Editorial & Letters

EDITORIAL

Toward a Transparent Federal S&T Budget

Everyone recognizes that advances in science and technology are required to fuel future U.S. economic growth. It is for that reason that the federal government for nearly 50 years has been the steward of American science and technology (S&T), funding the education and training of scientists and engineers as well as the development of our scientific and technical knowledge base. Yet what exactly does the federal government spend each year in support of science and technology? How does each federal agency contribute to that support? Good answers to such questions are difficult to find.

One reason is that there is no comprehensive presentation, much less examination, of the federal S&T budget at any stage of the congressional budget process. Indeed, the annual federal budget treats this key contribution to the U.S. economy as an afterthought.

It's time to make it easier to take a closer look at what the federal government is investing in S&T each year. Fortunately, a mechanism for doing so already exists. Right now, when the President sends his budget request to Congress, he prepares a crosscutting analysis of federal expenditures that shows what we are spending in key categories—like national defense and natural resources and the environment. These categories don't change the way individual agencies are funded. They just provide a bird's-eye view of funding across areas so Congress can debate the larger themes in the budget and identify specific agency contributions to such themes. One category, called "General Science, Space, and Technology," details the annual budgets for the National Science Foundation, NASA, and several programs at the Department of Energy. But this is far from a comprehensive picture of our investment. Expanding the category to include the $20 billion of civilian S&T support currently hidden in other agency budgets would provide a clearer view of what is being spent for S&T programs in the context of overall federal spending.

In the annual budget resolution recently passed by the Senate, we successfully proposed such a change, which, if accepted by the administration, would take effect next year. This change in the way federal S&T programs are labeled would not change the funding or placement of those programs within federal agencies, the way they are authorized in legislation, or the way they receive their annual appropriations. What would change is that Congress and the public would have a global view, using bona fide numbers, of all federal civilian S&T.

This change, combined with what we already know about defense S&T spending, would be like a new pair of glasses, bringing our total S&T investment into focus for the first time. Congress and the public would at last be able to look at the entire federal S&T portfolio and ask intelligent questions about its balance, coverage, and emphasis. Such a "big picture" review could flag potential problems for all science if one particular agency abandoned its support for a key research area. The resulting review would also fulfill a key recommendation of the National Academy of Sciences, National Academy of Engineering, and Institute of Medicine in their 1995 report, *Allocating Federal Funds for Science and Technology*. These groups recommended that the federal S&T budget "be presented as a comprehensive whole in the President's budget and similarly considered as a whole at the beginning of the congressional budget process." *

Providing a means to examine all civilian S&T funding at the various federal agencies in one glance would also reflect the reality that all federal research and development (R&D) is interrelated. As cosponsors of legislation to double all federal civilian S&T spending (S.1305, the National Research Investment Act of 1998), we believe that we cannot speak meaningfully about the health of American S&T if we focus only on the activities of one or two federal agencies.

Our dependence on advances in S&T for economic growth will only increase in the future. We need a vigorous debate on how to craft the future federal investment in S&T if we want to maintain U.S. scientific and technical leadership into the 21st century. Having a clear accounting of today's federal S&T investment and of where the president and Congress propose to take that investment is a prerequisite for that debate.

Jeff Bingaman and Joseph Lieberman

Jeff Bingaman (D–NM) and Joseph Lieberman (D–CT) are U.S. Senators.

**Allocating Federal Funds for Science and Technology* (National Academy of Sciences, Washington, DC, 1977), p. 12.

LETTERS

From the past to the future

FORSTER ET AL.

The authors of a recent study of embryo drawings made in the 19th century explain why their findings support evolutionary theory. The debate over whether birds evolved from dinosaurs continues (left, a slashing claw on a birdlike fosil dug up in Madagascar). Estimates of life expectancy in the 21st century are given. The possible therapeutic benefits of an estrogen metabolite are described. And the history and future of science in Vietnam are discussed.

Haeckel, Embryos, and Evolution

A recent study (*1*) coauthored by several of us and discussed by Elizabeth Pennisi (Research News, 5 Sept. 1997, p. 1435) examined inaccuracies in embryo drawings published last century by Ernst Haeckel. Our work has been used in a nationally televised debate to attack evolutionary theory, and to suggest that evolution cannot explain embryology (*2*). We strongly disagree with this viewpoint. Data from embryology are fully consistent with Darwinian evolution. Haeckel's famous drawings are a Creationist cause célèbre (*3*). Early versions show young embryos looking virtually identical in different vertebrate species. On a fundamental level, Haeckel was correct: All vertebrates develop a similar body plan (consisting of notochord, body segments, pharyngeal pouches, and so forth). This shared developmental program reflects shared evolutionary history. It also fits with overwhelming recent evidence that development in different animals is controlled by common genetic mechanisms (*4*).

Unfortunately, Haeckel was overzealous. When we compared his drawings with real embryos, we found that he showed many details incorrectly. He did not show significant differences between species, even though his theories allowed for embryonic variation. For example, we found variations in embryonic size, external form, and segment number which he did not show (*1*). This does not negate Darwinian evolution. On the contrary, the mixture of similarities and differences among vertebrate embryos reflects evolutionary change in developmental mechanisms inherited from a com-

mon ancestor (5).

Haeckel's drawings are used in many modern textbooks, but not always as primary evidence for evolution. In *Molecular Biology of the Cell* (6), the drawings are used

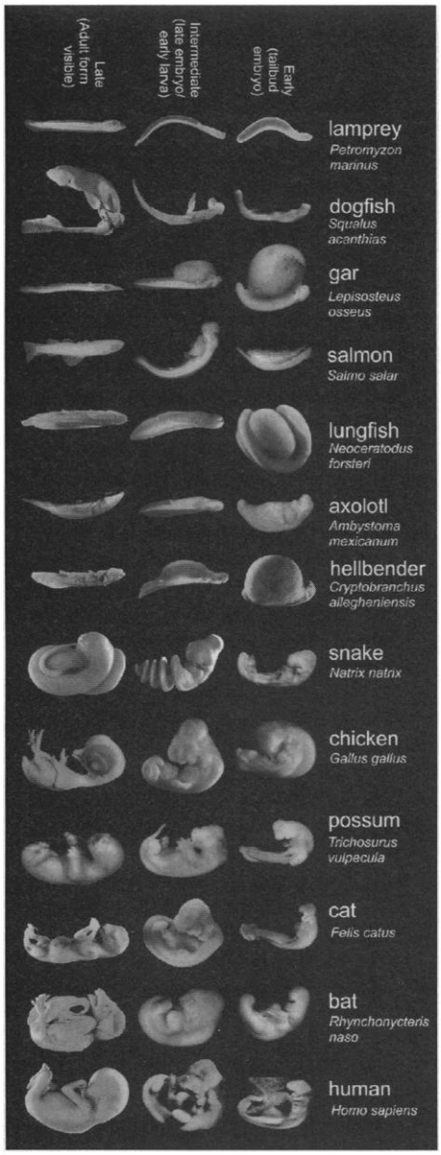

Fig. 1. Vertebrate embryos (not to scale) at three arbitrary stages of development: from early (approximately the tailbud stage) through late (when the definitive adult form is visible). No evolutionary sequence is implied in the was the specimens are arranged. Details of secimens are available from M.K.R. Early human embryo photographs courtesy of R. O'Rahilly.

mainly to support hypotheses about the stages of development acted on by natural selection. It is only in this limited context that we have reservations about the implications of the drawings. Thus, certain "phylotypic" embryonic stages, which Haeckel showed as identical, may in fact be significant targets for natural selection.

We are not the first to question the drawings. Haeckel's past accusers included His (Leipzig University), Rütimeyer (Basel University), and Brass (leader of the Keplerbund group of Protestant scientists). However, these critics did not give persuasive evidence in support of their arguments. We therefore show here a more accurate representation of vertebrate embryos at three arbitrary stages, including the approximate stage (Fig. 1, column three), which Haeckel showed to be identical. We suggest that Haeckel was right to show increasing difference between species as they develop. He was also right to show strong similarities between his earliest embryos of humans and other eutherian mammals (for example, the cat and the bat; Fig. 1, column three). However, he was wrong to imply that there is virtually no evolutionary change in early embryos in the vertebrates (see variations, Fig. 1, column three).

These conclusions are supported in part by comparisons of developmental timing in different vertebrates (7). This work indicates a strong correlation between embryonic developmental sequences in humans and other eutherian mammals, but weak correlation between humans and some "lower" vertebrates. Haeckel's inaccuracies damage his credibility, but they do not invalidate the mass of published evidence for Darwinian evolution. Ironically, had Haeckel drawn the embryos accurately, his first two valid points in favor of evolution would have been better demonstrated.

Michael K. Richardson
Department of Anatomy and Developmental Biology, St. George's Hospital Medical School, London SW17 ORE, United Kingdom
E-mail: m.richardson@sghms.ac.uk
James Hanken
Department of Environmental, Population, and Organismic Biology, University of Colorado, Boulder, CO 80309–0334, USA.
Lynne Selwood
Department of Zoology, La Trobe University, Bundoora, Victoria, 3083, Australia
Glenda M. Wright
Department of Anatomy and Physiology, Atlantic Veterinary College, University of Prince Edward Island, Charlottetown, Prince Edward Island, C1A 4P3, Canada
Robert J. Richards
Fishbein Center For History of Science, University of Chicago, Chicago, IL 60645, USA
Claude Pieau
Département Dynamique du Génome et Evolution, Institut Jacques Monod, 2, Place Jussieu, 75251 Paris, Cedex 05, France

Albert Raynaud
Laboratoire de Zoologie, Université Paul Sabatier, 31062, Toulouse Cedex, France

References and Notes

1. M. K. Richardson *et al.*, *Anat. Embryol.* **196**, 91 (1997).
2. "Firing Line with William Buckley," Public Broadcasting System (USA) (13 December 1997).
3. W.H. Rusch, *Creat. Res. Soc. Ann.* **6**, 27 (1969).
4. J. M. W. Slack, P. W. H. Holland, C. F. Graham, *Nature* **361**, 490 (1993).
5. R. Raff, *The Shape of Life* (Univ. of Chicago Press, Chicago, IL, 1996).
6. B. Alberts *et al.*, *Molecular Biology of the Cell* (Garland, New York, ed. 3, 1994).
7. M. K. Richardson, *Dev. Biol.* **172**, 412 (1995); and M. Coates, in preparation.
8. F. Verbeek, J. Bluemink, J. Narraway, and other staff of the Netherlands Institute for Developmental Biology provided assistance. Supported by the Wellcome Trust.

■

Demographic Thinking

In his commentary "The future of human longevity (*Science*'s Compass, 17 Apr., p. 395), John R. Wilmoth aptly captures the spirit of demographic thinking as well as the current demographic consensus. For nearly all demographers, a U.S. life expectancy of 85 in the year 2050 is well within the bounds of uncertainty. Life expectancy is heavily influenced by mortality early in life. Furthermore, life expectancy is a synthetic measure of *current* mortality conditions in a particular year: It is calculated by fixing age-specific death rates at prevailing levels. Hence, it is useful to examine other measures of longevity. Half of the babies born in the United States and other developed countries this year may survive to age 91. Half of the white female babies may live to celebrate their 95th or 100th birthday (depending on whether extrapolations are based on data from the past eight or the past three decades) (*1*). Although these are simply alternative ways of expressing the data summarized by Wilmoth, this perspective may be more illuminating. Demographers argue about details, but most agree that improvements in mortality at older ages will probably lead to very rapid growth in the number of octogenarians, nonagenarians, and centenarians, considerably more rapid than the official forecasts of the Social Security Administration (J. W. Vaupel *et al.*, 8 May, p. 855)(*2*).

James W. Vaupel
Max Planck Institute for Demographic Research, D-18057 Rostock, Germany
E-mail: jwv@demogr.mpg.de

References

1. J. W. Vaupel in *Longevity: To the Limits and Beyond*, J.M. Robine *et al.*, Eds. (Springer, Berlin, 1997), pp. 11–28.
2. V. Kannisto, *The Advancing Frontier of Survival* (Odense Univ. Press, Odense, Denmark, 1996); Social Security Administration, *Social Security Area Population Projections: 1997, Actuarial Study 112* (Social Security Administration, Office of the Chief Actuary, Washington, DC, 1997).

■

Bird, Dinosaur Link

Ann Gibbons's Research News article "Missing link ties birds, dinosaurs" about the discovery of the unusual Cretaceous bird *Rahonavis* (née *Rahona)* (20 Mar., p. 1851) includes commentary from two scientists who doubt that the forelimbs and hindlimbs belong to a single animal. One of the authors of the original report (20 Mar., p. 1915), Catherine A. Forster, is quoted in response that a source from two different animals cannot be ruled out, although "she contends that the hind limbs are clearly bird legs."

In fact, the study itself shows a stronger test of this hypothesis (Forster *et al.*'s note 22, p. 1919) that was not reflected in the News article. Phylogenetic analyses were run twice, once including the questioned forelimb ma-