an afternoon break, with beer and posters until the small hours. One year, the teenagers attending a tennis camp at the same venue complained that we were being too rowdy and keeping them awake. Revenge is just so sweet.

What do you think about high-impact journals that cater to a wider audience? I used to think that such journals were for the vain and insecure; however, I've just had my first article accepted by *Current Biology*, so I must of course re-consider. I think there is a place for journals suited to the more general reader, but I do worry that the decisions for some journals — even on whether to send the article out to review — are predicated on sex appeal rather than substance. An interesting development might be a journal that allows one to submit a brief (say two or three page) version of a paper that has already been published in a more specialist journal. This would then be accessible to the more general reader. Old farts like me would be re-assured that the article had been reviewed by specialist editors and reviewers, and, instead of moaning about the modern world, could just go and read the original.

What single thing would improve the quality of research in your field? I think that there are, say, seven or eight common logical mistakes that keep cropping up in different papers and presentations. If you go to a good conference, you will spot three or four. If you go to a bad one you can sit there all day ticking them off. It may seem trivial, but the errors are I think more common the closer one gets to research that might help patients. So I think we could all be a bit more watchful, and not be too shy or polite to educate our junior (and, OK, senior) colleagues.

What is your greatest ambition? To make one fundamental discovery that has a significant positive impact on patient health.

What do you think are the big challenges to be overcome next in your field? In terms of the basic science, we are still some way from knowing how important features of sound, such as pitch, are encoded and recoded at progressively higher levels of the auditory system. We also lag a long way behind visual science in understanding the interaction between sensory coding and prior knowledge. I think that the biggest applied challenge is to improve hearing by those who need it most, and whose speech perception remains poor despite our best efforts. These include the minority of cochlear implant patients who get little benefit from their device, and most patients with brainstem or midbrain implants.

What is your most embarrassing moment (in research)? I gave a departmental seminar in the States when I was a graduate student. I answered a question with a slightly condescending definition of the auditory nerve rate-level function. That evening my host gently pointed out that the questioner was Murray Sachs, an eminent physiologist who had published extensively on the subject.

What are you working on now? With Colette McKay and John Deeks, I've been studying patients with auditory nerve damage whose hearing has been restored by an auditory brainstem implant (ABI). There's still only a rudimentary understanding of the relationship between electrical stimulation of the brainstem and perception. Getting a handle on this is going to be vital if we are to improve the generally poor speech perception abilities of these patients.

If you knew what you know now when you were younger, what would you have done differently? I'd have spent more time studying physics, chemistry, and biology — at least up until age 18 — and would have taken some physics courses at university. People I know with this more formal scientific background have a better understanding of how the world works.

And would you still have pursued the same career? Definitely. Of course, we all know science is fun. One thing I like about my own particular field is this: if your logic is flawed you will be assailed from all sides, but no-one is obsessively defending their own patch. There is a sense of scrabbling together towards a common goal.

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Quick guide

Pearls

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What exactly are pearls? Pearls are calcareous deposits found inside the bodies of molluscs. Pearls form when the shell-formation pathway is induced in the wrong part of the animal. The pearls of many molluscs are smooth and chalky. Although these are typically of little value to humans, they can be impressive — the largest natural pearl on record is a 6.5 kilogram lump of glossy calcite secreted by a giant clam. Historical and contemporary interest in pearls is largely restricted to the small number of species that fabricate pearls coated in lustrous nacre (mother-of-pearl) (Figure 1A). Most commercial pearls come from freshwater mussels in the Unionidae family and marine pearl oysters in the family Pteriidae, although there are a number of other bivalves and gastropods (e.g. abalone and top shells) that are able to produce nacreous pearls.

How are pearls related to shells? Most molluscs produce shells that are composed of calcium carbonate tablets surrounded and perfused by an organic matrix of proteins, lipids and polysaccharides. The shell forms externally, adjacent to an organ called the mantle. The highly regulated secretion of these organic materials from the mantle's epithelial layer dictates the colour, shape and pattern of the shell, and underlies the amazing diversity of mollusc shells in nature. This organic matrix also dictates the type (polymorph) of calcium carbonate that will be deposited in the shell. In most molluscs, different zones within the mantle epithelial layer direct different calcium carbonate architectures, resulting in the generation of shells with multiple layers (Figure 1B). For example, in pearl oysters the inner nacreous shell layer is fabricated by the inner zone of the mantle, while the middle prismatic (porcelain-like) layer is produced from the more distal mantle epithelium; the proteinaceous (organic) outer shell periostracum is secreted from

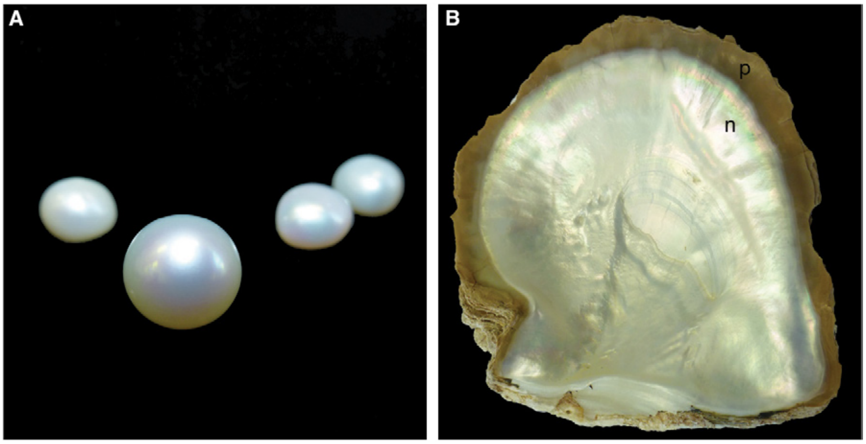

Figure 1. Pearls and shells.
(A) Nacreous pearls. (B) Shell of the silver-lip pearl oyster, *Pinctada maxima* (p: prismatic layer; n: nacreous layer).

a groove in the mantle's outer edge. Pearls are also composites of calcium carbonate and organic matrix, and can likewise exhibit nacreous, prismatic or 'organic' architectures.

How are pearls biofabricated? The common misconception is that formation of natural pearls is triggered by a foreign particle (usually a grain of sand) becoming lodged within the animal. Although many natural pearls do contain a foreign body (commonly a parasite) at their core, the critical condition for pearl formation is that epithelial cells from the mantle are transported to another location within the animal. This typically occurs after some kind of injury, such as puncture to the shell or burrowing by a parasitic organism. The ectopic mantle cells proliferate to form a sac and then secrete internally the material that will create the pearl. Structural analysis of pearls indicates that they are essentially inside-out shells, with an inner core that resembles a periostracum being surrounded first by a prismatic layer and then an outer nacreous layer. However, in many pearls this layering is disrupted, which is likely to cause at least some of the variation in quality that is a critical factor in assessing the pearl's value.

Have pearls always been valuable? The outstanding natural beauty of pearls has been treasured by humans throughout history. Evidence for the use of pearls as decorative items dates from the Babylonian era, and early scriptures from diverse cultures pay testament to the widespread appreciation of what must have been one of the first accessible, albeit rare, precious gemstones. Although pearls historically have been a symbol of status and wealth, the advent of mass culturing techniques in the 1950s has made pearls more affordable.

Am I wearing a natural pearl? Unless you are very wealthy, probably not! Natural pearls are still extremely rare and valuable. In gemmological nomenclature, the word 'pearl' refers solely to natural pearls — pearls that are the result of culturing or artificial techniques must be appropriately designated. Natural pearls can be discriminated from cultured pearls using various X-ray techniques, although detection is not always easy and requires specialist knowledge. Cultured pearl production exploits the ability of transplanted mantle epithelia to form a pearl sac (Figure 2). Mantle cells (usually from a second 'donor' animal) are implanted into an appropriate area of the host (usually the gonad), often along with a circular bead (nucleus). The donor tissue ('saibo') then grows around the nucleus to completely enclose it, forming the pearl sac, and secretions are deposited on to the nucleus to form a (hopefully) round pearl. Although a number of different pearl culture techniques have been tried throughout history, the saibo and nucleus method is the most efficient. The technique was most likely developed in Australia by William Saville-Kent before being taken by two of his fellow workers to Japan, where the patents were eventually acquired by the 'Pearl King' Kokichi Mikimoto. This technology paved the way for mass production of cultured pearls.

How does the pearl sac develop? Cultured pearls provide insight into several aspects of pearl sac development. First, mantle cells can be easily transplanted between different individuals (even between closely related species), indicating that allorecognition pathways do not operate in these tissues. Second, the cell types involved in pearl sac development display a high degree of plasticity. The donor tissue selected for implantation is generally taken from the nacre-producing region of the mantle, which contains cells that are distinct from that of the regions producing the periostracum or prismatic layer. However, the successive production of pearl layers and the observed expression in the sac of genes associated with either prismatic or nacreous shell formation suggest that the implanted cells may revert to an earlier periostracum and then prismatic production state. This implies that these cells follow a temporal developmental program that is related to the spatial arrangement of the epithelial zones of the mantle. This program may be similar to that used for shell repair, and it is not understood whether these processes involve a cell type switching between different shell formation pathways, or dedifferentiation of nacre-producing mantle epithelial cells into an earlier periostracum or prism-producing state. Pearl sac development also appears to include a complex interplay between cells of the host and donor, with both genomes ultimately contributing to the synthesis of pearl matrix proteins. As the operation is performed in the gonad tissue, this implies that the transdifferentiation of host gonad cells into biomineralising cell types takes place. If this indeed is the case, it is possible that spontaneous transdifferentiation of an unknown mesenchymal cell type may occur in nature, giving rise to natural pearls.

Are there pearl genes? In the quest to improve the quality of cultured pearls, recent research has turned from fine-tuning culturing techniques to selectively breeding pearl molluscs that produce pearls with the desired traits. As a consequence, the last decade has seen a significant

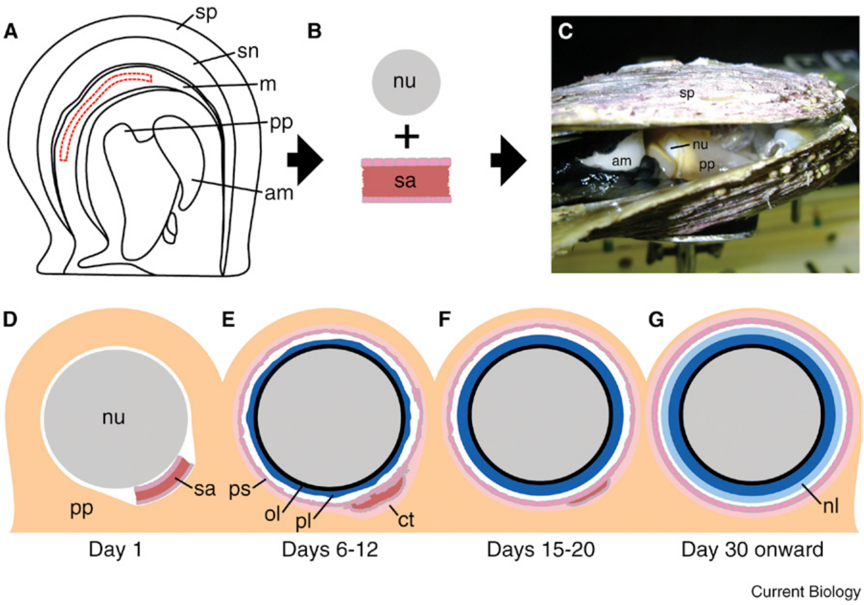

Figure 2. Pearl culture.
(A) Schematic of the internal anatomy of the pearl oyster. The region from which donor tissue (saibo) is extracted is indicated by the red dotted line. (B) A marble-shaped nucleus and small piece of saibo are implanted into the host oyster. (C) Host oyster after harvest of first pearl and insertion of second nucleus. (D–G) Schematic of pearl sac development. On day 1, nucleus and saibo are inserted into the pearl pocket (D). After approximately 6–12 days, the incision has healed and epithelial cells from the saibo have migrated around the nucleus to form the pearl sac. Organic material has been deposited onto the nucleus, followed by an irregular prismatic layer (E). On days 15–20, the prismatic layer now has a regular appearance (F). After approximately 30 days, the pearl sac has a homogeneous appearance and no trace of the saibo graft remains. The nacreous layer of the pearl has begun to form (G). (am: adductor muscle; ct: connective tissue; m: mantle; nl: nacreous layer; nu: nucleus; ol: organic layer; pl: prismatic layer; pp: pearl pocket; ps: pearl sac; sa: saibo; sn: nacreous layer of shell; sp: prismatic layer of shell.)

increase in the amount of genetic data available for pearl molluscs, including the sequencing of the *Pinctada fucata* genome last year. Transcriptome sequencing of both the mantle and pearl sacs and proteomics of shells and pearls has shown that the same genes and proteins are involved in their synthesis — to date, no unique 'pearl' genes have been found. There are, however, indications that genes that are highly expressed in the nacreous region of the mantle are not necessarily also highly expressed in the pearl sac, and that pearl formation may be more complex than originally supposed.

Where can I find out more?

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Primer

Intelligence

Ian J. Deary

Some people are cleverer than others. I think it would be a good thing if more biologists began with that observation as the starting point for their research. Why? Because it is a prominent and consistent way in which people differ from each other; because the measurements we make of people's cleverness produce scores that are correlated with important life outcomes; because it is interesting to discover the mechanisms that produce these individual differences; and because understanding these mechanisms might help to ameliorate those states in which cognitive function is low or declining.

Psychologists study intelligence in two different ways. First, cognitive psychologists mostly focus on trying to find out how the normal mind works. They try to enumerate the mental functions that we share. They try to discover how those functions fit into a mental system. Second, differential psychologists mostly focus on how people differ in the workings of their minds. They try to enumerate the major domains of function in which people differ. They try to discover the causes and consequences of these differences. The two types of psychologist studying intelligence don't communicate very well. For example, if you look at texts on cognitive psychology, you will find few mentions of individual differences. This primer is about the differential psychology of intelligence.

Most academics who do not work in intelligence differences are skeptical when the field is mentioned. This might be for a number of reasons. First, the word 'intelligence' can appear to be too general; surely, it is argued, that there are so many distinct cognitive capabilities that we are all good at some mental skills. Second, there are some events in the history of intelligence research that have appeared to discredit the field; some people will recall divisive 11-plus tests of the old UK school system, or have heard about the Cyril Burt affair (there is debate about whether