Smallpox and Public Health: a Reality Check

THE UNITED STATES IS CONSIDERING THE vaccination of hundreds of thousands of medical and emergency personnel against smallpox as a preventative measure. The CDC has released guidelines for vaccinating the entire U.S. population in the case of a smallpox attack (*1*). Before we begin such a campaign, which in either case would involve a massive public health effort, it is imperative that we step back from the sensationalist press and marketing hype emerging from the burgeoning biodefense industry and ask if such a vaccination scheme is a good idea.

In her recent letter "Smallpox transmission risks: how bad?" (5 July, p. 50), L. H. Kahn suggests that "planning for a worst-case scenario such as the one envisioned in 'Dark Winter' [a scenario developed by U.S. bioterrorism experts to model a possible smallpox biological attack] makes the most sense." However, "Dark Winter" is not a technically sound depiction of the course of its particular epidemic in either time progression or casualty numbers. Many smallpox scenarios are now being promulgated as "ground truth" to lawmakers and the public and are being used to justify the potential vaccination of possibly hundreds of thousands of people, without the necessary peer-reviewed science to back them up.

Ellis McKenzie and the staff of the NIH Fogarty Center and the Rutgers University DIMACS program have recently held workshops with leading modelers to address the difficulties involved in modeling smallpox outbreaks. For the past several years, the Department of Defense has been carefully analyzing historical epidemics and hypothetical contagious disease threats against its forces while striving to improve its modeling capabilities at all scales of analysis, both temporal and geographic (*2–4*). More of such peer-reviewed scholarship is desperately needed.

Variola virus is known to exist in only two guarded repositories. It is widely assumed that it exists elsewhere and that these other stocks pose a terror threat, driving the need for emergency vaccination programs. We know from history that such programs will injure or kill a small number of people (*5*), at least a few in a million; such a risk was considered to be acceptable in the days of natural and very real smallpox epidemics.

If there are no unofficial stocks of variola virus, and assuming that no one could or would create the variola virus in a lab, the potential vaccine casualties would be in vain. It is thus incumbent upon any government, agency, or individual with specific and credible knowledge of the whereabouts of unofficial stocks to report this information openly. Only then can the full weight of international opinion and resolve be brought to bear to rid the world of the threat from this terrible disease. Lacking such revelations, we will continue to unjustifiably invest scarce public health resources in preparations against a phantom threat, to the delight of our adversaries and to the detriment of public health. We should carefully weigh bioterror risks against the likely consequences with careful peer-reviewed scholarship.


Women line up to be vaccinated during the 1947 New York City smallpox epidemic. Another large-scale vaccination could happen in the near future if the United States decides to vaccinate medical and emergency personnel.

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Ancient Animals or Something Else Entirely?

IN THEIR REPORT "DISCOIDAL IMPRESSIONS AND trace-like fossils more than 1200 million years old" (10 May, p. 1112), B. Rasmussen and colleagues present evidence for what might be the oldest known animals, from the Stirling Range Formation of southwestern Australia. Thanks to the kindness of Rasmussen and Fletcher, I recently had the opportunity to study this material. I suggest that some of their conclusions may be premature. The supposed trails are clearly all of a kind, but they show three peculiar features. First, although not remarked upon by Rasmussen *et al.*, some ridge margins show a striking imbrication with the adjacent sediment, reminiscent of the overfolding of a flexible surface. Second, on one surface, despite the presence of discrete "trails," an adjacent area is strongly corrugated (see left-hand side of Rasmussen *et al.*'s Fig. 2E). The texture and scale of this region are closely similar to the supposed trails, indicating a possible common origin. Finally, albeit a weaker argument and one already addressed by Rasmussen *et al.*, there is the striking parallelism of the two most prominent "trails" (Fig. 2, C and D), the ridges of which show the same sense of imbrication.

These observations suggest that alternative explanations may be preferable. The most probable is that these structures result from flexible microbial mats that coated sediment surfaces and were subsequently disrupted. The associated discs (unillustrated) have only a vague resemblance to the later Ediacaran structures known from type localities in Australia and Russia. A striking feature of some of the Stirling Range discs is that the concentric rings show pronounced undulations. Despite Rasmussen *et al.* rejecting this possibility, interpretation of these structures as microbial colonies seems reasonable.

Claims of pre-Ediacaran traces are important if they verify a deep metazoan ancestry, consistent with molecular clock estimates. Nevertheless, to date, all such claims are controversial and share two features. All differ from one another, and all are highly localized. Nor is it explained why such a biological invention that existed circa 500 million years before "Snowball Earth" failed to take off. Pre-Ediacaran metazoans (*1*) there may well be, but searching for images based on Phanerozoic expectations may be misleading.

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Response

WE WELCOME A DISCUSSION OF THE ENIGmatic Stirling biota. Like us, Conway Morris accepts a biological origin of the fossils and rejects the earlier identification of the discoidal forms as Ediacaran. Unlike us, however, he thinks that the trace-like fossils were probably formed by disruption of flexible microbial mats. He does not account for, or even mention, the features that constitute our evidence that the structures were made by vermiform, motile organisms: the recurrent pattern of ridge pairs with a distinct U-shaped ending.

We tried in vain to find a plausible mechanism whereby such a pattern could be formed through disruption of a microbial mat. Conway Morris does not present such a mechanism; he merely lists three "peculiar" features, all given the label "strong" or "striking," which in his opinion would favor alternatives over our trace-fossil interpretation. None of them challenges our interpretation—in fact, they are to be expected in a situation where mucus trails left by organisms in a muddy environment occasionally crowd and break up, get replaced by sand, and suffer compaction and low-grade metamorphism. On the other hand, the regular, recurrent structures that we have described in the less crowded areas are indeed peculiar, strong, and striking, and they pose a formidable challenge to the microbial-mat hypothesis. Any explanation that doesn't take them into account 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 energy 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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