the immune system, which are susceptible to attack by HIV. One unanswered question is how the unpaired artificial chromosome will behave at meiosis, when maternal and paternal chromosomes pair up before separation.

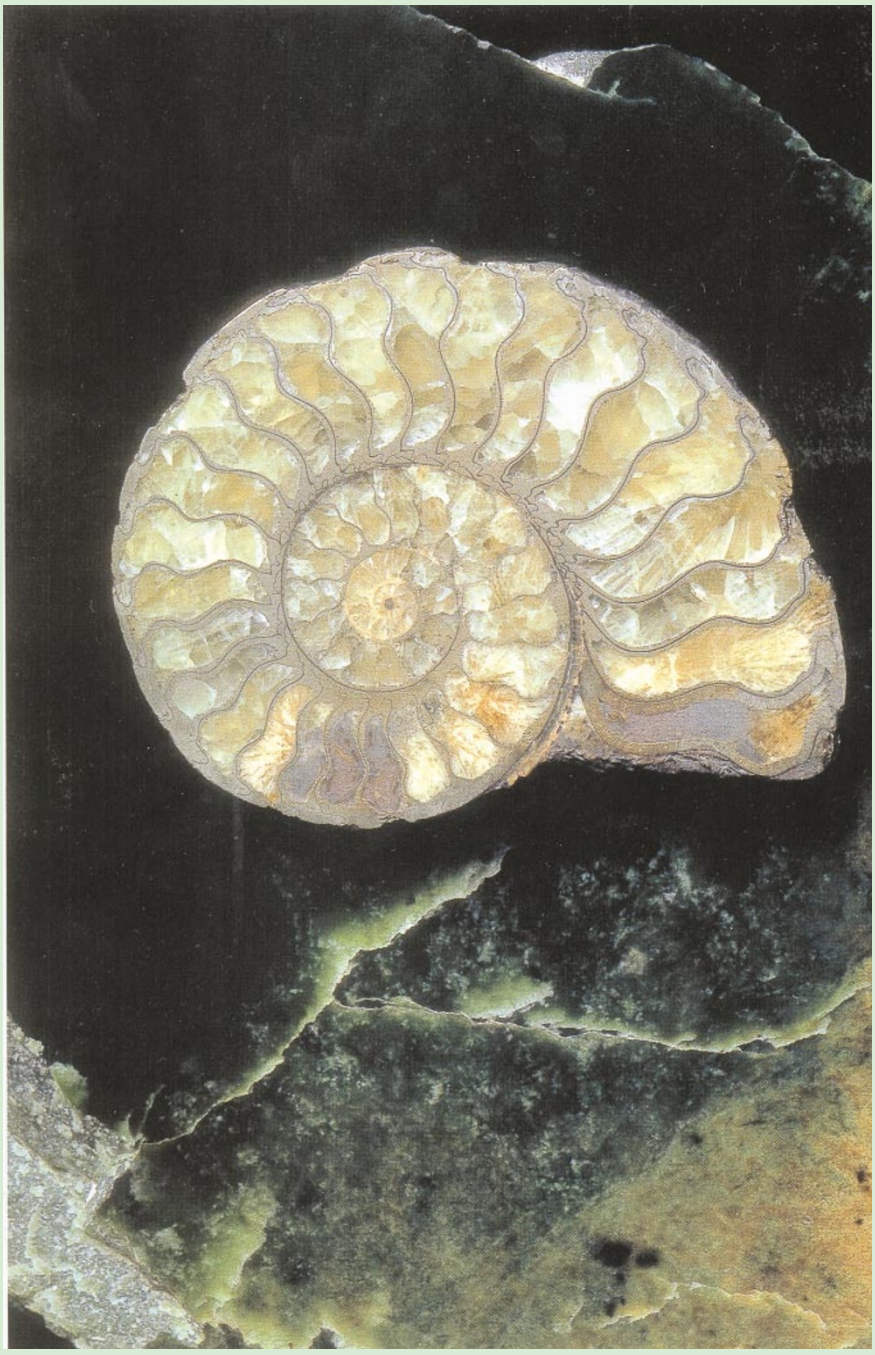
Another suggested application of germline gene therapy is the prevention of prostate or breast cancer. According to this stratagem, a toxin gene would be inserted which would be active only in certain tissues and would be expressed only in response to a specific external trigger should the tissue turn cancerous. Similar schemes are envisaged for preventing cell death in neurodegenerative diseases — once the protective genes have been defined. The resident gene would have to be silenced to ensure the correct 'dosage' and to prevent any interference when the inserted gene was turned on — a difficult molecular control task. But, assuming that such technology can be implemented, there is the problem of how we would select individuals for prophylactic engineering that would be carried out decades before the disease developed.

Lee Hood predicts that gene manipulation will be used to 'enhance' desirable traits such as emotional stability, intelligence and longevity, once we conquer the biology sufficiently to understand how these complex traits are controlled. But this may take 50 years. That gives us time to assess whether we can alter gene regulation with the degree of fine control required in these cases. Much of the technology for manipulating DNA already works in model systems, although there have been very few reports of changes to specific nucleotides — the building blocks of genes — and certainly not simultaneously at multiple gene positions as envisaged for engineering aimed at human enhancement.

Because we are starting to identify genes that affect ageing, it has been suggested that we might be able to prevent ageing by delivering a cocktail of beneficial genes using artificial chromosomes. However, not all participants at the symposium were keen to extend their children's lifespan, since quality of life is perceived to be more important than its duration. And there was some concern about the changes in population dynamics that increased longevity would create.

Jim Watson's view that no novel ethical dilemmas are raised by the concept of gene therapy on the germ line — the set of genes that are passed on to the next generation — is being taken up by some. They believe that the germ line is not particularly sacrosanct; if people think they can safely improve it using new technologies they should be allowed to do so. Watson is particularly eloquent about the moral imperative of seizing any opportunity to redress the genetic inequalities evident in all populations. However, only one or two participants mentioned the tremendous economic costs of such procedures. These would inevitably reinforce and exacerbate the inequalities that already plague us — or, more precisely, that plague the United States, since most of the discussion was centred on the free enterprise, no-federal-interference North American system. The predilection for state regulation in European countries is seen as undue squeamishness which hampers the development of robust, affordable new technology.

Although it seems that the ethical problems raised by germline gene therapy can be dealt with in our current moral framework, as a geneticist I feel strongly that the technological difficulties of safe but



Scientifically speaking

Crossing Over: Where Art and Science Meet **(Crown, $27.50) is a collection of essays by Stephen Jay Gould and photographs by Rosamund Wolff Purcell which aims to present science and art in conversation. In this context, a gibbon and Fred Astaire — "brothers under the hair" — are juxtaposed, and a tin toy illustrates the role of bilateral symmetry in creating complexity. The fossil ammonite shown above, cut, polished and set against a slab of jade, is a symbol of the arbitrariness of extinction and survival — ammonites survived two major mass extinctions, only to succumb to the catastrophe that obliterated the dinosaurs.**