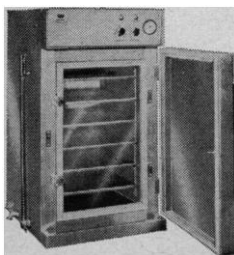


PROBLEM
How to:
A. Maintain 37.5°C.
B. Maintain 98% RH
C. Maintain 5% CO₂

...solved with National CO₂ Incubators

- A.** Most microorganisms grow at temperatures around 37.5° Centigrade. However, the various optimums range from 18 to 80° C. And, National CO₂ incubators provide closest possible control throughout this range with uniformity as close as 0.2° and a safety control which precludes loss of cultures and time.
- B.** For accurate measurement of growth of microorganisms, control of moisture content is essential. Humidities close to 98% RH without excessive condensation are possible in National CO₂ incubators. Cultures can be incubated without fear of medium drying or extreme weight fluctuation.
- C.** An increasing number of microorganisms show accelerated growth under higher than normal concentrations of carbon dioxide. While five to 10% CO₂ is the most widely accepted concentration, varying percentages to 20% are often necessary. National CO₂ incubators offer close, metered control of CO₂ from 0-20 percent.



*For complete
information
write:*



NATIONAL APPLIANCE CO.
P. O. Box 6408
Portland 23, Oregon

Eastern Representative
H. REEVE ANGEL & CO., INC.
9 Bridewell Pl.
Clifton, New Jersey

now given, do for mathematics courses.

If what has been said about the need for such a course seems reasonable, then we should proceed to make such a unified presentation. There remains a problem as to just what to call such a course. I submit that an appreciable part of such teaching has been given for some years at various schools under the name of "dielectrics" courses. It therefore seems reasonable, although perhaps not entirely unobjectionable, to suggest that the name "electromagnetics of matter" be used for the broader unified discipline which includes the study of the interaction of matter with electric and magnetic fields. This would release the restrictions upon the study of dielectrics which previously held—restrictions which precluded study of the effects of other than "adiabatic" electrical polarization and dipolar influences. This release of the restrictions would be an advantage, for we now know that electronic processes such as conduction, incipient corona, avalanching, and ionization play major roles in real materials, roles that cannot be incorporated in the older, classical considerations.

The phenomena of polarization, excitation, conduction, and magnetization would be the essence of the newer, unified discipline.

HERBERT A. POHL

*School of Engineering, Princeton
University, Princeton, New Jersey*

On Cause and Effect in Biology

In the thoughtful article on cause and effect in biology [*Science* 134, 1501 (1961)], Ernst Mayr mentions some difficulties presented by the classical concept of final cause. He acknowledges that this concept was introduced by Aristotle in order to explain the goal-directed activities of organisms and to account for the over-all harmony of the world. However, the definition of final cause which Mayr quotes and seems to accept—namely, "the cause responsible for the orderly reaching of a preconceived ultimate goal"—is not easily harmonized with the letter of Aristotle or with his natural realism.

Aristotle frequently refers to the final cause as that for which or for the sake of which something is made or done. He defines the final cause as the goal of action and says that it is recognizable as such when we see that it is regularly

Liquid Helium Dewars for Maser Research



Solid state researchers in the nation's scientific centers rely on Hofman Laboratories for liquid helium dewars and related low-temperature equipment. Hofman stainless steel dewars are used in microwave spectrometry, superconductivity studies, nuclear research, low temperature chemistry, solid state physics, free radical research, etc. Hofman dewars have retained small quantities of liquid helium for longer than 280 hours in tests conducted at a leading government laboratory. Remember . . . Hofman stands for high standards at low temperatures.

SEND FOR
**NEW
CATALOG**



Also: Containers for Liquid Oxygen, Nitrogen, Hydrogen and Helium. Accessory Low Temperature Equipment.

hofman

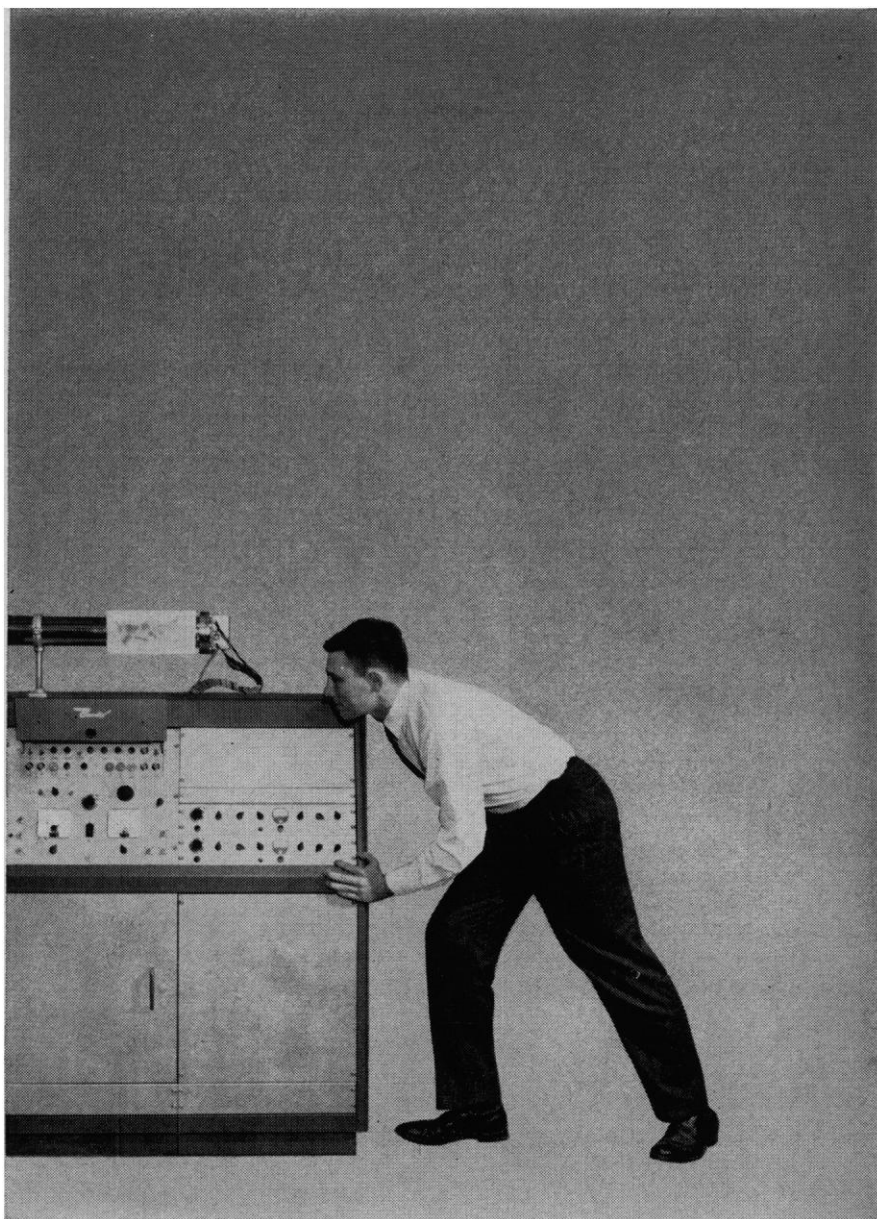
LABORATORIES, INC.
5 Evans Terminal, Hillside, N. J.

Representatives in principal industrial and military centers.

attained by either natural or purposive agents and is something worth acting for—that is, something better than what was before the action took place. According to Aristotle, the cause at work for the orderly reaching of a goal is the efficient cause, not the final cause. In order to attain a goal regularly, not by accident, the efficient cause must be oriented toward the goal and act for it, but it need not have any knowledge of the goal. Man is the only natural being capable of acting for a preconceived goal which he understands as such and freely chooses to pursue. The activities most characteristic of man are purposive in this sense, but man performs many other activities which are naturally determined, not freely chosen, some of which require sense knowledge for direction to the goal, as in maintaining balance, while others, such as digestion, do not require knowledge of the goal.

Goal-directed action is more manifest and more marvelous in living organisms than in the chemical elements and compounds, but even these tend to preserve and protect themselves and to promote the general harmony of the world. Organisms are composed of elements and compounds united in a very complex and orderly system, and many of their goal-directed activities, as Mayr points out, have an analyzable physicochemical basis. However, it is by no means clear that physicochemical activity is purely mechanistic, and much less clear that the behavior of an organism is mechanistic. We understand machines better than organisms, and we know that a machine is not a natural unit but an artifact made from suitable but not specifically determined materials joined together by the maker working from without and aimed or directed to his goal. On the other hand, an organism is a natural and primary whole, not a mere aggregate, with complex but highly specific composition of parts joined and unified from within, and possessing an active nature by which it preserves and perfects itself and reproduces its kind. Mayr uses the word *individual* in such a broad sense that he includes both an organism and a machine, as if there were no essential differences, and then concludes that the purposiveness of the organism is purely mechanistic.

How organisms came to be as they are is a very interesting question. Mayr notes that the Aristotelians and their successors asked themselves what goal-directed process could have produced such a well-ordered design in nature.



SHHH! METALLURGY IS "BORROWING" THE MASS SPEC FROM PHYS CHEM

This could happen at your laboratory. Bendix makes the time-of-flight mass spectrometer to do a multitude of research and analytical jobs. It's compact, easy to move, a breeze to maintain, and about as versatile as the user's imagination. Five basic inlet systems help to make this versatility possible: the molecular leak inlet, the fast reaction inlet, the hot filament inlet, the Knudsen cell, and the vapor phase chromatograph. To be more specific, the Bendix® mass spec will do almost any routine analytical problem, plus all of the following:

- Monitoring chromatograph output
- Determination of vapor pressures
- Determination of heats of vaporization
- Free radical studies
- Solids analysis
- Thermal decomposition
- Shock tube research
- Appearance potential measurements
- Fast reaction studies
- Photoionization studies
- Molecular structure studies
- Photochemical reaction studies
- Negative ion analysis
- Pilot plant studies
- Combustion analysis
- Plasma jet analysis
- Rocket jet analysis
- Ion-molecule reactions

Here's versatility that makes a mass spec really pay off. Isn't this what you want in your lab? Write Dept. C-3 at 3130 Wasson Road, Cincinnati 8, Ohio.

Cincinnati Division



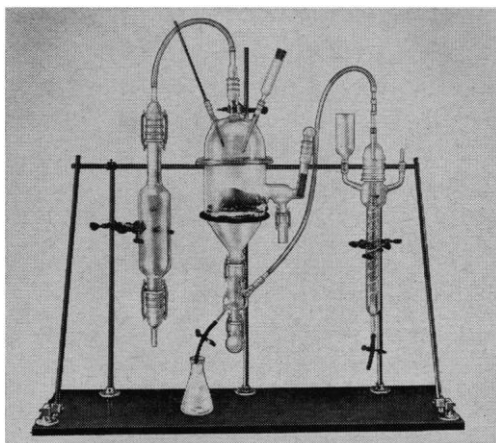
new concepts in scientific glassware

METABOLISM CAGE

For Carbon-14 tracer studies in rats and mice.

The only available high precision apparatus for quantitative metabolism studies. It offers total control of input and collection for metabolic processes. The design features a unique method for separating feces and urine, and for virtually total absorption of expired CO_2 . A feeding system prevents animals from bringing food into the system. The Delmar Metabolism Cage simplifies collection of precise data. It is especially convenient to use and easy to clean. Comes complete in 3 cage sizes: 3½" cage for mice, DS-7000; 6" cage for rats, DS-7005; 8" cage for guinea pigs, DS-7010.

For complete data, ask for Biological Glassware Bulletin S.



See this equipment in Booth 51 at the FASEB meeting April 16 thru 19th.



Delmar
SCIENTIFIC LABORATORIES

317 MADISON ST., MAYWOOD, ILL.

A SUBSIDIARY OF COLEMAN INSTRUMENTS, INC.

For full details
on Delmar's new
MITE-O-WARE line
ask for Catalog 61-MS.



GAS DENSITY DETECTORS

by **GOW-MAC** FOR GAS ANALYSIS
AND VAPOR PHASE
CHROMATOGRAPHY

**QUANTITATIVE
RELIABILITY**

Write for Bulletins
on Thermal Conductivity
Detectors, Hot Wire Filaments
and Power Supplies

	AREA FACTOR	Q	CALC. %	TRUE %	ΔE %
BENZENE	6.36 × 1.56	9.92	33.78	33.40	+0.38
M-XYLENE	7.10 × 1.36	9.65	32.83	33.20	-0.37
PSC	7.55 × 1.30	9.81	33.40	33.42	-0.02

1.0μL CHARGE
COL. 773 - 96°C
53/70 ML/MIN. N₂ FLOW
N₂ PRE-HEAT - 100°C

Available with hot wire or thermistor detector elements, brass or stainless steel blocks. As detector elements are up-stream of sample and there are no moving parts, high reliability is assured... no coking, coating, contamination or corrosion. For complete data, request Bulletin GADE 461.

GOW-MAC INSTRUMENT COMPANY

100 KINGS ROAD, MADISON, N. J., U. S. A. • Telephone: FRontier 7-3450

GAS ANALYSIS INSTRUMENTS SINCE 1935

It is no secret that they interpreted the evidence as pointing ultimately to divine wisdom. Human art does not suffice to produce a natural thing, nor does any man know exactly how natural things are produced now, or how new species were produced in the past. We are gradually learning more about natural processes, as Mayr's article shows, but he does not enlighten us very much by appealing to natural selection and excluding "Nature" or "God," who created a superior design or plan. Evolutionary adaptation may not require a special divine intervention, but it does seem to require more than chance variation and fortuitous preservation of the fittest.

WILLIAM H. KANE

*Albertus Magnus Lyceum,
River Forest, Illinois*

Ernst Mayr emphasizes that the phenomena of development and evolution, which were always the domain of teleologic concepts, are actually "teleonomic." This term is supposed to cover purposiveness programmed by a preformed code of information contained in DNA. Since it seems that this code was formed simply by a long historic process of an interplay between chance events (in the form of mutations) and natural selection, the "purposiveness" programmed by this code and appearing on the level of an individual is purely mechanistic. In conformity with the opinion now prevailing among biologists that there is no evidence for "plan and design" in nature, Mayr rejects any form of Aristotelian teleology as it appeared in the nonscientific ideologies of vitalism and finalism of Driesch, Bergson, and Lecomte du Noüy.

Without entering into a discussion of the philosophical implications of this view, I would like to point out, from the sense of historical justice, that vitalism and finalism were not so unscientific as one is led to believe. When Driesch, Bergson, or Lecomte du Noüy spoke about entelechy, élan vital, or telefinalism, they wanted to designate by one word an unknown x that presides over biological processes, unable as they were to convince themselves that mechanistic physics is a sufficient basis for a biological theory. It was not realized at that time how well suited the language of information theory is to formulation of the problems of biology. Had, for instance, Driesch realized that, from the viewpoint of the

second law of thermodynamics, biological phenomena are distinguished by a high degree of improbability, and had he known that thermodynamics was to be made the backbone of information theory of virtue of Szilard's recognition of the correlation between information and entropy, he could then have spoken about "negative entropy" instead of "entelechy" and would thus have avoided being accused of autonomizing biology. Of course, even then Driesch would probably have spoken about entelechy, Bergson, about *élan vital*, and Lecomte du Noüy, about telefinalism simply to emphasize that the manner by which biological open systems increase their information content is largely unknown. These men would probably have pointed out that there must be some unknown factor involved in the processes of development and evolution, of the type postulated, for example, by Prigogine and Wiame [*Experientia* 2, 451 (1946)], which would come close to what they meant by those specific terms they chose for the unknown *x*. In any case, it was mainly because Driesch, Bergson, and Lecomte du Noüy were not dogmatists, because they looked upon the phenomena of life as something which can be gradually revealed in a never-ending inquiry rather than by a simple reduction to the physics of the day, that they subscribed to vitalism and finalism. This, to me, seems to be the crucial point.

The word *teleonomy*, suggested by Pittendrigh and used by Mayr, was coined on the opposite grounds—those of a dogma, which, moreover, rests upon a mere hypothesis. It is an established fact that development is programmed by an inherited code. But the assumption that this code is only a result of the interaction between the chance events of mutation and natural selection is an unproved hypothesis. It is dangerous to accept this hypothesis as a dogma only because, at the present time, we have no idea about the real mechanism. It means closing the door where it should have been left open. It is true that, at the present time, the only safe abode for theories of evolution is in Darwinism, but one should not assign to this abode more territory than it can cover. With all due recognition of the greatness of Darwin's achievement, we cannot remain blind to the fact that not a single step in the evolutionary mechanism has been clarified. Evolution means primarily an increase in the content of information in the code of DNA, but natural selection

BURRELL

... for Balance Satisfaction

STANTON UNIMATIC



SINGLE PAN
BALANCE

- Complete Weighing In Seconds
- Easy Access Front Opening
- Convenient Grouping Of Controls, Pan, Counter Indicator And Graticule Screen Simplify Operation
- Beautiful Design, Sturdy Construction

The Stanton Unimatic Single Pan Balance, Model CL1, is a completely new precision balance. It is constructed on the constant-load principle thus avoiding errors due to inequality of lever arms, and slight variations in sensitivity due to major changes in load. Synthetic sapphire knives and planes give longer life and the grouped controls at bench level simplify operation.

Features include air damping, full external weight loading to 200 grams without use of loose weights or extra dials plus numerous other important advantages.

Cat. No. 2-567-51...750.00

... for Balance Satisfaction

BURRELL CORPORATION

SCIENTIFIC INSTRUMENTS AND LABORATORY SUPPLIES
2223 FIFTH AVENUE, PITTSBURGH 19, PA.

means only the elimination of an error in information, or mutation (in the most favorable case, only a modification of information), not an increase in the quantity of information. Correcting a misspelled word or substituting one word for another one is, after all, something quite different from writing down a sentence, an article, a whole book.

For these reasons it seems to me that a teleonomic concept of biological end-directed processes in development and evolution is not any more "scientific" than a teleologic concept. It is only more dogmatic. The use of mechanical

models for the representation of biological problems had in the past a rather comical effect on the thinking of a certain segment of scientific circles. When the great successes of mechanistic physics became obvious, concepts of free will and purpose disappeared from the writing and the theoretical (but not the practical) thinking of biologists. It was only when engineers constructed devices with prefabricated purposeful behavior in the form of computing machines, electronic brains, and so on, that the same scientific public felt that it may be, after all, legitimate to speak again about purposeful behavior, provided

that we are machines with the information code built in by shuffling and reshuffling and by natural selection.

Of course, a man-made machine can be of excellent pedagogical value for demonstrating a point in physiology, but to expect that one can derive the principles of biological causality from these man-made models rather than from the study of biological systems themselves may seem rather far-fetched to those who are not dogmatically set upon mechanical models. The following proposal may illustrate the situation: When the biologist borrowed from the engineer the intellectual capital for the construction of his (the biologist's) theory, he might as well have repaid the engineer by suggesting that the latter construct the machines by a simple process invented by the biologist—namely, by shuffling and reshuffling and by selection—and then await the engineer's answer.

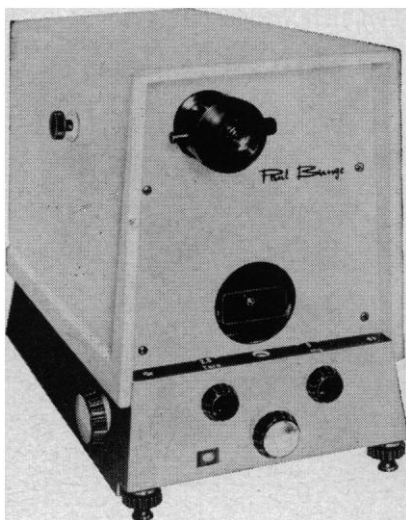
SILVIO FIALA

Department of Pathology, Columbia University, and Francis Delafield Hospital, New York, New York

The very interesting article by Mayr (1) seems to call for some comment. Mayr distinguishes between an unacceptable and an acceptable form of finalistic explanation; the former is teleological or vitalistic, the latter "teleonomic," or, in the phrase I have used, "quasi-finalistic." But having made this distinction between types of hypothesis, Mayr proceeds to assert that there is a corresponding cleavage between types of phenomena. "The development or behavior of an individual," he writes, "is purposive" [that is, in the acceptable sense], natural selection is definitely not"; and by "is not" he seems to mean "cannot be," since in another place he writes, "Historical processes, however, can *not* act purposefully." I have for some years been urging that quasi-finalistic types of explanation are called for in the theory of evolution as well as in that of development (2).

If any process is set going (for example, if two chemical substances are allowed to start reacting with one another) it will eventually reach some end. The question of "finalism" arises when there is something interesting about the end—in particular, when it is both complex and definite in character. We then have three main types of explanation available: (i) that the end itself acts as a cause, directing the process so that it terminates at the pre-

The Ultimate in Weighing Precision



**0.000000lg
(0.1 μ g)**

with the

BUNGE "25UM" ULTRA-MICRO BALANCE

CAPACITY:

2 mg optical scale
9 mg automatic weight loader
2.5 g built-in tare weights
2.511 g Total

SENSITIVITY:

0.1 μ g
Estimations to $\pm 0.01 \mu$ g

ILLUMINATION:

An affixed temperature controlled tungsten light source evenly illuminates the read-out device

OUTSIDE LOADING:

By automatic pan
extraction through front panel

TEMPERATURE STABILITY:

Triple housing of heavy gauge metal
and double heat absorbing glass

PRECISION + RELIABILITY = BUNGE

Pfaltz & Bauer, Inc.

EMPIRE STATE BUILDING, NEW YORK

CHickering 4-6485

SCIENTIFIC INSTRUMENTS • CHEMICALS
BIOLOGICAL STAINS • ESSENTIAL OILS

SPECIALISTS IN BECKMAN INSTRUMENT SALES AND SERVICE, • MICROSCOPES, BALANCES AND ALLIED EQUIPMENT

LEA & FEBIGER

1962 BOOKS

Radioactive Isotopes in Medicine & Biology

QUIMBY & FEITELBERG: I. PHYSICS

By EDITH H. QUIMBY, Sc.D., and SERGEI FEITELBERG, M.D., College of Physicians and Surgeons, Columbia University, New York.

Instrumentation and Laboratory Methods. In this new, complete and authoritative presentation, Dr. Quimby gives, first, a complete picture of radiation, radioactivity, nuclear reactions and nuclear fission, how to avoid radiation hazards, and disposal of radiation waste. Dr. Feitelberg describes, in detail, instruments available and measurements to be made with them.

New. About 280 Pages. 75 Illustrations

SILVER: II. MEDICINE

By SOLOMON SILVER, M.D., The Mt. Sinai Hospital and College of Physicians and Surgeons, Columbia University, New York.

Clinical Applications. From an extensive personal experience, Dr. Silver presents, in this new and equally authoritative work, the many diagnostic and therapeutic uses of all radioactive isotopes used in clinical practice today. In addition to diagnosis and treatment of the thyroid gland, full consideration is given to the use of isotopes in other disease entities.

New. About 300 Pages. 49 Illustrations

► Both Books Ready in April

LEA & FEBIGER

Washington Square
Philadelphia 6, Pa.

Please send me, when ready, books circled above or listed in margin below.

I will return books or pay for those I keep within 60 days of their receipt.

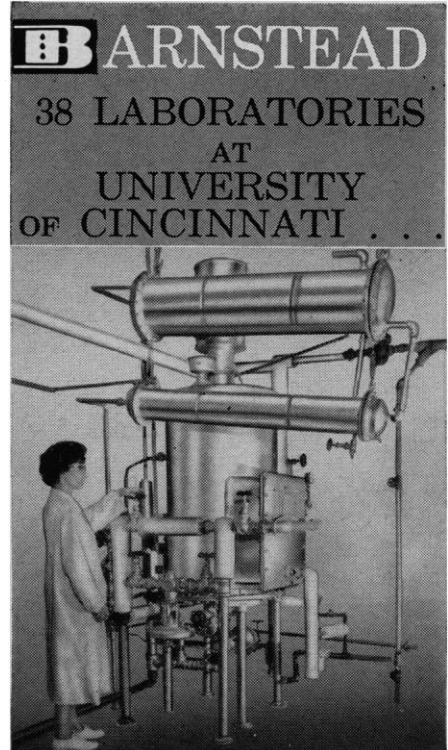
NAME

ADDRESS

CITY ZONE ... STATE
Sc. 3-16-62

determined end state; this is Aristotelian finalism, which we reject because it involves a concept of causation quite outside our accepted range of ideas; (ii) that some nonmaterial agency directs the process to the predetermined end; this is "vitalism," which we also reject; (iii) that the end state of the process is determined by its properties at the beginning; this is "mechanism," and our recent experience of such mechanical systems as computers has led us to realize that it is a more powerful type of hypothesis than it had previously appeared to be. We can set up a process in such a way that it will reach an assigned end state by building into the initial situation a set of conditions which act as a "programme," and by providing suitable negative-feedback relations to bring the process back onto the right course if it should diverge from it. Conversely, if we find any process to be characterized by a programme and feedbacks, we can deduce that it will proceed towards some end which should in principle be ascertainable from the nature of the programme and the feedbacks (the degree of precision with which the end is determined will depend, of course, on the particular characteristics of the programme and feedbacks).

Mayr accepts the theory (3) that ontogenetic development depends on a quasi-finalistic mechanism of this type, the programme and feedback relations both being incorporated in the genotype which has been moulded by natural selection. But there is nothing in the nature of such quasi-finalistic mechanisms which makes it impossible to suppose that the evolutionary process itself is also of this kind. It is obviously characterized by a programme, that involved in the theorem of natural selection. This in itself suffices to determine, to a certain degree, the nature of the end towards which evolution will proceed; it must result in an increase in the efficiency of the biosystem as a whole in finding ways of reproducing itself. And there are, surely, many feedback relations which will serve to determine ends in a more precise fashion. The two to which I have previously directed attention are (i) that involved in the fact that an organism's behavior influences the nature of selection pressures which will operate on it (loosely, an animal selects its environment before its environment selects it), and (ii) that arising from the fact that selection of previous generations for stability or flexibility of development will influence the type of



DEPEND UPON BARNSTEAD FOR PUREST DISTILLED WATER ...AUTOMATICALLY

Student research facilities at the chemical and metallurgical engineering departments of the U. of C. include 14 major instructional laboratories, 10 large and 14 small research laboratories. All of them (38) are served by a Barnstead SS-50 Still . . . producing water of the highest purity needed for analytical work.

Located on the top floor of the chemistry building, the Barnstead SS-50 produces distilled water at the rate of 50 g.p.h. . . . automatically meeting all distilled water needs with two storage tanks integrated into the system. Since the Still is self-starting, self-stopping and self-flushing (steam pressure is likewise automatically controlled), it requires no attention whatsoever from university personnel. The Still operates on an average of 12 hours per day, seven days a week. Since its installation (November, 1960), the Still has performed very satisfactorily without inspection or maintenance.

Why not get the benefit of Barnstead's 84 years of engineering experience in producing all types of water purification equipment. Catalog "G" describes Barnstead Water Stills and Catalog #160, Barnstead Mixed-Bed, Two-Bed, and Four-Bed Demineralizers. Write today.

Barnstead
STILL AND STERILIZER CO.
49 Lanesville Terrace, Boston 31, Mass.

SCIENCE, VOL. 135

phenotypic effect likely to be produced by new mutation. There are certainly many others. For instance, increasing phenotypic diversification of a population to fit it to deal with different habitats will eventually be counterbalanced by the development of barriers to interbreeding of the different varieties.

It seems to me that it is becoming inadequate to point out, as Mayr does, that natural selection is not purposive. In itself it is of course no more purposive than is the process of formation of interatomic chemical bonds. But just as the latter process is the basic mechanism underlying the protein syntheses which are integrated into the quasi-finalistic mechanism of embryonic development, so natural selection is the basic mechanism of another type of quasi-finalistic mechanism, that of evolution. The need at the present time is to use our newly won insights into the nature of quasi-finalistic mechanisms to deepen our understanding of evolutionary processes.

C. H. WADDINGTON

*Institute of Animal Genetics,
University of Edinburgh, Scotland*

References

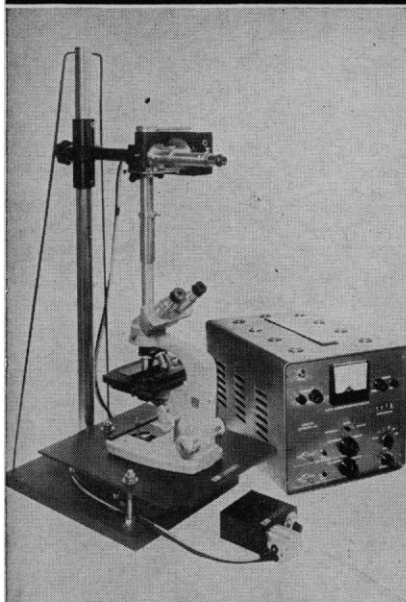
1. E. Mayr, *Science* **134**, 1501 (1961).
2. C. H. Waddington, *The Strategy of the Genes* (Allen and Unwin, London, 1957); *The Nature of Life* (Allen and Unwin, London; Atheneum, New York, 1961).
3. ———, *Organisers and Genes* (Cambridge Univ. Press, Cambridge, England, 1940).

Father Kane would have a valid point if he were right in his belief that the "preservation of the fittest" was purely "fortuitous." The evidence is, of course, all opposed to this assumption. Natural selection is merely another word for differential reproduction, and the probability of successful reproduction is not strictly a matter of luck but is correlated with properties of the genotype. Both the observational and the experimental evidence for this is quite overwhelming. Naturally, reproductive superiority is true only in a statistical sense, and this is what makes the understanding of natural selection so difficult for one who is used to typological thinking. This is why the term *survival of the fittest* is so inappropriate and not used by modern evolutionists.

Evolution is a two-stage phenomenon. The first stage is the production of an enormous variety of different genotypes through mutation, recombination, and so on, and at this stage accident is rampant. The second stage, the selection of those genotypes that give rise

16 MARCH 1962

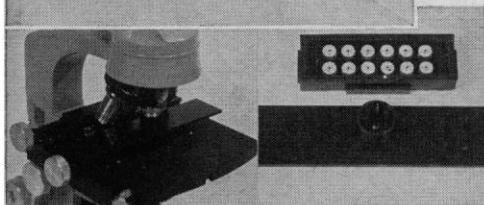
CANALCO ANALYZERS TAKE THE LABOR OUT OF LABORATORY



IN MICRO-CHEMISTRY the new Ultra-Microspectrophotometer

Ultra-Microspectrophotometer gives fully automated quantitation, in both the visible and the U.V. for

- cell components
- tissue extracts
- fluorescence
- micro-liquids (10-50 ul)
- interference microscopy
- autoradiographs
- micro-chromatography (10 ul flow cuvettes)



Two Models

1. Digital Ratio Reporter, for one and two wavelength analysis
2. Absorption Curve Computer, for spectral curve recording

Micro-chemical Cuvettes

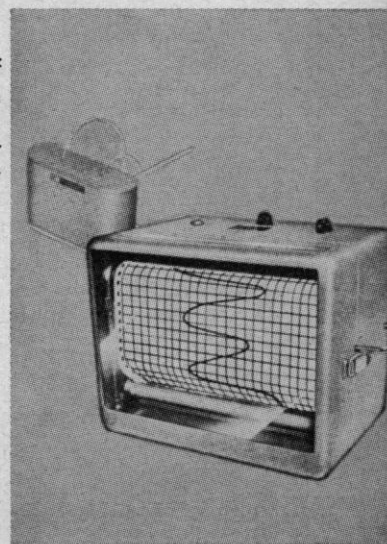
... IN FRACTION ANALYZING

Base Compensating U.V. Flow Analyzer

For automatic location and measurement of ultraviolet-absorbing materials in flow, with flat base line and full sensitivity maintained in the presence of U.V.-absorbing solvents. For use in column chromatography and other flow systems.

FIVE MODELS for . . .

- broadly absorbing materials
- specific wavelengths
- monochromatic density studies
- 260/280 ratios
- simultaneous monitoring of one to eight columns at one or more wavelengths.



**CANAL
INDUSTRIAL
CORPORATION**

4935 Cordell Avenue, Dept. E-33
Bethesda, Maryland

Freeing the Scientist for Science

to the next generation, is to a large extent controlled by the quality of these genotypes. Genetic recombination puts together in each generation unique novel gene combinations which in turn are exposed to natural selection in the next generation. This is why geneticists like Muller and Fisher have emphasized the remarkable capacity of natural selection to make the highly improbable in the course of time a certainty, and this is why evolutionists like Simpson and Dobzhansky have quite rightly used the epithet "creative" for natural selec-

tion. Nothing is known, in the living universe, the evolutionary interpretation of which is inconsistent with the theory of natural selection. As a matter of fact, natural selection is not even a theory but, as differential reproduction, an easily demonstrable universal phenomenon.

I plead guilty to a less than precise definition of Aristotle's "final cause." But then Aristotle's own ambivalence makes such a definition a tough task. Aristotle used *final cause* both for the completed result of a process (obvious-

ly not a cause in the modern sense nor even strictly an *aition* in Aristotle's sense) and for the goal which was incipient in the process from its beginning. The latter meaning dominated medieval philosophy, as I see it, and has dominated finalistic ideologies ever since. It was the object of my discussion to show that there is a fundamental difference between those seemingly goal-directed processes that are based on a built-in program (teleonomic) and those that are not (teleological).

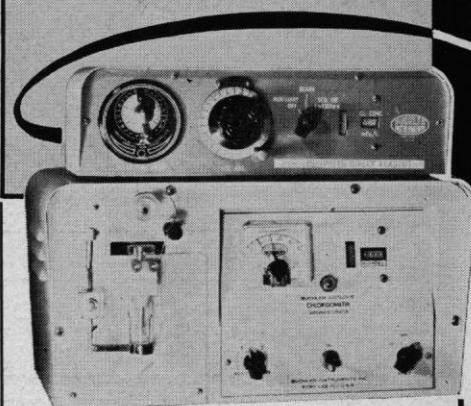
Fiala, by stating that I had labeled the phenomena of development and evolution teleonomic, by saying that "not a single step in the evolutionary mechanism has been clarified," and by implying that the biologist has derived his ideas on causation from a study of machines rather than of biological systems, reveals a mode of thinking so far removed from my own that we cannot, in the Letters column of *Science*, achieve a common basis for discussion. It is true that Driesch and other vitalists of his day had been provoked by exceedingly naive attempts to describe biological processes in grossly mechanistic terms. Modern vitalists cannot make this accusation against modern biologists. Indeed, one of the conclusions of my recent article was that the simplifications of classical mechanics were not applicable to biology.

In the case of the points raised by Waddington, it is evident that there is no disagreement as to facts, nor even a disagreement as to emphasis, but merely one of classification. Ultimately, the difference of opinion between Waddington and myself boils down to the question of what is deterministic. Waddington stresses the unquestioned fact that the complete interdependence of the gene-physiological and developmental processes sets severe limits to the evolutionary potential. No evolutionist would expect a line of tetrapods to develop suddenly a six-legged side line. A line of terrestrial animals that has become aquatic or has acquired the power of flight will go its merry way until it has either reached near-perfection in the adaptation to this new adaptive zone, or invaded a new zone, or become extinct. No good biologist would deny the pseudofinalistic nature of such processes. It was precisely observations such as these which led earlier biologists to sponsor theories of orthogenesis. And yet any detailed analysis of a single evolutionary line demonstrates the complete absence of any truly finalistic aspect to these

Now You Can Read Chloride Concentration Directly In Milliequivalents...

with the

Buchler DIRECT READER ATTACHMENT*



for the COTLOVE CHLORIDOMETER® AUTOMATIC TITRATOR

If it has an end point . . .
the CHLORIDOMETER will
find it more quickly,
accurately, automatically . . .
in 6 steps and in less than
60 seconds!

DIVERSIFIED FOR ALL
CHLORIDE TITRATION
APPLICATIONS

The DIRECT READER automatically subtracts the reagent blank time and presents the net titration time in milliequivalents per liter on a digital register.
Easily attached to Any Cotlove automatic chloride titrator.

- Does not diminish the reliability and accuracy of the original automatic titrator. Variation with 0.1 ml samples $\pm 0.05\%$
- Eliminates calculation errors and tedious labor. SPEEDS OUTPUT!
- Inexpensive—pays for itself quickly in any busy laboratory.
- Full instructions on installation and calibration supplied.
- Connections made quickly and easily. May be installed free of charge at factory, with only shipping costs to pay.

Ref. "Automatic Titration with Direct Read-out of Chloride Concentration," *Clinical Chemistry*, Vol. 7, No. 3, June, 1961, pp. 285-291.

ANOTHER "FIRST" FOR
BUCHLER INSTRUMENTS, INC.

*Developed in the Department of Pathology, the Clinical Center, National Institutes of Health, Bethesda, Md.

SEND TODAY FOR
COMPLETE DESCRIPTION

Direct Reader—Bulletin S 4-2050
Chloridometer—Bulletin S 4-2000

LABORATORY APPARATUS



PRECISION INSTRUMENTS

BUCHLER INSTRUMENTS, INC.

514 West 147th Street, New York 31, N. Y.

ADirondack 4-2626

changes, no matter how regular they appear to be. But evolution is usually very capricious. Evolutionary lines may become stagnant, the trends may change their direction, the rates may accelerate for one organ and slow down for another, and one is forever impressed by the evident opportunism of evolution. When lines split it is quite impossible to predict how similar or different the independent lines will become in due time. In other words, one can often specify for an evolutionary line what it will not do (I would not expect any evolutionary line of cats to develop horns), but one cannot specify for a line what it will do.

Waddington states that if any process is set going, it will eventually reach some end. As far as evolution is concerned, he claims, only three ends are possible. Here I disagree with him. In addition to the three possibilities admitted by Waddington, there is a fourth one—namely, that the end state of the process is determined neither by the end itself nor by a supernatural agency nor by the properties at the beginning but by a general principle (natural selection) interacting successively with materials ever new in every generation.

Perhaps the difference between Waddington and myself is that we define *process* differently. He says "that the end state of the process is determined by its properties at the beginning; this is 'mechanism'." Where is the beginning and the end in a concrete case? Is the development of man from a primitive protozoan such a process? Does the development of man from marine prechordates qualify, or the development of man from primitive anthropoids? As soon as we list such illustrations, it becomes apparent how dangerous it is to say that "the end state of the process is determined by its properties at the beginning." The development of an adult organism from a fertilized or unfertilized egg cell can be considered a single process. For this, all that Waddington says about the quasi-finalistic nature of this process is correct. On the other hand, it seems inescapable to me that the change in an evolutionary line is not such a process—its end is not determined by its beginning and it is not finalistic, nor even quasi-finalistic. To my mind, the similarities between the changes in an evolutionary line and those of a developing individual are pure analogies. Surely there are evolutionary feedbacks, surely the biosystem tends to increase in efficiency (but there are countless ways

of doing so), surely behavior plays a great role in evolution, but it seems to me that nothing is gained and much is lost by trying to imply that the changes in an evolving evolutionary line are of the same nature as those in a developing individual. I am sorry that somehow I cannot see how one can designate as "quasi-finalistic" a phenomenon as unpredictable as evolution.

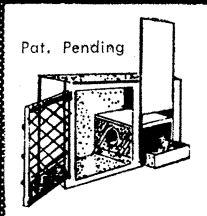
ERNST MAYR

*Museum of Comparative Zoology,
Harvard College,
Cambridge, Massachusetts*

Resistance to Discovery

The article "Resistance by scientists to scientific discovery" by Bernard Barber [*Science* 134, 596 (1961)] is provocative. Could it be that such resistance is a proper and desirable function of the scientist? To distinguish between fact and fallacy can be difficult. A scientist's bias toward acceptance or rejection can be influenced by some or all of the factors noted by Barber. It is possible for a correct new development to be introduced with insufficient

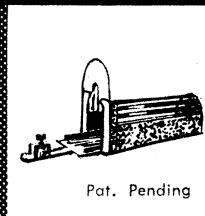
For CAGES and LABORATORY EQUIPMENT Specify PORTER-MATHEWS Over a century of experience, blended with modern manufacturing facilities



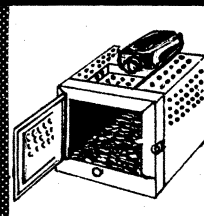
CAT CAGE



RACK UNIT



RAT RESTRAINER



RAT, GUINEA PIG CAGE

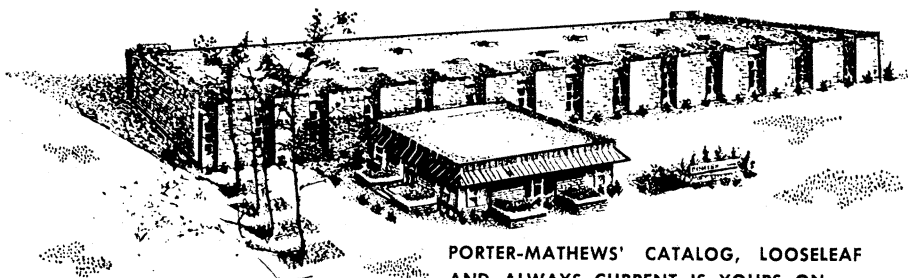
In this vast new Princeton Plant, Porter-Mathews' century-odd, metal manufacturing experience has been combined with the most modern manufacturing facilities. Porter-Mathews' small animal cages and laboratory equipment, both deluxe and custom, are sturdily built . . . designed for efficiency . . . made to meet the most rigorous requirements of those we serve.

Our design and developmental staff is available for consultation to all interested companies and institutions.

CAGES . . . Mice to monkeys and chickens . . . and RACKS, of stainless steel, galvanized and aluminum.

RESTRAINERS, STERILIZING CASES, AUTOPSY TABLES, FOOD FEEDERS and WATER TUBES of stainless steel.

Deluxe and Custom-made



Your inquiry will receive immediate attention.

PORTER

SINCE 1830

MATHEWS COMPANY, INC.

U.S. ROUTE #1,

PRINCETON, NEW JERSEY

WALnut 1-2550

PORTER-MATHEWS' CATALOG, LOOSELEAF AND ALWAYS CURRENT, IS YOURS ON REQUEST. USE THE COUPON BELOW.

PORTER-MATHEWS COMPANY, INC.
Princeton, New Jersey
Please send your complete catalog to:

Name _____ Position _____
Company _____ Institution _____
Address _____