

1527 This Week in *Science*

Editorial

1529 Uncertainties About Global Warming

Letters

1530 Takeover Bid: Chiron's Discussions with the Media: W. J. RUTTER ■ Patent Court Scientist: K. A. REAM ■ Organoids and Genetic Drugs: T. MACIAG ■ Department Size and Quality: J. A. GALLANT AND J. W. PROTHERO

News & Comment

1532 Déjà Vu in AIDS Priority Fight ■ Gallo's Potential Jurors

1534 Hot Fusion: A Meltdown in Political Support

1536 MIT Tenure Case Heads for Trial
Call for Environment Institutes

1537 Bacteria Effective in Alaska Cleanup

1538 Imported Monkey Puzzles
Trouble Ahead for the SSC?

1539 *Briefings*: Better Numbers on Primate Research ■ Activists Urge Ban on Herbicide R&D ■ Schizophrenics' Brains ■ Tyler Prize Goes to Cornell Scientists

Research News

1540 Dissecting the Complex Diseases ■ From the Tomato to the Mouse

1543 Spontaneous Order, Evolution, and Life

1545 The Chase Continues for Metallic Hydrogen

1546 Hubble Space Telescope Takes Aim at the Stars

Articles

1548 Population Dynamics of the United States and the Soviet Union: B. B. TORREY AND W. W. KINGKADE

1553 Soft X-ray Lasers and Their Applications: S. SUCKEWER AND C. H. SKINNER

Research Article

1558 Precise Monitoring of Global Temperature Trends from Satellites:
R. W. SPENCER AND J. R. CHRISTY

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COVER Skull of the earliest known relative of the higher primates (including humans) *Catopithecus browni* from early Tertiary deposits in northeastern Africa. Of probable late Eocene age, this skull shows several characteristics that rank it with the early higher primates of the Old World (Catarrhini). See page 1567. [Dave Leonhard, senior photographer, Audiovisual Medical Photography, Duke University]

Reports

- 1563 A Cellular Automaton Model of Excitable Media Including Curvature and Dispersion: M. GERHARDT, H. SCHUSTER, J. J. TYSON
- 1567 Discovery of the Oldest Known Anthropoidean Skull from the Paleogene of Egypt: E. L. SIMONS
- 1569 Intragranular Diffusion: An Important Mechanism Influencing Solute Transport in Clastic Aquifers?: W. W. WOOD, T. F. KRAEMER, P. P. HEARN, JR.
- 1572 Orientational Dielectric Relaxation of Collisionless Molecules: F. W. FARLEY AND G. M. MCCLELLAND
- 1575 The Actin-Binding Protein Profilin Binds to PIP₂ and Inhibits Its Hydrolysis by Phospholipase C: P. J. GOLDSCHMIDT-CLERMONT, L. M. MACHESKY, J. J. BALDASSARE, T. D. POLLARD
- 1578 Binding of GAP to Activated PDGF Receptors: A. KAZLAUSKAS, C. ELLIS, T. PAWSON, J. A. COOPER
- 1581 A New Member of the Leucine Zipper Class of Proteins That Binds to the HLA DR α Promoter: H.-C. LIOU, M. R. BOOTHBY, P. W. FINN, R. DAVIDON, N. NABAVI, N. J. ZELEZNIK-LE, J. P.-Y. TING, L. H. GLIMCHER
- 1584 T Cell Antigen Receptor-Mediated Activation of Phospholipase C Requires Tyrosine Phosphorylation: T. MUSTELIN, K. M. COGGESHALL, N. ISAKOV, A. ALTMAN
- 1587 Limit of T Cell Tolerance to Self Proteins by Peptide Presentation: H. SCHILD, O. RÖTZCHKE, H. KALBACHER, H.-G. RAMMENSEE
- 1589 Endogenous Cholecystokinin Reduces Feeding in Young Rats: A. WELLER, G. P. SMITH, J. GIBBS

Book Reviews

- 1592 The Uses of Experiment, *reviewed by* Y. GINGRAS ■ Synthetic Fuel Technology Development in the United States, P. J. T. MORRIS ■ Some Other Books of Interest ■ Books Received

*Author Index to Volume 247 is found on pages I-X
Information for Contributors is found on XI-XII*

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Uncertainties About Global Warming

Virtually everyone, children included, is concerned about global climate change and especially about the greenhouse effect. They have learned of increases in the atmospheric concentration of carbon dioxide. They have been told repeatedly that temperatures will increase 9°F. Political pressure is mounting to take action regardless of cost, and to take action now. But how good is the evidence, and how likely is there to be substantial global warming arising from anthropogenic causes? When might it happen? If the situation is analyzed applying the customary standards of scientific inquiry one must conclude that there has been more hype than solid facts. Some of the questions include: Are the computer models that predict large-scale warming rigorous? What has been the effect on climate of anthropogenic additions of greenhouse gases? Will atmospheric concentrations of CO₂ double by the middle of the next century.

Modeling of global climate is being carried out intensively by at least 14 different groups. They have largely concentrated on examining effects of doubling the atmospheric content of greenhouse gases. As might be expected, the answers they get are functions of the models they employ. The spread is from 1.5° to 5°C; that is, there is great uncertainty. In addition, if one examines some of the scientific articles on the subject, one finds virtually unanimous agreement that the models are deficient. For example, they do not adequately incorporate effects of clouds, which are expected to increase with warming. Clouds have both negative and positive effects on warming. Clouds exert a negative effect on temperature in part by reflecting sunlight off into space. They have a positive effect by trapping heat from below. The sensitivity of computer models to the properties of clouds was illustrated in a recent paper.* When the water content of clouds was recognized in the model, the predicted global average warming dropped from 5.2° to 1.9°C.

What have been the warming effects, if any, of anthropogenic gases? The typical answer is 0.5°C. But the answer depends on what time interval is chosen. There was substantial increase in temperature from 1880 to 1940. However, from 1940 until the 1960s, temperatures dropped so much as to lead to predictions of a coming ice age. New precise satellite data raise further questions about warming.† From 1979 to 1988 large temperature variability was recorded on weekly to multiyearly time scales, but no obvious temperature trend was noted during the 10-year period.

A fashionable estimate of the time when doubling of atmospheric CO₂ will occur is the middle of the next century. But past predictions of energy usage have been notoriously inaccurate. At the current rate of emissions of CO₂ the future doubling time would be of the order of 200 years. For a doubling to occur by 2050 would require a very large continuing exponential increase in CO₂ emissions. What fuels would be burned? Has the potential availability of the necessary fossil fuels been adequately considered? The large easily produced reserves of oil are in the region of the Persian Gulf. The principal reserves of coal are in the Soviet Union, the United States, and the Peoples Republic of China. Most of the less developed countries (LDCs) are comparatively bereft of fossil fuels. Yet the typical prediction of global emissions of CO₂ assumes large-scale enhanced expansion of burning by LDCs. Ten years from now (or before), when the Organization of Petroleum Exporting Countries is in full control of prices, who will be able to buy expanded amounts of oil? Not impoverished LDCs. Will the Soviet Union, the United States, or China be willing to ship to LDCs large amounts of coal gratis?

Production of oil in the United States is dropping rapidly, and imports are expanding. Were current trends of imports and trade deficits to continue, a crisis in energy usage and a sudden decrease in CO₂ emissions from automobiles is possible.

What should be the national response to the above uncertainties? Even were there to be a negligible greenhouse effect, we should be taking actions. For example, we should induce conservation and enhanced energy efficiency by increasing taxes on fuels, especially gasoline. We should greatly expand efforts to develop renewable resources, including biomass. But whatever we do should be based on well-thought-out long-range goals. It should not result from a half-baked political response.—PHILIP H. ABELSON

* J. F. B. Mitchell, C. A. Senior, W. J. Ingram, *Nature* **341**, 132 (1989).

† R. W. Spencer and J. R. Christy, *Science*, p. 1558.