LETTERS

Randomization in Clinical Trials

Gina Bari Kolata (News and Comment, 16 Dec. 1977, p. 1127) repeats the often stated belief that "The randomization [in controlled clinical trials] is designed to average out possible pertinent differences among the trial participants, such as age, sex, and general state of health. The treatment and control groups, then, should be medically equivalent." In fact, randomization never completely eliminates between-group differences; with small group sizes such differences may still be quite appreciable after randomization. It is questionable whether such groups could be considered medically equivalent.

The real rationale of randomization lies in the statistical theory of errors that distinguishes between systematic (biasing) errors and random (variable) errors. Even if the trial subjects were selected by identified criteria (age, sex, and so forth), there is no assurance that some attributes affecting the result may not be more (or less) predominant in one group than in the other. Since these factors are hidden, they cannot be measured, and the result cannot be corrected for the bias they introduce. Allocating by chance (randomizing) the subjects to the treatment and control groups does not make the groups medically equivalent, but it distributes the biasing factors to the groups also according to chance, that is, the biasing errors become random errors. Their magnitude can be calculated as the standard deviation and be allowed for in arriving at the result by tests of significance and confidence limits. Without randomization, such tests lack the appropriate logical foundation. That randomization also makes the subject groups more uniform is a by-product, welcome but not essential, of its primary function.

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OTEC: Feasibility and Costs

The article "Ocean thermal energy: The biggest gamble in solar power" by William D. Metz (Research News, 14 Oct. 1977, p. 178) inspired a vigorous discussion in the Letters section (9 Dec. 1977, p. 989), some of which related to statements made by me and to results obtained by my research group. This dis-

cussion unfortunately presents several excellent illustrations of what must be one of the roots of our most serious problems: the difficulty of communicating precisely.

In the original article, Metz said, "Experiments conducted so far in the OTEC [ocean thermal energy conversion] program indicate that only ¼ millimeter of slime would reduce the plant's performance by 60 percent." This is *technically* incorrect. However, it is incorrect only in that no experiments yet conducted have been allowed to continue long enough for ¼ millimeter of slime to accumulate. Avery, in his letter (9 Dec. 1977, p. 990), replies that "No experience indicates that ¼ millimeter of slime growth on marine hardware would reduce OTEC performance by 60 percent." This is technically correct for the reason stated above. However, it is fundamentally misleading. If, for example, we assume OTEC heat exchanger tubes 1 inch in diameter with a seawater flow velocity inside of about 6 feet per second, ¼ millimeter of slime growth will indeed reduce the heat transfer coefficient by about 60 percent if biological slime has a thermal conductivity equal to that of seawater. (In fact it probably has a lower conductivity, so the degree of degradation will be even greater.) Let no one then be misled. Metz's statement was indeed "a fair characterization."

The point is in any case not the important one. There is no longer any doubt that slime growth will reach unacceptable levels if it is not inhibited. The critical question, about which there exists so far only the most preliminary evidence, concerns whether a feasible method can be developed to prevent or remove slime growth. Most of us who are working on this problem feel confident that it can be done, but this has yet to be convincingly demonstrated. Of greater concern are the potentially more serious problems of scale formation and corrosion in the OTEC heat exchanges, which may take years to resolve. More effort should be concentrated in these areas.

The letter by Duguay (9 Dec. 1977, p. 992) is a good illustration of another aspect of the communication problem. Certainly the casual, or nonexpert, reader might be convinced by it that the OTEC program should be abandoned. Before doing so, however, it would be well to look more carefully at Duguay's arguments. In his first paragraph he argues, based on relative efficiencies, that "the cost of a competitive OTEC power plant would have to be 20 times less than the cost of an equivalent land-based

power plant." Here, he seems to mean by "equivalent" that the plants have equal thermal energy *input*. (Clearly, if he means equal output, competitive plants would then just need to cost about the same.) From this, he concludes in his second paragraph that ". . . OTEC supporters claim to be able to build and maintain a . . . power plant that would be 15 times cheaper than a land-based power plant."

Now this must certainly have a strong negative impact on the nonexpert reader. However, we can slightly reword Duguay's statement, making it more complete without changing its sense at all. It would then read ". . . OTEC supporters claim to be able to build and maintain a . . . power plant that would be 15 times cheaper than a land-based power plant *producing 20 times the output power*." In this form, the statement doesn't seem nearly so shocking.

Until now, I have felt constrained to compare power plant costs on the basis of energy output rather than input. If we are to be allowed to cast about for other figures of merit that are more suited to our own biases, we open up a whole new field of endeavor which, I confess, gives much freer reign to the imagination and is therefore more fun. As my first contribution in this area, I submit the following syllogism.

Coal-fired power plants require about 20,000 times as many pounds of fuel as do nuclear plants. The cost of fuel in nuclear plants is not a negligible factor in the cost of power. Proponents of coal-fired plants, therefore, claim to be able to obtain fuel at about $^1/_{20,000}$ of the cost of the equivalent fuel for a nuclear plant. In view of the implausibility, I may even say ludicrousness, of such a scenario, we must obviously shut down immediately all coal-fired plants.

On second thought, perhaps we should continue comparing costs of plants per unit of power output.

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In his letter of 9 December, Duguay suggests making cost comparisons rather than cost estimates for undeveloped energy technologies in order to reduce confusion and then proceeds to misrepresent the relative capital investment requirements of ocean thermal energy conversion (OTEC) and coal-fired power plants. Duguay is correct that the thermal-to-electrical conversion efficiency of modern coal-fired plants may exceed achievable OTEC efficiencies by a

Congressional Science Fellowship: Child Policy Applications Invited

The American Association for the Advancement of Science invites applications for the sixth year of its Congressional Science Fellow Program.

Program

The AAAS selects individuals from a broad range of disciplines and science-related professions to spend one year working in some area of Congress, and administers the program for its own and other sponsors' Fellows. The AAAS provides a two-week orientation. Each Fellow chooses his or her own assignment with guidance from the AAAS.

Awards

This year the AAAS will make five Congressional Science Fellowship Awards: four in some area of child and family policy—that is, child development, education, health policy, etc., and one in an unspecified area. The fellowship award includes an $18,000 stipend for the period of one year, beginning 1 September 1978, and $1500 for moving and travel expenses. Interested applicants requiring a higher stipend are encouraged to discuss their situation with the program director.

Application

Candidates may apply from any physical, biological, or behavioral science or field of engineering, or any health, education, or child-policy related area. They must be AAAS members or concurrently applying for membership.

Information on the selection criteria, application procedure, and program details are available from **Dr. Richard A. Scribner, Director, AAAS Congressional Science Fellow Program, AAAS, 1776 Massachusetts Avenue, NW, Washington, D.C. 20036.** Deadline for application is 15 March 1978. Announcement of the awards will be made before 1 May 1978.

factor of 20. However, the conclusion that, in order for OTEC to be competitive with coal, the capital cost ratio of the two designs must be equal to the efficiency ratio is misleading. Neglecting for the moment fuel costs, the cost of electricity to a first approximation is determined solely by the appropriate capital investment cost, capital recovery factor, and plant factor. Thus, the thermal-to-electrical conversion efficiency of the plant does not even enter into the calculation.

When fuel costs are included, the conversion efficiency and the cost of fuel determine the contribution of fuel charges to the cost of electricity. If the comparison is between designs using two alternative depletable fuel choices, then the ratios of fuel costs and efficiencies determine the ratio of fuel costs. In a comparison of technologies based on a nonrenewable resource (coal) and a renewable resource (solar), the thermal-to-electrical conversion efficiency plays an unusual role, since the fuel for the technology based on the renewable resource is effectively available at no cost.

Accordingly, it is entirely conceivable that competitive electricity prices may be obtainable from OTEC facilities with capital costs that are in fact higher than those for a coal-fired unit with an equivalent capacity. Moreover, the fuel costs of a coal-fired facility are subject to future price escalations, while the "fuel" costs of an OTEC plant are fixed at the time of construction. Thus, the OTEC supporters do not have to meet the stringent requirements that are suggested by Duguay. Conversely, if the cost of mining and transporting coal contributes about 25 percent of the cost of electricity and maintenance costs are neglected, competitive OTEC plants may be implemented with capital investment costs as much as 33 percent higher than those of a coal-fired facility.

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Bipedalism: An Early Warning System for Miocene Hominoids

In the article "Human evolution: Hominoids of the Miocene" (Research News, 15 July 1977, p. 244), Gina Bari Kolata quotes David Pilbeam as speculating on possible morphological and behavioral effects brought about by environmental changes. Specifically, he suggests that the movements of Miocene hominoids into more open country (from forest) may have contributed to the smaller of the species of this group becoming bipedal as a partial consequence of changes in the way they fed.

In open grassland bipedalism would have an additional advantage for small hominoids. A small hominoid not possessing highly developed olfactory or auditory senses, foraging in relatively tall grass, would have difficulty scanning the surrounding terrain. Such a hominoid would be easy prey for a predator hunting by sight and capable of looking over the grass. Line of sight contact would not be essential, as the predator could track the "submerged" hominoid by the disturbance its movements created in the grass.

A hominoid of similar size capable of adopting a bipedal stance who was placed in a similar situation would be able to see over the grass (if it were not too tall) and thus become aware of an approaching predator much earlier than the nonbipedal hominoid. Even intermittent bipedalism would serve as an efficient early warning system.

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