count is not only premature—it's stillborn.

Conway Morris remarks that alleged pre-Ediacaran trace fossils are all controversial, different, and localized. There is no question that pre-Ediacaran trace-like fossils are rare. If explainable as disrupted microbial mats, however, they should be all but rare in a world dominated by microbial communities unaffected by grazers. In any case, we shall never know how rare, different, and localized pre-Ediacaran traces are unless they are searched for, reported, described, and analyzed without being forced into currently accepted evolutionary scenarios. Only then will we have a reasonable chance of establishing whether and, if so, why motile multicellularity did not become a prominent theme in evolution until the Cambrian explosion.

As Conway Morris seems to take us to task for not providing an explanation of why the invention of motile multicellularity failed to take off until the Cambrian explosion, we must enter the merry realm of unfettered speculation. Thus, we offer the following:

A slimy young worm in the making
Found a gal he considered worth taking.
But she cried in despair:
"The Precambrian air
Is too stuffy—my neuron is aching!"

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Kleiber and Planck: The Missing Link?

IN P. MARQUET'S PERSPECTIVE "OF PREDATORS, prey, and power laws" (22 March, p. 2229) and C. Carbone and J. L. Gittleman's Report "A common rule for the scaling of carnivore density" (22 March, p. 2273), there is an interesting discussion on the interaction between metabolic requirements and locally available energy described by Kleiber's power law. Marquet writes, "a limited amount of available energy per unit area will sustain a larger number of individuals of a small-sized species than of a bigger species. Thus, assuming energy limitation, population densities (N) of large species are expected to be lower than those of smaller ones because of their higher metabolic demands [relates to body size W], and $N \sim W^{-3/4}$".

Formally, Kleiber's law in biology is reminiscent of Jeans's law in physics, which gives the amount of emitted/absorbed radiant ener-

gy per unit time (I) as a function of the wavelength (λ) of the emitted/absorbed radiation: $I \sim \lambda^{-4}$. Jeans's law, however, is correct only for large λ and, supported by another law of classical physics—that all radiated waves share equally in the distribution of the total available energy—leads to the well-known, incorrect prediction that all available energy will be concentrated in the region of infinitely short waves (ultraviolet catastrophe). Since 1900, it has been known that the problem of distributing the limited amount of energy among vibrations of different wavelength takes the form of a probability distribution given by Planck's law—the vibrations with high demands (short λ) have very small chances of having their demands satisfied, whereas long wavelength radiation, which asks for little, has a very good chance of getting it. That's the spirit of Kleiber's law discussed by Marquet and Carbone and Littleman. Planck's energy distribution curve, however, approaches zero at both limits—at the short wavelengths the radiation has practically no chance of receiving anything and at the long wavelengths the radiation has a very good chance of receiving practically nothing—with the bulk of energy being distributed among certain intermediate wavelengths. The conflict between approximated (Jeans) and accurate (Planck) laws moved physics into an entirely new field of thought and experience (quantum physics) and raises some interesting questions with respect to Kleiber's law: What are its fundamentals, what is its range of applicability, and, is there any fundamental relationship between Kleiber's and Planck's laws?

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Response

LIFE IS AN ENERGY-DEMANDING PHENOMENON. As was recognized by physicists such as Schrödinger and Prigogine, living systems are dependent on external energy fluxes to maintain their far-from-equilibrium state. Kleiber's law (*1*), in its original formulation, quantifies the amount of energy per unit time (P or metabolic power) required by a living organism at rest to remain alive, that is, to sustain the processes whose end result is the organism itself. Kleiber's great breakthrough was that he relates this energy to an easily measurable attribute of organisms, their mass (M), through a simple allometric equation of the form $P \propto M^{\alpha}$, where α is an scaling exponent taking a value of 3/4. This relationship has been recently shown to hold across 27 orders of magnitude in mass, from single molecules to elephants (*2*); thus, it is applicable to all living entities. However, it is by no means obvious why α should take a value of 3/4, and in fact during the past 70 years researchers have either contested it or tried to explain it (*3*, *4*); thus, there is still debate regarding its fundamentals. Interestingly, the maximum density of individuals (i.e., the maximum number of individuals of the same species per unit area, N) scales as $N \propto M^{-3/4}$ (*5*, *6*). Although, this is not Kleiber's law, as implied by Radny, it follows directly from it, for a limited amount of energy will be able to sustain, in isolation, more individuals of a smaller sized species that of a larger sized one.

Formally, Kleiber's law is reminiscent of Rayleigh-Jean's law in physics, to the extent that both relations involve the scaling of energy. However, while Kleiber's law represents an empirical pattern applicable to living entities and its components, Rayleigh-Jean's law is a theoretical derivation that aimed to account, although with limited success, for an empirical pattern (blackbody radiation) based on classical physics assumptions. Planck's radiation law, on the other hand, was able to account for blackbody radiation, proposing an exact formula, but was based on an entirely

different assumption that paved the way to quantum physics. But is there a fundamental relationship between Kleiber's and Planck's law? No. Kleiber's law is a pattern, not an explanatory model like Planck's law. Further, both apply to different domains, and although Planck's law accounts for unequal distribution of energy among different wavelengths, it follows from Kleiber's law that the total amount of energy used by populations of species of different body sizes, or power density, is about the same (i.e., $N \times P \propto M^0$), an empirical pattern dubbed the energy equivalence rule (*7*, *8*). Thus, contrary to hot objects for which power density is concentrated at intermediate wavelengths, for assemblages of living entities, the pattern to be explained is that of equipartition of energy, a widespread ecological regularity for which there is no satisfactory explanation as yet.

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Division of Planetary Science Statements

THE SCIENCE SCOPE ITEM "PLUTO OR BUST?" (26 July, p. 495) requires some clarification. The item implies that contradictory statements regarding a NASA mission to Pluto were made by the American Astronomical Society (AAS). In fact, these statements were issued by the Division of Planetary Science (DPS) of the AAS. Divisions of the AAS are able to make statements of their own as long as the statements are clearly identified as coming from the Division, not the Society as a whole.

The press releases announcing both statements of the DPS clearly indicate that they were made by the Division. This information was not mentioned in the Science Scope item.

The two DPS statements are in fact complementary. The first statement broadly endorses the newly released National Academy Decadal Survey of Planetary Science, which places the Kuiper Belt–Pluto mission as the highest priority medium cost mission for the coming decade. The second, more detailed statement endorses the Kuiper Belt–Pluto mission and urges Congress to act this year to augment the mission budget to achieve a launch in 2006. Launch in 2006 is necessary if gravity assistance is to be used to reach Pluto.

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Letters to the Editor

Letters (~300 words) discuss material published in *Science* in the previous 6 months or issues of general interest. They can be submitted by e-mail (science_letters@aaas.org), the Web (www.letter2science.org), or regular mail (1200 New York Ave., NW, Washington, DC 20005, USA). Letters are not acknowledged upon receipt, nor are authors generally consulted before publication. Whether published in full or in part, letters are subject to editing for clarity and space.