Cost of Corrosion

In his discussion of a report on fundamental corrosion processes presented at the Pittsburgh Conference (Research News, 22 Mar., p. 1431), Ivan Amato states that corrosion is a "natural process that costs society tens of billions of dollars a year." This estimate is almost an order of magnitude below other good estimates. In the 1970s Battelle Columbus Laboratories (BCL) and the National Bureau of Standards (NBS) conducted a thorough analysis of the impact of corrosion losses on the U.S. economy (*1*) and concluded that the annual cost of corrosion to the United States in 1975 was 4.2 ± 1.3% of the gross national product (which would be $218 ± 68 billion for 1989 if one assumes this extrapolation is valid).

The cost of corrosion through loss of consumer confidence and industrial competitiveness was not considered in the BCL-NBS study. If a U.S. manufacturer's product fails by corrosion and the consumer purchases a replacement from a non–U.S. manufacturer because of either loss of confidence in U.S. products or better corrosion prevention methods practiced by the foreign manufacturer, there will be an additional cost to the U.S. economy. Also, if a U.S. manufacturer experiences more failures and down time during manufacturing than do foreign manufacturers, then it will be more difficult for the U.S. manufacturer's product to compete in the marketplace. In fact, the U.S. Air Force's Electronic Failure Analysis Group has estimated that corrosion is responsible for about 20% of the failures of electronic equipment (*2*).

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RNA World

We have often argued (*1–3*) that an understanding of modern biochemistry must come from a focus on facts, not terminology. The recent criticism of our work by Karl Popper and Gunther Wächtershäuser (Letters, 23 Nov., p. 1070) suggests that these arguments have not been heard in all circles. Popper and Wächtershäuser's review of the ideas of Woese is splendid. However, their commentary on our work appears to be an attempt to superimpose our ideas, which they do not clearly represent, onto earlier, more familiar, notions concerning the origin of translation.

Our primary concern is neither the origin of life nor the systematics of modern organisms, two issues addressed brilliantly by Woese. Rather, we have developed a historical model that attempts to unify biochemical facts concerning mechanism, stereospecificity, kinetic behavior, metabolic organization, and sequence in modern proteins and nucleic acids (*3*). The model presumes two episodes in the evolution of life, the first involving RNA as the sole genetically encoded component of biological catalysis (*4*). Further, it postulates two particular organisms (*1*).

1) A metabolically complex, most recent common ancestor of eukaryotes, archaebacteria, and eubacteria containing a "protogenome" coding for homologs of many proteins that are present in modern life (*2*). Over 10,000 bases of this genome can be reconstructed from modern biochemical fact, readily distinguishing it from the transcriptionally and translationally inaccurate "progenote" described by Woese and Fox (*5*). The use of the prefix "proto-" to designate a reconstructed form is well established (*6*). Our earlier use (*1*) of the term "progenote" as a synonym of the "most recent common ancestor" was not intended to detract from Woese's many contributions, but rather recognized that this term is now nearly universally used with this meaning (*2*).

2) A metabolically complex ancestor of the protogenome, the "breakthrough organism" (*1*), the first organism to synthesize proteins by means of a messenger RNA. The "breakthrough organism" resembles superficially Woese's progenote; both are postulated to have invented translation, which presumably was relatively unsophisticated in its early stages. However, our model postulates that translation arose in an "RNA world" (*1, 4*) already containing a sophisticated metabolism based on RNA enzymes, while in the Woese-Fox model, translation arose in a "progenote" containing only a few genes linked tenuously to phenotype.

The Woese-Fox concept of a "progenote" (*5*) is fundamentally incompatible with models that presume an RNA world. It is based on the hypothesis that "an appreciable translation error" would have required "genome sizes [to be] considerably smaller . . . because they are limited by mutation rate, which is [a] function of *the proteins* involved in gene replication" (*5*) (italics ours). Of course, the point of the RNA world, the point that allows the "chicken or egg" paradox to be avoided, is that it is not necessary that proteins be involved in gene replication. Given an RNA world, imprecise translation no longer requires small genomes, unsophisticated metabolism, or the other "primitive" characteristics that define the Woese-Fox "progenote."

The RNA world remains hypothetical. However, models that assume an RNA world bring much coherence to biochemical fact (*1, 4,* 7). Further, our model has prompted new experimental work, including the selection of functional RNA molecules from pools of random sequences (*8*), reconstruction of ancient proteins in the laboratory (*9*), expansion of the number of nucleotide bases that can be incorporated by template-directed polymerization (*10*), and the elucidation of new features of archaebacterial metabolism (*1*). While theory is necessary to guide experimental work, it is only through fact-seeking that we can validate our models. Therefore, we now return to "the forbidding difficulties facing those who toil to establish new facts" and hope that theorists will recognize the power of new ideas to both organize existing facts and stimulate the discovery of new facts.

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