eyes, considered essential when a plane is in congested terminal areas. This loss is made all the more acute because these same computers need reprogramming whenever the preset flight plan is changed for any reason, which in turn calls for the pilot who is not flying to have his head "in the cockpit" punching numbers into the black box. The pilot in control will already have his head in the cockpit flying his instruments, so that more often than not no one is looking out of the cockpit window searching for conflicting traffic.

More insidious, however, is the prospect of a fallible piece of software controlling a critical flight path of the aircraft and which the pilot is barred from correcting. And I would rather not think about the demented introduction of a virus into all of this.

In my own continuing experience of more than four decades of professional flying, I have yet to flick on a light switch at home or an autopilot in airliner in which sooner or later those pesky electrons did not misbehave. So the manufacturer's insistence that the fly-by-wire controls on the Airbus A320 "makes it impossible" to create an error will bring nothing but cynical chuckles from even the neophyte pilot.

Their statisticians invariably get into the argument at this point and insist that these potential glitches only happen once in a trillion times, but they fail to add that there is no mathematical guarantee it will happen on the trillionth rather than the first time. But I can assure them it will probably happen on my flight, when I least need or expect it.

This sort of sophistication should be left to the single-seat fighter, where it appropriately belongs and where the pilot can bail out in a hurry when the inevitable occurs—a privilege neither I nor my passengers enjoy.

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### Animal Experimentation

For more than a century, as so deftly illustrated by the recent attack on my work by Charles S. Nicoll and Sharon M. Russell of the University of California, Berkeley Department of Physiology (Letters, 26 May, p. 903), physiologists have been using the antivivisection movement as a "straw man." Historian Gerald Geison has shown that many physicians expressed skepticism about the value of animal experimentation as a therapeutically effective method of discovery during the 19th and early 20th centuries (as many do today) (*1*). In that inhospitable environment, laboratory physiologists were able to survive as a profession by mounting the most successful propaganda campaign in medical annals: They convinced much of the medical community, the public, and the media that the dramatic advances in 20th century therapeutics were a result of animal research.

It is therefore particularly ironic that the physiologists accuse me of concocting "written distortions of medical history." My work demonstrates that the real threat to animal researchers was never the antivivisection movement, but physician-scientists who do not agree with the provivisection propaganda. The list of elite physicians who have decried the exaggerated claims of bench scientists reads like a Who's Who of outstanding physician-scientists of the 20th century. In 1919, no less a clinical investigator than Archibald Garrod, who himself discovered the one gene–one enzyme hypothesis by brilliant clinical deduction, warned against "a tendency to ascribe almost all advances of medicine to the workers in pathological laboratories [animal experimenters and microscopists] and to represent the members of the clinical branch as merely applying in practice knowledge which has been gained in the laboratories" (*2*). In 1952, the epidemiologist who finally overturned the dogma that cancer is a purely genetic disease, wrote, "The overestimation of animal experiments is so rampant that the issue is of general interest" (*3*). In 1967, the physician who ushered in the New Immunology by interpretation of incisive natural experiments on the human body, disputed physiologist Julius Comroe's contention that heart transplantation was pioneered by laboratory physiologists (*4*). In 1979, Paul Beeson, the doyen of American internal medicine, wrote that "progress by the study of man is by no means unusual, in fact, it is more nearly the rule" (*5*).

The statements of such eminent authorities constitute a prima facie case that the historical importance of animal experimentation has been grossly exaggerated by physiologists.

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In the inflammatory letter by Nicoll and Russell, I was used as an example of a " 'moderate' animal rights advocate" who had supposedly made the statement that "it is pointless to use animals for AIDS research." I made no such statement. There is a great difference between writing off an area of research as "pointless" and a reasoned discussion of its limitations.

The authors went on to describe as "anti-scientific and anti-intellectual" my statements that "there is no good animal model for AIDS. There are monkeys which have a disease similar to AIDS but it is caused by a different virus." In fact, this is supported by many others. Note, for example, the *Report of the Presidential Commission on the Human Immunodeficiency Virus Epidemic* (*1*).

To date, adequate animal models have not been developed for human HIV-related research. An appropriate model is one in which the animal can be infected with HIV and can develop disease similar to that produced by HIV infection in humans. . . .Difficulties with animal models persist. Chimpanzees, for example can be infected with HIV, but, to date, have not developed AIDS. . . .The lack of appropriate animal models for HIV research makes the application of animal research to humans uncertain. . . .There is also a lack of adequate animal models for vaccine development.

This is not to say that animal research is pointless. But it is to say that the inadequacies of animal models, combined with the extraordinary stresses of isolation, confinement, and manipulation, which are routine in infectious disease research, should encourage a shift toward other methods. Or should the Presidential Commission also be labeled "anti-scientific and anti-intellectual"?

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## Shortage of Scientists

The article by Constance Holden, "Wanted: 675,000 future scientists and engineers" (News & Comment, 30 June, p. 1536), deals with an issue of vital importance to the nation. Holden's discussion of the topic is concise and thoughtful, but misleading in one respect. In the article she states: "White men now make up 47% of the total workforce and about 80% of the science and engineering workforce of 4.6 million. But they will constitute only 15% of the net number of 25 million people entering the workforce in the last 15 years of the century. By 2010, they will make us less than one-third of the college-age population." This statement and the accompanying pie-chart with the caption "The decline of the white male" can be misinterpreted unless they are examined carefully.

The figure of 25 million people is the estimated *increase*, from 115.5 million to 140.5 million, in the workforce between 1985 and 2000 and takes into account not only the number entering but also those who leave. White males, far from disappearing, increase their numbers by almost 4 million. Although their proportion falls from 47% to 41%, they remain the largest group (58 million in 2000). Despite a 10.5 million absolute increase by white women, their representation only rises from 36% to 37% (52 million in 2000). The total of all other groups, increasing by 10.7 million, rises in representation from 17% to 22% (30 million in 2000). The change in makeup of the workforce, while not insignificant, is not as startling as implied by Holden's article.

White males already constitute less than 50% of the workforce. Using the rates of percentage change (−0.4% per year for white males, +0.07% per year for white females), it would take until 2009 for the white male number to be equalled by white females, at which time each group would constitute about 38% of the workforce.

Although white males' dominance of the labor market is declining, it is a slow process and their numbers will remain significant for many generations. It is critical, for a variety of reasons, to increase the number of women and minorities entering the scientific workforce. But no matter how successful we may be in that regard, such efforts will not meet the nation's needs for technically trained people. Graduate fellowships and other incentive programs targeted only at women and minorities will miss the largest pool of potential recruits. The subtitle of Holden's article is "A shortage of technically trained workers is looming, unless more women and minorities can be attracted to science." That recommendation will not suffice. We need to attract more young people to science from all segments of the population.

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