

artificially activated. Encouragingly, these blastocysts exhibited an appropriate gene-expression pattern. But their full developmental potential is unknown.

These caveats aside, the three papers^{1–3} represent steps towards deriving primordial germ cells and, subsequently, eggs and sperm from ES cells. In the future, it will be important to develop means of controlling ES-cell differentiation into germ cells more tightly: in many respects, current methods rely on spontaneous and stochastic events, which makes it difficult to analyse each of the complex steps leading to the production of sperm and eggs. Systematic studies of germ-cell specification and properties (see, for example, refs 8, 9) will benefit from greater control over these steps *in vitro*.

So, what could be done with the 'synthetic' eggs and sperm? At present we are largely in the realms of 'fantastical thought experiments' — can we, for instance, generate viable embryos from synthetic germ cells? This could find applications in animal breeding, although researchers have yet to make ES cells from most mammalian species. Perhaps it might also prove possible to derive germ cells from human ES cells. If so, it would allow studies of human germ cells, about which very little is known. Use of such cells might also illuminate the causes of infertility and germ-cell tumours. It might even be possible to use synthetic sperm to treat male infertility. And, with improvements, the culture system could be used to examine many complex processes, including the roles of key genes and the mechanisms underlying imprinting and the halving of chromosome numbers.

Perhaps more importantly, however, a limitless supply of human eggs derived from existing ES-cell lines could have a radical impact on medicine. These synthetic eggs need not be perfect because, stripped of their own genetic material, they could be used as

recipients for nuclei or genetic material from adult cells such as skin cells. If such reconstituted eggs can 'reprogramme' the adult nucleus and develop to the blastocyst stage, researchers could derive new ES cells from them (Fig. 2). These cells in turn could be prompted to produce specific cell types for transplantation, to treat specific human conditions. Progress in this area is currently hampered by the scarcity of human eggs, the use of which also involves legitimate ethical considerations.

Human eggs derived in culture could also have an even more exciting use. By following the same procedure, it might be possible to use these eggs to generate ES cells that produce diseased tissues — the adult nuclei for the process being taken from patients with complex diseases such as diabetes. As noted at a meeting earlier this year, such ES cells would provide an unlimited resource, allowing approaches to the study of disease that are currently impossible¹⁰. This might, in turn, lead to new treatments.

And simply being able to study human germ cells in culture might allow more thorough investigations into the origin and properties of these remarkable cells. This could give us a grip on our destiny in more ways than we can imagine. ■

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100 YEARS AGO

Some experiments have recently been made to test whether the radio-activity of radium is influenced by the continuous bombardment to which it is subjected by its own radiations. In an article in this *Journal on radium* (April 30, 1903) Prof. J. J. Thomson suggested that the radio-activity of radium may possibly depend upon its degree of concentration, and that a given quantity of radium, diffused through a mass of pitchblende, may be less than when concentrated in a small mass. In order to test this point, measurements of the radio-activity of radium bromide were made when in the solid state and when diffused throughout the mass of a solution more than a thousand times the volume occupied by the radium compound... This experiment shows that, over the range investigated, the radio-activity of radium is not influenced by its own intense radiations. E. Rutherford
From *Nature* 7 January 1904.

50 YEARS AGO

During September 21–25, 1953, a conference was held by invitation of Prof. Linus Pauling at the California Institute of Technology in Pasadena, to discuss progress in the X-ray studies of the structure of proteins (and to a lesser extent of nucleic acids). The last conference of this kind was that arranged by the Royal Society and held in London during May 1952; it had been the first to include a full-scale discussion of the new polypeptide chain configurations proposed by Pauling and Corey, especially the α -helix... The most general and fundamental concept underlying the discussions was that helical arrangements are at the basis of many important biological structures, either at the atomic level as a type of configuration for long-chain molecules, or at the molecular level as a way in which larger units of structure may naturally aggregate. Although a helical model had been proposed for the polypeptide chain by H. S. Taylor as early as 1941, ... it cannot be said that the helix as a structural principle had entered into the fundamentals of our thinking up to the time of the Royal Society conference: indeed on that occasion there was strong disagreement as to the existence of helical chains. The Pasadena conference revealed that the helix has now come into its own with a vengeance; finding helices is a game played by nearly everyone in the field. J. C. Kendrew
From *Nature* 9 January 1954.

Ecology

Clouded futures

J. Alan Pounds and Robert Puschendorf

Global warming is altering the distribution and abundance of plant and animal species. Application of a basic law of ecology predicts that many will vanish if temperatures continue to rise.

Evidence that climate change is affecting life on Earth continues to mount^{1,2}. But how great is the threat to biodiversity? On page 145 of this issue, Thomas *et al.*³ show that global warming, projected to the year 2050, could sharply increase extinction probabilities for a sample of 1,103 species representing terrestrial regions from Mexico to Australia. If temperatures follow middle-of-the-road projections, the study suggests, about one-quarter of these species may dis-

appear — a loss that would exceed that expected from habitat destruction.

Thomas *et al.* assume that each species can persist only under a particular set of climatic conditions. This 'climate envelope', assessed by modelling current geographical distribution in relation to climatic gradients, serves to predict future distribution. As warming alters these gradients, many species are shifting towards the poles or to higher elevations, their ranges often contracting as the area of

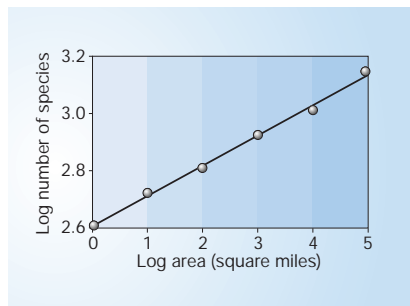


Figure 1 H. C. Watson's demonstration of the species–area law for Britain's vascular flora. The smallest sampling area was a plot in Surrey; each successively larger area was an expansion of the preceding one. Thomas *et al.*³ apply this law to assess how extinction risk increases as global warming reduces the area of climatically suitable habitat. (Adapted from ref. 4.)

climatically suitable habitat declines^{1,2}.

To predict the outcome, Thomas *et al.* turn to one of ecology's few ironclad laws: the species–area relationship. Basically, smaller areas support fewer species. In 1859, the year in which Darwin's *Origin of Species* appeared, H. C. Watson demonstrated this law for Britain's vascular flora by comparing sampling areas ranging from a square mile to all of England⁴. Plotting the logarithm of the number of species as a function of the logarithm of area, he found a linear relationship (Fig. 1). This pattern, we now know, is typical of regional scales, where a power-law equation usually describes the relationship between number of species and area⁴. At these scales, the species–area curve probably reflects the configuration of species' ranges and thus the history of speciation, dispersal and extinction.

Using this relationship to assess climate-related extinction risk, Thomas *et al.* explore three approaches. Their conclusions are the same with each of them. They consider change in area summed for the various species, proportional loss of area averaged across species, and change in area for each species individually. Averaging the results of these methods, applied under two dispersal scenarios, they estimate the extinction probability for different amounts of warming as 18% (0.8–1.7 °C), 24% (1.8–2.0 °C) and 35% (above 2.0 °C).

These estimates might be optimistic. The risk of extinction increases as global warming interacts with other factors — such as landscape modification, species invasions and build-up of carbon dioxide — to disrupt communities and ecological interactions. Furthermore, the models might not capture some key climatic changes. One pillar of Thomas and colleagues' analysis is the modelling of range contractions in the tropical rainforests of northeast Australia⁵. But the authors of that study⁵ emphasize that it considers only the effects of rising temperatures and that other changes could magnify the impacts. In the highlands, for example, an increase in the

altitudes at which clouds form^{6–8} could affect communities that require frequent immersion in clouds and mist.

Changes in cloud cover might also be important. Warming accelerates evaporation and increases the air's capacity to hold water, thereby increasing its content of water vapour⁹. Cloud formation, however, depends on relative humidity, which varies inversely with temperature, so warming may reduce cloudiness over some regions. In contrast, where air masses cool sufficiently — for instance where they ascend mountain slopes — increased water vapour should translate into enhanced cloud formation, even if condensation begins at increased altitudes. Accordingly, widespread increases in cloud cover are under way⁹.

Are changing cloud patterns already contributing to the extinction of species? Thomas *et al.*³ refer to amphibian declines and disappearances in the mountains of Costa Rica as the one example in which recent warming has been implicated in such losses (Fig. 2). Various biological changes in these mountains are associated with unusually dry weather attributed to an increase in heights of cloud formation⁶. Understanding amphibian extinctions is crucial, given that they are taking place in highlands around the world^{10,11}. For example, most of the 70-odd members of the harlequin frog genus *Atelopus*, endemic to Central and South America, have vanished or declined markedly (E. La Marca, personal communication).

Nevertheless, few studies have examined how climatic changes might be linked to the immediate causes of these declines^{12,13}. The climate-envelope concept championed by Thomas *et al.* might help to shed light on one such cause — outbreaks of the chytrid fungus *Batrachochytrium dendrobatidis*^{14,15}. This lethal parasite of amphibian skin thrives under cool, moist conditions. In culture, it grows at 6–28 °C but dies at higher temperatures. Experiments with the Australian frog *Litoria chloris*¹⁶ show that elevated body temperatures, reached naturally by basking in the sun or seeking warm microenvironments, can rid the frogs of this fungus. The low humidity typical of warm microsites might likewise enhance frog survival.

Both increased cloud cover and unusually dry weather might hamper these defences. In highland tropical forests, ambient air temperatures generally lie within the climate envelope of *Batrachochytrium*. But these forests include shaded and sunlit microhabitats. Under clear skies, temperatures in the latter can quickly exceed 30 °C, so an amphibian can 'escape' from this envelope. Under cloudy skies, however, microhabitat temperatures mirror ambient temperatures, making escape difficult. Dry conditions may have similar consequences: with limiting moisture, an amphibian might have to stay in cool, damp places.

Although exploring these potential links



Figure 2 Absent amphibians. Both the golden toad (*Bufo periglenes*, top) and the Monteverde harlequin frog (*Atelopus* sp.) were found in the mountainous Monteverde region of Costa Rica, but have not been seen since the late 1980s. New DNA evidence indicates that the latter was a yet-unnamed species (R. Ibañez, personal communication). The disappearance of these amphibians, linked to declines in mist frequency ascribed to global warming⁶, might be due to climate-related outbreaks of an emerging pathogen.

between climate and recent extinctions is essential, the patterns implicating global warming in such losses attest to the urgency of Thomas and colleagues' principal recommendation³. Reducing the concentrations of greenhouse gases — and reducing them soon — could minimize this warming and hence the number of extinctions. The threat to life on Earth is not just a problem for the future. It is part of the here and now. ■

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Astronomy

To catch a stellar thief

Thomas Matheson

A supernova seen in 1993 defied explanation. Astronomers suspected the dying star had lost much of its hydrogen before the explosion. The discovery of a companion to this star suggests where that gas went...

In March 1993, something new appeared in the nearby galaxy M81. A star had exploded, becoming the brightest supernova visible in the Northern Hemisphere since 1954. The exceptional brightness of SN1993J, as it is known (Fig. 1), meant that detailed observations of it were possible across virtually the entire spectrum of electromagnetic radiation. But these studies produced some unexpected results, forcing astronomers to change the way they classify supernovae. Peculiarities in the sequence of emission from SN1993J led many to conclude that the dying star must have lost a considerable amount of its outer envelope of hydrogen gas before it exploded^{1–7}; probably this mass was transferred to a companion star. Ten years later, in a dramatic vindication, Maund *et al.*⁸ report the discovery of this companion (page 129 of this issue).

That SN1993J was missing some of its hydrogen is a key factor in understanding the mechanisms that produce supernovae. Supernovae are classified according to certain features in the spectrum of radiation they produce at optical wavelengths⁹. Originally, the distinction was based solely on the presence or absence of emission from hydrogen atoms (hydrogen lines). Supernovae without hydrogen lines were called type I, those with hydrogen lines type II. Subsequent analysis of many of these objects revealed that this empirical classification scheme in fact reflected two different mechanisms for the supernova explosion. The consensus is that type I supernovae (lacking hydrogen) are the result of the thermonuclear disruption of a white-dwarf star that has absorbed almost as much mass as it can (it is near the Chandrasekhar mass limit for such stars, around 1.4 times the mass of the Sun). Type II supernovae (with hydrogen) are thought to be the result of core collapse in a massive star.

As stars develop, they begin by fusing hydrogen into helium. Once a star has exhausted its hydrogen reserves, it will then

fuse helium into carbon. Massive stars (more than eight times the mass of the Sun) can fuse carbon and heavier elements. So several stages of nuclear burning occur, giving the star a layered, onion-like structure, with an outermost shell of hydrogen surrounding shells of helium and of heavier elements. The creation of iron marks the limit for normal stellar fusion; fusing iron into heavier elements no longer releases energy. At this point, there is nothing left to counteract gravity, and the stellar core collapses to form a neutron star or, possibly, a black hole.

With bigger telescopes, better instruments and more data on supernovae, it became clear, however, that the empirical classification scheme could not remain so simple. Some supernovae that lacked hydrogen (hence type I)

did not match the homogeneous spectra expected for the thermonuclear disruption of a white dwarf. In the time-honoured astronomical tradition of inscrutable nomenclature, the original class was now renamed type Ia; the new subtypes were called type Ib (if they showed helium lines) or type Ic (if they did not). The question then arose: what mechanism created these different types of supernova?

A circumstantial case grew that type Ib and Ic supernovae were in fact related to type II supernovae: all three types are associated with massive stars and occur in similar galactic environments; a while after the explosion, their spectra look alike, except that type II supernovae show hydrogen lines. But the data for SN1993J brought another surprise¹⁰. Shortly after the explosion, its spectrum contained hydrogen lines — a type II supernova — but within a few weeks strong helium lines developed. The spectrum then looked more like a type Ib supernova, as though the envelope of hydrogen had lifted to reveal a helium layer (it was then called a IIb). A natural explanation is that these types (II, Ib and Ic) all arise from the same mechanism of core collapse, and the different spectra reflect different outermost layers for the progenitor star: the progenitors of type II supernovae retain their hydrogen; those of type Ib supernovae lose their hydrogen, but keep their helium layer; and those of type Ic supernovae have lost both hydrogen and helium layers.

If this is the case, then there must be a process by which the outer parts of the progenitors are removed before they explode. Stars can lose mass through winds (such as the solar wind of our own Sun), but this method is not efficient enough to explain the mass loss in



Figure 1 The beautiful spiral structure of the galaxy M81, one of the brightest galaxies in the sky. In 1993, a dying star in one of the arms of this galaxy exploded in a supernova, now called SN1993J. Radio-wavelength images¹³ (lower images) trace the development of SN1993J over the first year of its existence.

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