

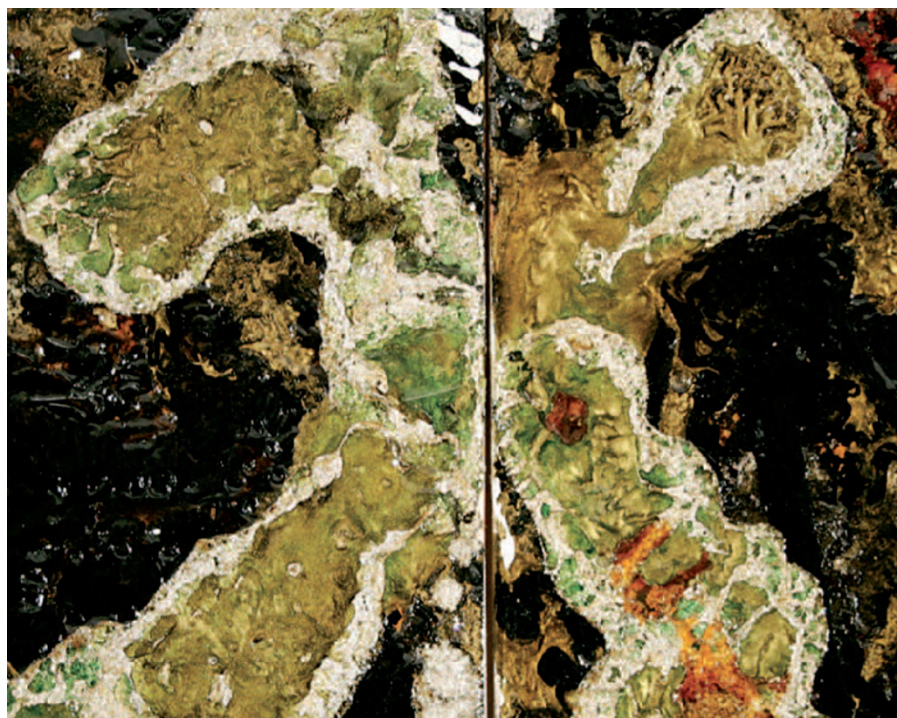
of QED. The result was so powerful that, according to US-based physicist Freeman Dyson, Feynman could do a calculation that once took several months “in half an hour” on the blackboard.

When he won his Nobel prize in 1965, Feynman felt his methods were merely useful, not profound. Today, his approach is considered a more fundamental way to look at quantum theory than the formulations of its founders, such as Niels Bohr, Werner Heisenberg and Erwin Schrödinger. It is the basis of how physicists think about particles interacting, exchanging carriers of force, fluctuating in and out of existence. It is also, ironically, the basic tool of both string theory and quantum cosmology.

Krauss does a good job of imparting Feynman’s fascination with all physical phenomena, and goes on to describe Feynman’s later groundbreaking work in other fields — on the weak interactions, the theory of liquid helium and his parton model, which provided evidence for the existence of quarks. Intertwined with the physics are snippets of Feynman’s personal life, including his habit of working on physics in a strip club, and his undying love for his first wife Arline Greenbaum, who died from tuberculosis in 1945, just a few years after they were married.

As Krauss acknowledges, the book contains little that is new. Jagdish Mehra’s *The Beat of a Different Drum* (Clarendon Press, 1994) is a far more detailed account of Feynman’s science, equations and all; and James Gleick’s best-seller *Genius* (Little, Brown, 1992) covers Feynman’s personal life in greater depth. Still, I found the account of Feynman’s hard work, passion and discoveries inspirational, and, for a physicist at least, good bedtime reading. For those without a strong physics background, however, the prose can be tough going, especially the more technical passages. Personally, I love being talked to that way. ■

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**Size Matters:** Detail from *Figure 6* (2008) by Ian Harvey and Koo Kyung Sook.

BIOTECHNOLOGY

# Making people

Today’s wariness of reproductive technologies stems from myths, legends and Hollywood, finds **Chris Mason**.

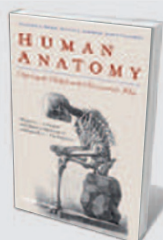
Stem cells, cloning, regeneration and life extension are frequently in the news. When they are, the media often resort to sensationalist clichés — invoking Frankenstein to conjure up a stereotypical mad scientist ‘playing God’ by creating out-of-control monsters. Whereas the creation of non-human artificial life, such as Craig Venter’s engineered microbes, gets a mixed press, the making of humans is invariably controversial. Clearly, human life has a special moral status.

In *Unnatural*, science writer Philip Ball explores the history of our fascination with — and fear of — creating artificial people, from ancient folklore to today. Tracing a clear path



**Unnatural: The Heretical Idea of Making People**  
PHILIP BALL  
*Bodley Head: 2011.*  
384 pp. £20

from medieval alchemists’ homunculi to routine assisted conception is a feat. Through his impeccable research, Ball successfully argues that the tenacious myths of the past that surround the making of people or ‘anthropoeia’ (his coinage) affect life-science research today.



**Human Anatomy: Depicting the Body from the Renaissance to Today**

Benjamin A. Rifkin, Michael J. Ackerman and Judith Folkenberg (Thames & Hudson, 2011; £19.95)  
This beautifully produced book presents more than 500 years of anatomical illustration. It charts how our knowledge about the body has changed along with our interpretation of what we see within it.



**Wetware: A Computer in Every Living Cell**

Dennis Bray (Yale Univ. Press, 2011; \$18)  
By treating a single-celled organism as a computational system, biologist Dennis Bray explains how it balances internal chemistry, responds to light and hunts prey — all without a nervous system. He sees cells as unique molecular circuits that perform logical operations.

Ball traces the concept that nature is good and *techné* is bad back to Aesop's and Ovid's Prometheus, maker of humanity from earth and water, and provider of technology to man. After Prometheus came recipes for making miniature humans called homunculi. Starting in the Middle Ages, initially as a cure for childlessness, the art of homunculi-making evolved into a debate over whether the miniscule men had a soul. Johann Wolfgang von Goethe's nineteenth-century poetic play *Faust* raises this spectre. Deploying the biological equivalent of alchemy, Faust's former assistant, Wagner, creates his homunculus: a tiny super-being with magical powers who is trapped in a glass vessel, doomed to remain captive without the capacity to become a proper man. In 1818, Mary Shelley published *Frankenstein*, appropriately subtitled 'The Modern Prometheus', in which her eponymous scientist unintentionally constructs a monster, by unexplained means, from human parts. There are also golems — the animated beings of Jewish folklore, made from clay and brought to life by religious magic for the purpose of imitating God's creation.

Ball distills out of all this a set of universal myths surrounding anthropoeia that are deeply ingrained in society, resulting in the widely held view that artificial people-making is unnatural and deeply wrong — heretical, as in the book's subtitle. His thesis is that humans fear that uncovering forbidden knowledge will result in either divine or other retribution. Prometheus, Faust and Frankenstein all pay a heavy price for their transgressions into anthropoeia. Even today, Ball points out, societal and cultural debate is pervaded by the belief that technology is intrinsically perverting and thus carries certain penalty. Views that human cloning will be used for social engineering, eradicating one gender or resurrecting undesirable figures from the past, for example, all reflect age-old fears about the consequences of meddling in the 'unnatural'. Ball warns that, as there is no

global ban on human reproductive cloning, there is a strong chance that it will happen. It is thus likely to become a de facto reality without the well-informed debate it deserves.

As scientific knowledge accumulates and makes some acts of anthropoeia more and more plausible, the challenge for the public will be to separate fact from fiction. For example, Ball ends his literary tour with Aldous Huxley's novel *Brave New World*. In 1931, the book's *in vitro* production of embryos in the Central London Hatchery and Conditioning Centre was pure conjecture by Huxley, based on the scientific forecasts of his day. Today, *in vitro* fertilization (IVF) is mainstream medicine — more than four million babies have been born using this technique. But the technology

still has its critics, including within the Vatican. On the awarding of the 2010 Nobel Prize in Physiology or Medicine to IVF pioneer Robert Edwards, Ignacio Carrasco de Paula, head of the Pontifical Academy for Life, stated that the award was "completely out of order", as without IVF there would be no market for human eggs "and there would not be a large number of freezers filled with embryos in the world". For some, such words conjure up images of unscrupulous profiteering and factory-like storage of human lives, generating fears that human procreation will be reduced to mere money and industrial bioprocessing.

Huxley was more futuristic in including humans conceived and grown entirely outside the body. As Ball explains, the artificial womb remains fiction, albeit moving slowly towards fact. Its leading exponent, Hung-Ching Liu, at the Center for Reproductive Medicine and Infertility in New York, has grown human uterus lining (endometrium) and thinks it will eventually be possible for fetuses to be grown outside a woman's body. Progress has been

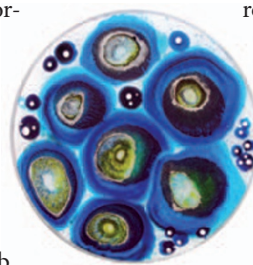
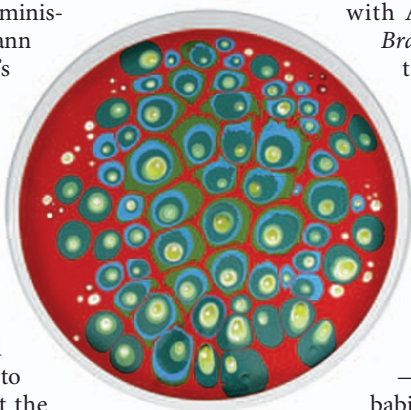
made in other species, including mouse embryos gestated to almost full term in 'bubbles' of endometrial tissue and premature goats kept alive by artificial placentas.

Meanwhile, headlines about three-parent human embryos and mice with two fathers continue to fuel science fiction. Back in 1978, the film *Boys from Brazil* imagined Nazi physician Josef Mengele attempting to resurrect Adolf Hitler by reproductive cloning. Some 20 years later, in *The Matrix* (1999), countless humans are bred and kept in pods so that their body heat and electrical activity can be harvested as energy for the machines that have taken over the world. More recent films, such as *The Island* (2005) and *Splice* (2009), have further built on the science fiction of reproductive science.

The challenge for innovative biological research is that, until it translates into real benefits, it is often viewed with mistrust and worse-case scenario imagery. In reality, once products and services are released into society, they are adopted by a few enthusiasts and then, if successful, by the wider community. In the 1970s, for example, anxieties were rife about the unfounded threat that IVF posed to human welfare and dignity, let alone whether a test-tube baby could ever be wholly human. Yet the first IVF baby, Louise Brown, was just like everyone else, so IVF became socially acceptable. We cannot predict whether human cloning will proceed in the same manner, so the past is our only pointer.

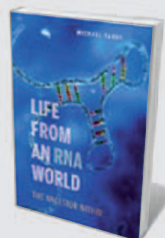
For scientists, clinicians and biotechnology business people, understanding deep-rooted ideas, however irrational, is vital for successful dialogue with the public. The fiasco of genetically modified (GM) crops came about because of the failure to predict that the media would label GM products as 'Frankenfood' — together with the moral judgement it would infer. Today, stem cells and cloning are under the media spotlight. *Unnatural* is therefore a must-read for all stakeholders of these advanced technologies. ■

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LARGE PICTURE TEST 2 (2011) BY KLARI REIS. COURTESY OF THE ARTIST

PETRI TEST 1 (2011) BY KLARI REIS. COURTESY OF THE ARTIST



#### Life from an RNA World: The Ancestor Within

Michael Yarus (Harvard Univ. Press, 2011; \$17.95)  
Many biologists think that today's DNA-based life forms evolved from RNA molecules. Biochemist Michael Yarus marshals arguments in support of that theory in his book, which explores the principles of Darwinian evolution, the tree of life and the diverse abilities of RNA.



#### Biology is Technology

Robert H. Carlson (Harvard Univ. Press, 2011; \$21.95)  
Robert Carlson explains how to build synthetic biological systems from basic components and the technology used to manipulate them. "An informative view of the future prospects for biotechnology and its regulation," wrote reviewer Michael Goldman (*Nature* **464**, 1129–1130; 2010).