where greater value lies and the will to act upon such information plus the creative drive to improve the economy, appears to be universal and opposite in the sense of the inanimate world tending to run down, since here the economic universe tends to "run up." That may be just as fundamental a property as the entropy law in the physical domain.

Properties of Ecentropy and Negacentropy

Perhaps it should be pointed out that there is a difference in the spontaneous character of the tendency toward the increase in entropy in the physical world and toward the increase in negacentropy in the economic world. The former is one hundred percent spontaneous and automatic in the sense that something like heat requires no inducement to flow from a hotter to an adjacent colder body, whereas wealth or capital always requires some added human intervention or arrangement to induce the change in negacentropy. This requires, as a rule, some combination of labor and additional capital such as inanimate energy, transport devices, added expenses in the form of overhead and other incidentals, etc., to move the wealth or capital to the location where it is more valuable, so that it is almost never purely and automatically spontaneous. For instance, lumber in the form of trees in an isolated woodland area requires labor and transportation until the lumber mill stage is reached in which the value of the wood, which is now accessible to builders, will be very much higher. (However, the perceptive reader will note that in any real practical situation involving the utilization of heat going from a hotter to a colder body, i.e., not counting indiscriminate warming of areas, air or ocean currents, storms, hurricanes, or similar disasters due to unequal heating, some human intervention with labor is necessary to arrange the process.) Thus, as will be seen in the illustrations of the application of the second law given below involving added labor and capital, it is rarely the identical capital which leaves the lower value locale that enters the higher value locale. It is

In confirmation of this fundamental law it is apparent from history that the world as a whole has been growing economically and becoming progressively richer. One need only compare world pictures in successive centuries.
rather something almost the same and which has higher value in the new location. The point of this fundamental second law and use of the concept of value is that the increase in negentropy is not explainable in terms of only added capital and labor, for in such a case there would be no need for a second law of ecodynamics. Value is created by human needs, desires and aspirations. Thus the difference in the value of either a gem or an essential medicine between the time that the purchaser or consumer obtains it and the time that it is first located in a remote natural area is very much greater than can be accounted for by just the added labor of making it accessible. In fact, in a certain sense, whenever enormous profits are involved there must be some tendency toward spontaneous movement of capital in the generalized sense (i.e., not, of course, physically automatic) to where it has greater value per se, even after allowing for the comparatively lesser amount of added labor and capital which is involved in this relocation.

At this point one may be reminded that, just as the spontaneous dissipation of heat can be arrested by introducing work from the outside (e.g., as in refrigerating machines) likewise, in situations where there would be a tendency toward spontaneous deterioration in value of some particular kind of capital, we can almost always introduce outside economic influences in the form of either labor or additional capital which can prevent such deterioration and furthermore, can even increase the value of that capital.

Because this concept of intensive value has so many economic, social, psychological, and even philosophical aspects, at this stage it might be expedient to forego further discussion, deeper analysis, and attempts at a more precise and comprehensive definition of value.

Unlike heat flow, which requires the contiguity of the reservoir at the lower temperature (or if there is a channel connecting those two reservoirs, some portion of that channel must be cooler than the hotter reservoir), in the transport or flow of capital or labor to where it is more valuable, the two regions may be thousands of miles apart. Also, in general, physical channels for economic connection need not exist initially, obvious illustrations being in the construction of necessary roads or long pipelines from oil fields to transport depots or directly to refineries. Furthermore, as noted above, unlike the flow of heat from one place to another, we may speak of a flow of capital in time alone, without any change in location, to a condition of greater value. E.g., antiques, stamps, coins, works of art, and rare books have a tendency to become more valuable through the passage of time alone, without any shift of locale. Thus the parallelism between ecodynamics and thermodynamics is seen to have limitations in that in the former we may have both a spontaneous increase or decrease of negentropy function which may occur in space or time alone as well as in space and time together.

A suitable value scale for $T$ can provide the basis for developing a quantitative measure of the entropy function to compare different economic states, such as societies, assemblages of capital and human resources, etc., not just for the total wealth involved which comes under the first law, but also as to the extent of organization, development, productivity—all from the general standpoint of negentropy. By analogy we may note that thermodynamics with only a first law of conservation of energy would reduce to little more than an energy balance sheet. It is the application of the second law that indicates which way the energy will flow and which reactions or processes are possible. A similar second law for economics in terms of negentropy should lead to a systematization of the vast number of different economic states, with quantitative comparisons to characterize those that are more likely to exist or to transform into other states.

Just as in physical thermodynamics, to measure the difference in entropy between any two states $a$ and $b$, we might have to devise a series of idealized operations that are economically reversible, i.e., non-dissipative, non-wasteful, non-profitable, and, of course, non-consumptive in nature for passing between those two states $a$ and $b$, say via $a_1, a_2$, etc., so that:

$$\int_{a}^{b} \ldots = \int_{a}^{a_1} \ldots + \int_{a_1}^{a_2} \ldots + \int_{a_n}^{b} \ldots,$$

where we may calculate each:

$$\int_{a_j}^{a_j} \frac{d(wealth)}{value} = \int_{a_j}^{a_j} \frac{dH}{T},$$

and then combine the results. For example, one of the idealized stages in passing from $a$ to $b$ could be an exchange of capital by non-profitable barter or sale. Even though that does not actually occur in passing from $a$ to $b$ we may introduce such stages in a purely conceptual manner.

To summarize so far, in addition to the increase in entropy in the same sense as in physical thermodynamics which is also that of Georgescu-Roegen, we have here a vastly predominant increase in negentropy governing the location and distribution of all total wealth in the economic society and an increase in entropy that applies to a certain economic dissipation of wealth that is analogous to the dissipation of physical energy. Increase in entropy occurs with deterioration or obsolescence of capital, erosion of economic society, inflation, aging, natural disasters, and the destructive
effects of human conflicts and wars. Also we must bear in mind Georgescu-Roegen's indication of how consumption or enjoyment of wealth is a very widespread and primary example of dissipation of economic wealth or energy. However the facts of economic growth through human organization and development make the increase in negentropy the important and prevailing factor. It should be noted here that there is nothing self-contradictory in admitting that capital might tend to go spontaneously to a state of either more or less value, depending upon the circumstance, even though the tendency to go to a state of greater value is much more influential.

One interesting problem occurs in deciding upon the dimensionality of this negentropy function. Of course it is not a pure number (as might appear at first glance if we erroneously think of —capital/value being of the same dimensionality as —money/money), since value is used here in an intensive sense. Here value, when expressed as so many dollars per certain unit of capital which is the same as that in the numerator, for all different forms of capital under the present comprehensive definition, gives for negentropy $-n_1$ units of capital$/n_2$ dollars per unit of capital) = $-n_2$ (unit of capital)$^2$/dollar. This is seen to yield varying units for negentropy which depend on the kind of capital under consideration as well as the size of the chosen unit. Of course, the simplest case is when the unit of capital is the dollar itself, in which case negentropy is in negative dollars. Some standardization of the negentropy unit may be desirable, but that problem will not be studied here.

**Other Ecodynamic Functions**

Gibbs introduced two other fundamental energetic quantities which, in the Lewis and Randall notation, are given by $A = E - TS$ and $F = H - TS = E + PV - TS = A + PV$. The function $A$ is known as the Helmholtz free energy while $F$ is known as the Gibbs free energy. The function $A$ is an available energy function when the temperature alone is kept constant, whereas the function $F$ is an available energy function when both temperature and pressure are kept constant, the latter being more widely used when reference is made to a free energy function without further specification. Both $A$ and $F$ have ecodynamic analogues, the former denoting an available capital function when the surrounding value in the immediate neighborhood is kept constant, and the latter denoting an available capital function when both the surrounding value and "labor potential" (some suitably defined intensive labor function $P$ which is the economic analogue of mechanical pressure) in the immediate neighborhood are both kept constant. However, there is an important difference in the application of the $A$ and $F$ available energy functions, which holds also for the $E$ function, namely in the criteria for a tendency toward spontaneous change. In thermodynamics this occurs when there is a spontaneous release of energy, which means a lessening of the energy within the system and which is expressible by:

$$(dE)S = \text{constant} \leq 0, \quad (dA)T = \text{constant} \leq 0$$

or

$$(dF)T\text{ and } P = \text{constants} \leq 0$$

(8)

In ecodynamics, as a consequence of the greater tendency for increase of negentropy instead of entropy, the $\leq$ signs in (8) are replaced by $\geq$ signs, which implies that in economic non-equilibrium states there is a tendency toward the acquisition of wealth, capital or labor. This would correspond to the absorption instead of release of free energy. For ecodynamic equilibrium we have (8) as it stands (already noted above for $E$), but for thermodynamic equilibrium the signs are reversed.

In the economic world there may be some problems in having just a single function $T$ to denote intensive value, since value can be composed of different elements, such as expensiveness, demand, utility, rarity, skill, organization, as well as intellectual, artistic, cultural, moral, and hedonic value. Even in physical thermodynamics there are many supplementary functions of a potential nature besides the primary heat potential function $T$ or temperature and the work potential function $P$ or pressure, such as electromotive force, surface tension, and the countless chemical potentials for different material components in a heterogeneous system. There are numerous laws involving the different physical potential functions $T$, $P$, $e = \text{electrical potential}$, $\mu = \text{chemical potential}$, etc., according to which they are interchangeable. Thus we can anticipate many economic systems where one intensive value function might be just as inadequate for fully describing it as temperature alone when applied to other than the simpler thermo-mechanical systems. Then for money value, cultural or artistic value, moral value, hedonic value, etc., it may be essential to have separate notations similar to $e$, $P$, $\mu$, etc. There should then be reason to expect to find equations connecting those different forms of value, just as we have thermo-pressure equations of Clausius - Clapeyron [2, p. 134] or thermo-electric equations of Gibbs - Helmholtz [2, p. 172].

Incidentally, just as the historical order of development of physical entropy begins with $dH/T$ and leads to a state function where many variables other than $H$ and $T$ may enter, likewise the introduction of $-dH/T$ for negentropy does not preclude other economic variables, including those of a potential nature, as $e$, $P$, $\mu$, . . . from also entering into the determination of the negentropy.
Ecodynamic Third Law

To complete the analogy of the discipline of ecodynamics with that of classical equilibrium thermodynamics having fundamental laws, since the latter has a comparatively recent third law, namely that at absolute zero the entropy of any crystalline or regular substance is actually zero, we might attempt to formulate something which is comparable about entropy or negecentropy being zero in any completely valueless condition. Just as in the physical world we can come extremely close to zero absolute temperature even though it is not theoretically possible to attain it, in the economic world there may not be anything in such a state as to be "absolutely valueless." In thermodynamics the third law makes it possible to obtain precise measurements for the entropy, heat content and related functions, instead of their differences. A third law of ecodynamics resembling that in thermodynamics could play a similar role in obtaining numerical absolute values of various ecodynamic functions by integration from a state of zero ecentropy.

Quantitative Illustrations

A good way to make these two ecodynamic laws more plausible and widely acceptable is by numerous illustrations employing quantitative methods and suitable units. The few simple ones that follow are fairly rough and also rather elementary.

For the first law there are many very obvious examples. For instance, doing a thousand dollars worth of labor to repair a second-hand machine worth a thousand dollars makes its worth equal to two thousand dollars (we use the word "worth" in place of "value," since value here has that special intensive meaning). Again, suppose that a poorer country imports surplus food from another country, which is worth $1 units of its currency. Assuming that the food is offered at a bargain price, the importing country pays only 0.5 units where 0.5 < 1. Suppose that during the time of import the poorer country loses some workers due to migration, say 0.1 in number, and that the average worker would have produced in his lifetime $1 monetary units of labor profitable to that country, i.e., after deducting the cost of his wages. Then dE, or the capital gain from this combination of importing and emigration would be 1 - 0.5 = 0.5 units of its currency.

The real tests of the usefulness of the present formulation of ecodynamics will lie in productive applications of the second law. This will require some constructive thinking in comparing two different states by a succession of reversible processes. We start with a single problem, assuming at the outset that there is some kind of scale of absolute value which is analogous to absolute temperature. Just as the latter has a rigorous and precise thermodynamic definition, by making it the mathematically simplest possible function that will parallel the expression for the efficiency in a Carnot cycle, we can devote some study to devising a universally applicable scale for economic value. It is well known that the thermodynamic definition of absolute temperature may be completely identified with the absolute temperature scale that is defined by an ideally perfect gas. However, for value in ecodynamics, pending more investigation and reflection, we may tentatively try price in gold per unit of capital or labor for absolute value in the computation of negecentropy.

As a first example, suppose that over a period of time 1,000,000 agricultural laborers leave rural areas and migrate to the city for industrial jobs, and we wish to estimate (here just roughly) the change in negecentropy. We can measure the value of their labor by the average wages. If we confine the calculation of negecentropy to the laborers alone, apart from the economic society as a whole, assuming that they averaged $2,000 per annum per worker as agricultural workers and $5,000 per annum as industrial workers, the gain in negecentropy per annum, denoting each worker as a "labor unit," is then -1,000,000 labor units²/$5,000 which is offset by a loss in negecentropy per annum of -1,000,000 labor units²/$2,000, so that the net gain in negecentropy per annum will be -1,000,000 labor units²/$5,000 = -1,000,000 labor units²/$2,000 = 300 labor units² per dollar. However it may not be realistic to estimate the change in negecentropy by isolating the laborers from their economic society. To calculate the total gain in negecentropy in this labor shift we should take into account the economic deterioration in the areas from which the workers migrated (idle land, less trade, etc.) the expenses in relocation and education, the economic improvement in the industrial areas and also the profit by the employing industries which may appear as surplus wealth or more capitalization of those industries, etc., expressing the ecentropy or negecentropy in every such change by some wealth/value, employing more than one such term when necessary for any one of such changes.

Finding the negecentropy in a profit might be somewhat elusive until one realizes that we cannot have profit created out of nothing, as that would contradict the first law of conservation of total wealth. Otherwise expressed, negecentropy in a profit should not be expressed by -profit/value since profit is not really a form of economic energy like labor or capital. Instead we should calculate the increase in negecentropy when some product, say a unit of capital or labor having an original value of $1, which is the price that the seller paid when he bought or produced it, has acquired a higher value $2, which is what the buyer paid. Here $1 and $2 are expressed in money when the operations involved are just buying and selling at a profit. The
Ecodynamic Analogues of Chemical Components and Potentials

For further ecodynamic parallels to physical thermodynamics, we may consider what would be the
The question concerns the economic analogue of \( m_i \) and \( \mu_i \) so that we may deal with more than just a general and undifferentiated economic energy or capital, and open the way for possible new laws involving the interaction and coexistence of different economic “components.” Reserving the dimension of economic energy for capital in its various forms, the role corresponding to component \( m_i \) could be filled by various specific elements making up capital or labor. Thus for capital we may have machinery, land, natural resources, money, etc., and for labor we may have different nationalities, sexes, ages, degrees of training, etc. Countless situations involving these specific economic components \( m_i \) and specific capital potentials \( \mu_i \) will exist, and the problem will be to find their quantitative interrelations when they coexist in an economic system having different “phases.”

It will not be hard to find the economic analogue of different phases of the same component, since that could apply to variations of the same class of components in which it is possible to go fairly readily from one variation to another. For example, money deposited in savings bank accounts may be readily transferred into money deposited in commercial bank accounts, and vice versa, so that we have here two different phases of the capital component of money. It is an interesting problem to investigate the circumstances under which an economic analogue of a phase rule may be formulated by reasoning parallel to that employed by Gibbs in obtaining his celebrated phase rule [3, pp. 96-100].

With the introduction of \( m_i \) and \( \mu_i \) in ecodynamics we must also bear in mind this semantic difference from the \( m_i \) in physical thermodynamics, namely that in the latter the components or masses \( m_i \) are not different forms of energy, even though they are bearers or containers of energy, whereas using \( m_i \) in ecodynamics as a “component of capital” gives them the double role of being economic energy while behaving exactly as a material variable. To express this somewhat differently and more explicitly, in physical thermodynamics there are different forms of energy \( E_i \) and different components \( m_i \), where the \( m_i \) are, so-to-speak, definitely “nouns,” whereas in ecodynamics the \( m_i \) are employed as nouns only in the mathematical sense of being separate variables in the equations of equilibrium states corresponding to those in physical thermodynamics—in economic reality they are “adjectives” which describe the various forms of capital or economic energy. This difference arises because we must maintain an energetic, rather than material interpretation of capital in order to preserve the parallelism with the first two laws of thermodynamics which are expressed in terms of energy only. This possible ambiguity in the interpretation of \( m_i \) in ecodynamics should be more than compensated by an enrichment in the entirety of that science, where countless specific situations can now be studied using the variable \( m_i \), as is apparent from the science of thermodynamics before and after Gibbs.

Non-equilibrium Ecodynamics

At the present stage in this suggested new discipline of ecodynamics, we have confined the preceding remarks on possible economic parallels to equilibrium thermodynamics. But if there is a successful application of the foregoing we might be interested in developing some economic parallels to the non-equilibrium thermodynamics which was founded and developed in the period around 1930 to 1950 by L. Onsager and I. Prigogine and expounded in textbooks by I. Prigogine [5], S.R. de Groot and P. Mazur [6], and D. Fitts [7]. Also that non-equilibrium thermodynamics is far from being completely general, since it is concerned mainly with “near-equilibrium” states, and still further extensions have been developed more recently. By analogy to non-equilibrium thermodynamics which deals with non-static systems having fluxes or flows of matter, energy, entropy, etc., we should expect a non-equilibrium ecodynamics to deal with fluxes of capital, money, labor, etc. Corresponding to physical forces and chemical affinities which induce flows of heat, electricity, mass, and progression of chemical reactions, we should have economic forces that induce fluxes of capital or labor and progress of economic operations and changes. In connection with physical forces there are coupling coefficients which connect the forces with the flows, and Onsager’s fundamental law of reciprocity which applies to most cases in which these coupling coefficients are constant, all of which may be readily expected to have ecodynamic analogues. Corresponding to equations of entropy flow there would be equations of negentropy flow and conditions for steady states and stability which would involve ecodynamic coupling coefficients. Finally, just as the Onsager reciprocity laws enable us to derive many inter-related physical effects, e.g., thermo-electric, thermodiffusive, electro-chemical, etc., we may be able to develop interesting economic effects, expressed by equations involving economic potential or value functions of different types in conjunction with various kinds of capital or labor flow (e.g., monetary, scientific, artistic, and intellectual values in conjunction with the fluxes of financial capital and special forms of mental labor).
REFERENCES


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