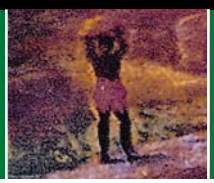

LETTERS

edited by Jennifer Sills

Neuroscience and the Soul

SCIENCE AND RELIGION HAVE HAD A LONG RELATIONSHIP, BY TURNS COLLEGIAL AND ADVERsarial. In the 17th century Galileo ran afoul of the Church's geocentrism, and in the 19th century Darwin challenged the biblical account of creation. The breaches that open at such times often close again, as religions determine that the doctrine in question is not an essential part of faith. This is precisely what happened with geocentrism and, outside of certain American fundamentalist Christian sects, evolution.

A new challenge to the science-religion relationship is currently at hand. We hope that, with careful consideration by scientists and theologians, it will not become the latest front in what some have called the "culture war" between science and religion. The challenge comes from neuroscience and concerns our understanding of human nature.

Most religions endorse the idea of a soul (or spirit) that is distinct from the physical body. Yet as neuroscience advances, it increasingly seems that all aspects of a person can be explained by the functioning of a material system. This first became clear in the realms of motor control and perception (*1*, *2*). Yet, models of perceptual and motor capacities such as color vision and gait do not directly threaten the idea of the soul. You can still believe in what Gilbert Ryle called "the ghost in the machine" (*3*) and simply conclude that color vision and gait are features of the machine rather than the ghost.

However, as neuroscience begins to reveal the mechanisms underlying personality, love, morality, and spirituality, the idea of a ghost in the machine becomes strained. Brain imaging indicates that all of these traits have physical correlates in brain function. Furthermore, pharmacologic influences on these traits, as well as the effects of localized stimulation or damage, demonstrate that the brain processes in question are not mere correlates but are the physical bases of these central aspects of our personhood. If these aspects of the person are all features of the machine, why have a ghost at all?

By raising questions like this, it seems likely that neuroscience will pose a far more fundamental challenge than evolutionary biology to many religions. Predictably, then, some theologians and even neuroscientists are resisting the implications of modern cognitive and affective neuroscience. "Nonmaterialist neuroscience" has joined "intelligent design" as an alternative interpretation of scientific data (*4*). This work is counterproductive, however, in that it ignores what most scholars of the Hebrew and Christian scriptures now understand about biblical views of human nature. These views were physicalist, and body-soul dualism entered Christian thought around a century after Jesus' day (*5*, *6*).

To be sure, dualism is intuitively compelling. Yet science often requires us to reject otherwise plausible beliefs in the face of evidence to the contrary. A full understanding of why Earth orbits the Sun (as a consequence of the way the solar system was formed) took another century after Galileo's time to develop. It may take even longer to understand why certain material systems give rise to consciousness. In the meantime, just as Galileo's view of Earth in the heavens did not render our world any less precious or beautiful, neither does the physicalism of neuroscience detract from the value or meaning of human life.

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An Optimistic Read on Digital Libraries

IN THE NEWS STORY "NSF RETHINKS ITS DIGital library" (Special Section on Education & Technology, 2 January, p. 54), J. Mervis captures the uphill struggle digital libraries have faced as they try to sustain funding and gain visibility among educators and students. However, the picture the article paints of sustainability in general and the Digital Library for Earth System Education (DLESE) in particular is too pessimistic. The process by which the National Center for Atmospheric Research (NCAR) assumed responsibility for the DLESE collection is attracting a good deal of attention through articles, presentations, and grants addressing models of sustainability for digital efforts. The advantages of curated digital libraries are clear to many users. DLESE's collections of Earth science materials, now managed by the NCAR Library, have been selected by educators and scientists specifically because they are scientifically accurate, grade-level appropriate, and effective for teaching.

The University Corporation for Atmospheric Research, which operated the technical arm of DLESE and continues to run the NSDL Resource Center, is very proud of the impact of these digital library efforts. Although DLESE has lost its NSF funding, the open-source DLESE technical infrastructure underpins initiatives at NASA, NOAA, DOE, and scientific

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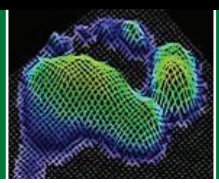

Fossilized behavior

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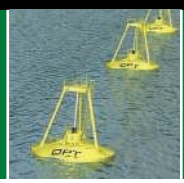

Extracting energy from the ocean

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data centers and digital libraries from Britain to China. It is notoriously difficult to demonstrate the impact of educational innovations, but a current project with Denver Public Schools leveraging DLESE collections holds promise for helping us evaluate the value of digital library collections in transforming teacher practice and learning outcomes. In many ways, NSF's investment in digital libraries has been transformative.

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Developing Psychomotor Skills the Wii Way

IN HIS PERSPECTIVE "IMMERSIVE INTERFACES for engagement and learning" (Special Section on Education & Technology, 2 January, p. 66), C. Dede only briefly touched upon the particularly important area of psychomotor skill development. Hand-eye coordination and fine three-dimensional control of limbs in space are areas that are usually neglected by the educational system, despite the fact that they are crucial to a huge number of professions. There is evidence to suggest that surgical simulations can improve speed and accuracy (*1*). Moreover, the opportunity for motor skill development by immersive interfaces is not limited to specialist training—the Nintendo Wii console is one example of a commercially available games system that integrates hand and, in some cases, whole body movements in a range of simulated environments. Games systems provide opportunities to improve motor skills both for laypeople and for professional trainees in places that cannot afford full-scale simulators.

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Explaining the Reasoning-Fact Gap

THE EDUCATION FORUM BY L. BAO *ET AL.* ("Learning and scientific reasoning," 30 January, p. 586) raises the question, why doesn't knowledge of scientific facts (in physics specifically) seem to correlate with skill in reasoning? I suspect that one factor is that American curricula generally emphasize a broad range of technical and nontechnical subjects, only one year of which is devoted to physics. Reasoning skills learned from these other subjects likely compensate for the dearth of physics, relative to that in Chinese schools. A second factor is probably the way in which science is taught. Science education in the United States is not focused on national college entrance exams (neither the SAT nor the ACT test factual science knowledge). Requirements and exams vary from state to state, but guidelines from the National Academy of Sciences emphasize reasoning over facts (*1*). Overall, educators have greater leeway to focus on reasoning and other less testable skills.

Teaching American students more scientific knowledge is a laudable goal, but we should be careful about what gets sacrificed in the process. It is worth considering how much value most people will derive from advanced specific knowledge (Gauss's Law, for example) compared to broader background in a variety of subjects. Science education in the United States is woefully inadequate in many respects (*2*), and the number of failing schools is embarrassing. We must correct these failures but also remember what we've done right. The broad education characteristic of both K–12 and higher education in the United States has done an excellent job fostering creativity and innovation, measured by publications, patents, and growth in the science and technology work force (*2*, *3*). We should work to improve scientific education by building on that success.

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TECHNICAL COMMENT ABSTRACTS

Comment on "Multipartite Entanglement Among Single Spins in Diamond"

Brendon W. Lovett and Simon C. Benjamin

Neumann *et al.* (Reports, 6 June 2008, p. 1326) recently reported the preparation of multiparticle entanglement among single spins in diamond. However, two of the system's nuclear eigenstates are incorrectly described as product states when they are inherently entangled. Consequently, three of the six states reported, namely the odd-parity Bell states and the *W* state, were not actually produced.

Full text at www.sciencemag.org/cgi/content/full/323/5918/1169c

Response to Comment on "Multipartite Entanglement Among Single Spins in Diamond"

P. Neumann, N. Mizuochi, F. Rempp, P. Hemmer, H. Watanabe, S. Yamasaki, V. Jacques, T. Gaebel, F. Jelezko, J. Wrachtrup

Our study reported entanglement among single spins in diamond. Lovett and Benjamin argue that three of six described entangled states were not achieved. Here, we explain our choice of entangled states and discuss their importance for quantum information processing. We also show that the eigenstates discussed by Lovett and Benjamin, although formally entangled and routinely generated in our experiments, cannot be used to detect nonlocal correlations.

Full text at www.sciencemag.org/cgi/content/full/323/5918/1169d

Letters to the Editor

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