on inequality in the United States (although this neglects the startling reversal in the past few decades). Third, it rightly takes to task the self-appointed doomsters who perhaps do not deliberately exaggerate, but who exaggerate because of poor research and inadequate questioning. The general *laissez-faire* tone of the volume will offend some, but, if so, the offended should be prepared to answer the case made in the book.

Holdgate accepts there is an array of environmental problems and spends more time telling us what has to be done. The recommendations are familiar but no less important for that: empowering communities, moving from outright conservation to sustainable use, education and new alliances between interest groups. He is sincere in his belief that we need a 'new ethic' of care, but the menu of action looks strangely naive: building a new conscience and spirituality, reforming the international economic order, and "new economic thinking" (when we have hardly made use of the power of the 'old' economic thinking) to improve our lot and the lot of other species.

Holdgate's volume is a worthwhile read but it has an inner risk. Spiritual shopping lists calling for 'changes in values' invite others to philosophize and debate while the environment burns. Holdgate is wise enough to see some of this risk and he calls for other action too. But one wonders if the dreamers really understand that it is all about competition between humans and other species for space, for a slice of the Earth. Until environmental assets secure economic value greater than that embodied in the competing uses of the land on which they rely, the state of humanity really is at risk, as much, it seems, from the concerned as from the benign optimists. □

David Pearce is at the Centre for Social and Economic Research on the Global Environment, University College London, Gower Street, London WC1E 6BT, UK.

New in paperback

The Strange Case of the Spotted Mice and Other Classic Essays on Science by Peter Medawar. OUP, £7.99.

From Here to Infinity: A Guide to Today's Mathematics by Ian Stewart. OUP, £7.99. A revised and retitled edition of *The Problems of Mathematics*.

Natural Acts: A Sidelong View of Science and Nature by David Quammen. Avon, \$11. "Quammen's book is full of strange information about animals and their habitat, about Tycho Brahe's artificial nose, and other such oddities. His exuberance carries one, sometimes unwillingly, along", wrote Walter Gratzer in a review in *Nature* **318**, 116 (1985).

Reality bites

Freeman J. Dyson

The End of the World: The Science and Ethics of Human Extinction. By John Leslie. Routledge: 1996. Pp. 305. £16.99, \$23. To be published in the United States in May.

THE subject of this book is a philosophical speculation that the author calls the "doomsday argument". The same speculation was independently put forward in *Nature* (**363**, 315; 1993) by Richard Gott, who gave it the more appropriate name of the Copernican principle. The idea is to estimate the probability of the survival of the human species by using the Bayes rule. The Bayes rule says that (probability of A) multiplied by (probability of B given A) is equal to (probability of B) multiplied by (probability of A given B). The rule is supposed to apply to any two hypotheses A and B, because both sides of the equation are equal to the probability of the hypothesis (A and B). Formally, the rule is almost a tautology. But when it is applied to hypotheses in the real world, it can easily lead to absurd conclusions, because of ambiguities in the meaning of probability. Every estimate of probability must be based on a certain division of the world into known and unknown. The Bayes rule is valid only if the four probabilities in the equation are all based on the same division of the world. The phrase (probability of A) has no absolute meaning independent of previous knowledge.

Leslie applies the Bayes rule to a variety of situations of which the following is typical. Hypothesis A says that the human species will ultimately give birth to less than X people. Hypothesis B says that Leslie and his readers live at a time when the human species has given birth to fewer than Y people. Evidence from history and palaeontology indicates that (probability of B) is close to unity when Y is of the order of a hundred billion. Also, (probability of A) cannot exceed unity. Thus the rule implies that (probability of A given B) does not exceed (probability of B given A). Now, the probability that Leslie and his generation should happen to be among the first Y people in order of birth, out of a total population greater than X , is less than Y/X . That is to say, (probability of B given A) is less than Y/X . Therefore the Bayes rule leads to the conclusion that (probability of A given B) is also less than Y/X . That is to say, there is less than a ten-per-cent chance that the human species will survive long enough to give birth to a trillion people. The conclusion is that our species has only a ten-per-cent chance of surviving as long as five hundred genera-

tions with our present size of population, or fewer than five hundred generations if the population grows larger. Leslie elaborates this conclusion with numerous variations. He examines many different hypotheses and deduces the corresponding probabilities of survival. But the essential core of his reasoning is as I have stated it. The reasoning stands or falls according to whether the application of the Bayes rule is valid or invalid.

After careful consideration, I state unequivocally that the application of the Bayes rule is here invalid. The reason the rule fails is simple. The two quantities (probability of B) and (probability of B given A) are not based on the same division of the world into known and unknown. When we estimate (probability of B) to be close to unity, we assume that we know enough about palaeontology to be sure that we are living among the first hundred billion humans. When we estimate (probability of B given A) to be small, we assume that we know nothing of our place in the history of our species. The two estimates of probability are based on incompatible assumptions and are therefore not comparable. The application of the Bayes rule is invalid because the rules of the probability game have been changed between the left and right sides of the equation.

Half of the book is devoted to theoretical discussion of the Bayes rule and its application to the question of human survival. This discussion is worthless, being based on an invalid use of the rule. The other half of the book is a recital of the many real dangers to which our species is exposed. Here Leslie has nothing new to add. He refers to a large number of sources from the literature of science and risk assessment, but does not examine them critically.

Almost two hundred years ago, in 1798, Robert Malthus published his famous *Essay on the Principle of Population as It Affects the Future Improvement of Society*, deducing dire predictions of future misery from two hypotheses that he called the geometrical increase of population and the arithmetical increase of subsistence. His predictions of inevitable poverty failed because his hypotheses were faulty. The increase of subsistence turned out to be much faster than arithmetical. Nevertheless, uncritical belief in Malthus's predictions helped to hold back political and social progress in Britain for a century. Because of this unhappy precedent, I consider it important to call attention to the fallacy in Leslie's argument. A mistaken philosophical argument may have serious consequences in the real world. □

Freeman J. Dyson is at the Institute for Advanced Study, Princeton, New Jersey 08540, USA.