Biojewellery

Designing rings with bioengineered bone tissue

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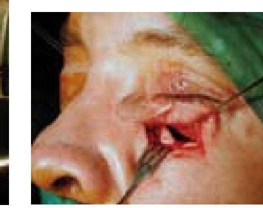
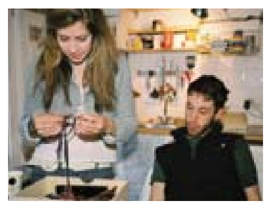


Example of a bioactive implant: at King's College London, the scan of a patient's head shows damage to the eye socket. Bioactive glass is cast and inserted into the orbital floor to help support the patient's eye.

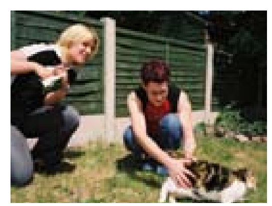




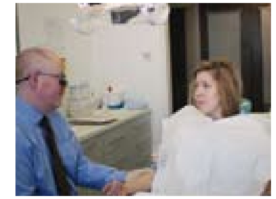
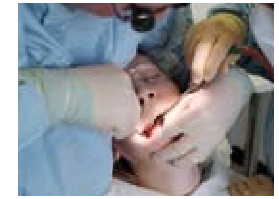




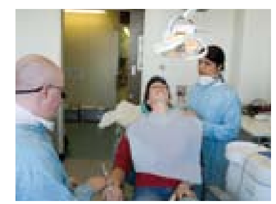


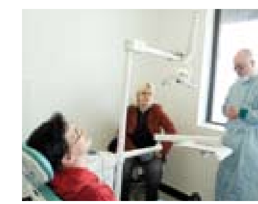


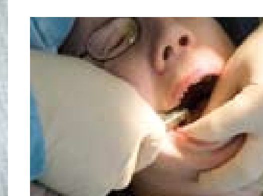

Four couples took part in the project and were visited at home by the designers in order to discuss ideas for their rings



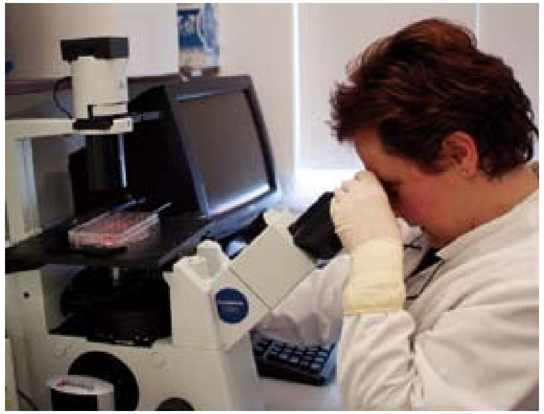


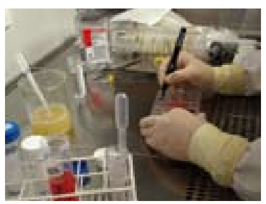




Images from Harriet's and Lynz's dental surgery. Fragments of jaw bone were removed along with their wisdom teeth. The teeth were discarded while the chips were prepared for cell culture.






Dr Lucy Di Silvio receiving bone fragments from Lynz's wisdom tooth removal. The chips are prepared for tissue culture in a sterile cabinet.

WHAT IS BIOJEWELLERY?

In the near future, bone tissue cultivated outside a patient's body may be used in reconstructive surgery to repair damage caused by injury or disease. As the science behind this process develops, it begins to spark curiosity, desire and speculation about alternative uses of this innovation. Biojewellery, a collaborative project involving scientists and designers, explored one of these alternatives. Employing the techniques of bone tissue culturing, we provided two couples with a unique symbol of their mutual love and sought to provoke debate about the relationship between scientific progress and the public imagination; about what is happening now and what might happen in the future.

A team of designers at the Royal College of Art and scientific researchers at King's College London worked together to create rings for several couples. Using chips of bone donated by the couples, bone tissue was cultured in a laboratory at Guy's Hospital. This tissue was then combined with precious metals to create the rings. The result: each person wears the body of their lover on their hand.

This exhibition documents each stage of the project, from the donation and culturing of bone tissue to the design of the jewellery and the actual making of the rings. It therefore aims to provide an intimate account of what can happen when our creative visions of science are brought to bear on its progress.

Collaboration between disciplines

Biojewellery was a collaborative project run by Nikki Stott and Tobie Kerridge, design researchers at the Royal College of Art, and Ian Thompson, a bioengineer at King's College London. In the course of the project we drew upon the skills and experience of many different disciplines and professions: materials engineering, cell biology, oral surgery, medical imaging, computer-aided jewellery design, graphic design, interaction design, product design, fine art, media relations, journalism, science communication, sociology and ethics. Such diversity of expertise was expected in a project which was, by definition, multi-disciplinary. However, perhaps the most striking feature of this project is that, instead of attempting to smooth over tensions between the disciplines involved, we actively sought to highlight areas of conflict. Our aim was to provoke debate – not only between specialisms but amongst the public at large. In other words, by confounding expectations of the nature of this kind of mutli-disciplinary work, we hoped to surprise both ourselves and others.

Technology and the public – them and us?

The future of technology is usually portrayed either as wholly utopian (today's problems are solved effortlessly tomorrow) or, more commonly, as wholly dystopian (today's solutions cause terrible problems tomorrow). However, the future of technology is all around us. It is latent in the ways we interact with current technology, the impacts of our behaviour and the social issues and phenomena that arise from its use.

This disconnection between the present and our ideas about the future is largely due to a lack of dialogue at the stage of design and development, between those that create technology and those that use it. We may no longer imagine men in white coats inventing the future – a vision propagated in the 1950s – but it still comes down to 'them' and 'us'. Take the case of genetically modified (GM) foods. Many of the news stories about GM foods oversimplified the issue for dramatic effect, patronising rather than informing the public.

Traditional depictions of the public as being 'ignorant of the facts' appear to be simplistic. Indeed, the public seeks and welcomes diverse sources of information on an issue and is not easily swayed by sensationalist media. Also, non-specialists are able to balance conflicting views and assimilate complex scientific information and principles quite readily.[1]

The more the public engages with current scientific and technological developments, and the earlier this happens in the development process, the better we can direct the future of technology. Here, 'we' means both 'them' and 'us'. After all, scientists and technologists are people too. They use the technology they create, and so, like the rest of us, influence the conditions in which they live and work.

[1] *Public Dialogue on Science & Technology* (Postnote 189, November 2002, page 3)

Bio-Bling was an evening event at London's Dana Centre, bringing the project team and the public together for presentations and discussion

Engaging the public

How does one initiate and focus public engagement in science? One approach is to stand between scientists and the general public, provoking and facilitating dialogue. A recent project at Cambridge University aimed to create such a dialogue about nanotechnology between, first, different types of engineer, and second — but just as importantly — these engineers and the public. Robert Doubleday, a sociologist involved in the project, said:

My role is to help imagine what the social dimensions might be, even though the eventual applications of the science aren't yet clear. A lot of what I do is translate and facilitate conversations between nanoscientists and social scientists, but also with NGOs and civil society.[2]

The Biojewellery project's approach was broadly similar, except that our main aim was not so much to 'translate' as to excite. We wanted to excite the public imagination. By forming a collaborative network, by foregrounding areas of conflict and by looking for the unexpected, we aimed to draw out fascination for bone tissue culturing, at which point it is over to you...

[2] *See Through Science* (Demos, September 2004, page 55)

ENGINEERING NEW MATERIALS

Overview

Tissue engineering involves harvesting cells from a patient, using these cells to grow new cells and implanting the resulting tissue into the patient. This process has the potential to dramatically improve the treatment of a wide range of conditions. For example, it could be used to regenerate a damaged liver, to grow a new bladder or to help with heart problems. However, the process is only about ten years old and scientists foresee that it could take another ten years to perfect all the necessary technologies. Even then, it will probably be much longer before government legislation opens the way for public use of these technologies.

There are three major problems that currently prevent tissue engineering from becoming a routine medical treatment:

- controlling the growth of tissue so that it forms an appropriate anatomical architecture with the suitable physiology
- creating a legislative framework to control the implementation of tissue engineering
- scaling up industrial technologies so that they are available to all patients at a reasonable cost

Research groups across the world are tackling these problems, involving engineers, biologists, designers and manufacturers, as well as a variety of legal and medical experts. What follows is a discussion of the role of materials engineers — the researchers who are developing the base scaffold on to which the harvested cells are seeded.

The structure of bone

The Biojewellery project drew upon research into the development of scaffolds suitable for the production of bone tissue. Tissue engineering requires an exact understanding of the structure and function of the tissues being regenerated or repaired and much effort has already gone into examining the complex structure of bone.

Bone is a composite of two main materials, a protein called collagen and a hard white mineral called hydroxyapatite (HA). Both substances are deposited in a structure which can be seen only with powerful microscopes. However, the cells also form colonies that create a structure on the macroscopic level that we can see with the naked eye. This is the structure that we recognise as bone.

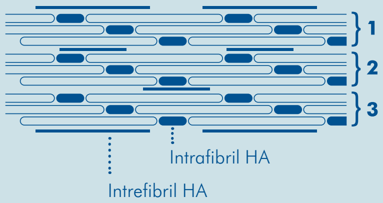


Fig 1

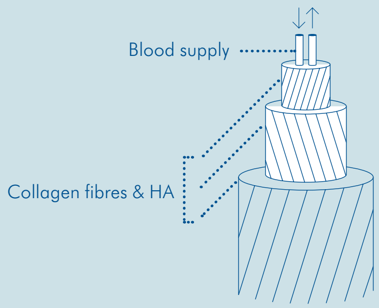


Fig 2

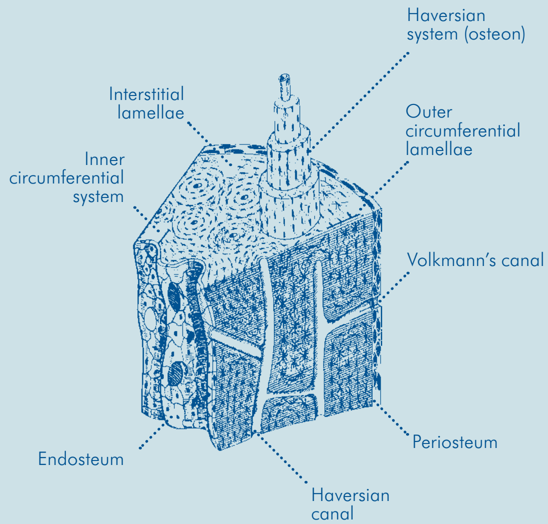


Fig 3

The three types of skeletal implant

Inert implants Inert metals and plastics simply act as a mechanical replacement for a piece of lost bone, typically hip and knee replacements. This method is speedy as it furnishes an instant replacement, but of course the implant cannot regain lost tissue and it usually fails within 20 years. Nonetheless, the majority of bone surgery done around the world uses inert implants.

Bioactive implants Bioactive materials such as collagen, hydroxyapatite and bioactive glass have all been used to try to regenerate parts of the skeleton. The aim is for the bioactive material to stimulate the growth of new tissue while breaking down and dissolving away. Bioactive materials regenerate very small areas of tissue, and even this takes a long time.

Tissue-engineered implants In tissue engineering, bioactive materials are seeded with osteoblast cells and blood to produce an instant load-bearing system which is quickly replaced by natural bone tissue. In the future, complex anatomy and physiology may be regenerated in this way, vastly improving the results of many surgical procedures.

Fig 1 A Microfibril formed from hydroxyapatite (HA) and collogen fibres
Fig 2 Microfibrils are wound together to form fibres, and fibres are wound together to form osteons
Fig 3 Osteons combine to form the spongy and compact osseous tissues of bone

Example of a tissue engineered implant: Hydroxyapatite is chemically similar to the material laid down by the osteoblast cells in the formation of new bone. Instead of pinning a fractured leg, orthopaedic surgeons could use a series of the bone rings stacked on top of each other, rather like a packet of Polo Mints.

Bioactive materials

Tissue engineering research has already made a number of breakthroughs. In the United States, fibroblast cells (skin cells) from an animal have been used to create an engineered bladder. But there is a long way to go before this process becomes viable for the reconstruction of human bladders and urinary tracts.

At King's College London, research into this area has produced a range of materials that may be suitable for tissue engineering. One such material is bioactive glass. This looks like much window glass but has a different chemistry. When implanted into the body, bioactive glass prompts tissues to begin repairing themselves. After several years of testing, it is now being used regularly as a bone graft material to repair damage to the face.

In the Biojewellery project, we attempted to use bioactive glass for tissue engineering but found it difficult to form the material into a complex shape. Our solution was to use pure hydroxyapatite (cast for us by Dytech, Sheffield, UK). Hydroxyapatite is chemically similar to the material laid down by osteoblast cells in the formation of new bone and, fortunately for us, it is easier to shape.

How designers and engineers worked together

Collaborating on the Biojewellery project proved wonderfully inspiring for both designers and engineers. What's more, the bone rings that we created may one day benefit people with serious bone injuries.

Scientists at King's College had already managed to grow bone cells on a range of materials. However, these materials were always flat. Of course, there are no flat bones in the body; all have tube-like structures. Jewellers, however, specialise in making tubes or, rather, rings. We thought: why not join forces?





Couples were invited to send photos to introduce themselves that captured something about their relationship

FINDING DONOR COUPLES

The romance of bone culturing

The purpose of extracting and culturing tissue is to put it back into the patient's body to heal them. We imagined however that this material could also be used outside the body – but to do what? The answer to this question may lie in another, more profound question: what value would people place on a product that has been manufactured with materials derived from their own cells?

Consider the ring. It's an item with special significance for its owner, especially when it symbolises love. Could the emotional charge of this piece of jewellery be further intensified by making it out of cultured bone tissue? To explore this notion we needed to find – or rather, to woo – couples for whom the idea of giving a physical part of themselves to each other, appealed.

Spreading the word

We built a website to present our initial ideas and this quickly attracted the attention of bloggers, whose comments on their own websites encouraged wider discussion. Over 200 couples sent us emails describing how they met, what the rings would mean to them and why they would like to donate their cells. We also notified newspapers and magazines, some of which printed articles slanted to the taste of their readers. For example, *New Scientist* emphasised the sophistication of tissue engineering and *Bizarre Magazine* focused on the extremities involved in cell donation.

Selecting and meeting couples

Having attracted the interest of many couples, we tried to involve them in the project both directly, by asking for design ideas about the rings, and indirectly, by asking for details about their lives (which could also inspire design decisions). To these ends, we added a form to the website asking couples to describe themselves. We encouraged them to provide photos that captured something about their relationship and personalities, and invited them to write about themselves – where they met, and why they were together. We were also keen to see design sketches, or simply images of things that were meaningful to a couple. At this point, we selected four couples.

The designers visited the four eligible couples in their homes to discuss the project. Michael Venning accompanied the designers to record these visits with photographs, partly to provide an additional perspective on the couples, and partly just to make a record of them at home – to remind us all that the project was as much about them as it was about innovative materials and the forthcoming procedure at Guy's Hospital.


Michelle and Ashley with Leon (left) and Matt and Harriet (right)

Michaela and Jon (left) and Trish and Lynz (right)


Michelle and Ashley

Michelle had seen an article about Biojewellery in *Bizarre magazine.* Her children, Freya and Leon, were unsure about us at first – until they pelted us with green play-dough. The children's toys and activities dominated the front room, and also the garden where Ashley was building a huge play area.

'My partner and I are planning on getting married and love the idea of having our wedding rings made out of bone using your bone harvesting method. After reading the article we both knew we had found the perfect material for the rings.' Michelle

Matt and Harriet

Both Matt and Harriet had strong ideas about their rings.

'Within 3 weeks of getting it together, we bought almost identical motorbikes and and razzed off around London swerving around taxis and getting high by chugging each others exhaust fumes. Neither of us had any riding experience. We stopped short at matching riding suits, and our friends said they thought it was really romantic, but I have since learnt that they were all convinced we were going to die.' Harriet

'I always wanted an extra arm — perhaps I can get them to grow me one on the side. In one sense I think it will be a bit of me in a similar way to hair, or fingernails. It grows as part of you, and you have an emotional relationship with it — maybe more hair than fingernails — but it doesn't have a strong physical relationship. The fact that it is grown through science to have a life as another object will make it precious and enhance the emotional connection.' Matt

Michaela and Jon

Jon and Michaela met four years ago, and wanted us to help design their wedding rings. They were keen to have simple silver bands, embedded with a circle of cultured bone. When we visted them they were halfway through redecorating their home. Both are keen musicians and have science and engineering backgrounds. It was this passion for science that drew them to the project, after Michaela saw an article in *New Scientist.*

'Both my fiancé and I are keen to find out more about this work, as we are very interested in having such rings manufactured for ourselves. We both have a fascination in science and engineering, and not only would we be glad to take part in an interesting new field of research in science and engineering, but we also have an interest in the idea of having wedding rings made of each other's bone.'

'We both have wisdom teeth that we are looking to have removed, and so it will be possible to donate the bone cells legally. Are there any other requirements in order to donate bone cells? What would the cost of having the ring manufactured be, or does the donation of the bone cover this? How long will the process take? Is the process perfected yet or is it still in the preliminary stages?' Michaela

Trish and Lynz

Although Trish and Lynz had met fairly recently, they had made a strong commitment to each other. They were looking for rings to symbolise this commitment when Lyns saw the article in *Bizarre.* Whilst they have much in common, we can reveal that Trish has a penchant for Salvador Dali's paintings and Lynz has a secret love of Rolf Harris.

'I have found my soulmate in Trish. She completes me and I love her with all that I am. She is everything I ever wanted in a partner and so many things I didn't know I wanted.'

'Although we have only known each other a short time, we are totally committed to each other. It took us two months to realise we could not bear to be apart, and so moved in together (one of us moving over 100 miles to do so). We are scarily similar in many ways, from music and film tastes to more strange and darker habits.' Lynz

The role of ethics committees is to safeguard the rights, dignity and welfare of people participating in NHS research

DONATING CELLS

Ethical and practical considerations

In the early stages of the project, we assumed (perhaps naively) that tissue samples would be provided by a biopsy. However, we soon learnt that obtaining cells for scientific experiments is far from simple. The whole process is scrutinised by everyone involved – the scientists, the surgeon and the local NHS Trust – as well as a National review panel called Central Office of Research Ethics Committee (COREC). For the project to become feasible, therefore, we had to create a framework for donation that balanced the couples willingness to provide cells, with the practical, legislative and ethical requirements. In short, we had to think again.

It was then that we decided that wisdom tooth extraction was, on all counts, a more likely route than a biopsy. Wisdom tooth extraction is the most common form of surgery in which bone is exposed, in fact chips of jaw bone are often removed during the procedure. This was therefore the most straightforward method – ethically, legally and practically – for the couples to donate bone cells. Our selection criterion was therefore pragmatic: we needed couples who had problems with their wisdom teeth. (They also had to be over 18, registered with the NHS and living in the UK).

Gaining sanction from the Central Office of Research Ethics Committee (COREC)

Until quite recently, each hospital involved with research had a local ethics committee made up of hospital staff and volunteers. Volunteers may have included local clergy and lay church members, some of whom had no experience of science. Scientists and medical staff applied to this committee to obtain permission to perform new types of surgery, or to pursue research involving hospital patients. This process meant that different committees sometimes made different decisions, and in 2000 the government standardised local procedures by creating a national body, COREC.

Patient referred to oral surgery from general dental practitioner

Appointment created and sent to patient

Patient arrives for assessment

Patient given information on project and discussed with oral surgeon and given until next appointment (if any) to decide

Patient assessment for wisdom tooth extraction

↓

PASS
Second appointment (surgical) arranged

Patient arrives for surgery

Patient approached again by oral surgeon if they wish to participate in the study

↓

PATIENT DOES CONSENT
Wisdom teeth removed, bone fragments retained

PATIENT DOES NOT CONSENT
Wisdom teeth removed, bone fragments destroyed

↓

FAIL
Discharge or refer to other department

This flow diagram for bone cell donation was part of an application to East Kent Ethics Committee for tissue engineering research

In order to obtain permission from COREC for tissue engineering research, we had to submit a fifty page application. This document explained why the bone cells would be collected, what scientific tests would be conducted on the cells and how the scientific results would be disseminated. The thrust of our argument was that although we intended to make jewellery from cultured bone, we also wished to refine the technique of growing new bone tissue and this might ultimately benefit people suffering from a range of medical conditions. In September 2005, following an exacting meeting about our proposal, permission was finally granted by an ethics committee in Kent. COREC were satisfied that the scientific merits of the project were sufficient to enlarge understanding of applied tissue engineering.

Harriet signs a form with Dr Ian Thompson, providing consent for fragments of bone from her jaw to be retained for tissue culture research

Ready and willing couples

We worked with the four couples we had selected from the many who applied to us. Three of the couples were then referred by their dentists to Guy's Dental Hospital, with a request for wisdom tooth removal (one couple having been ruled out by their dentist). An oral surgeon at Guy's confirmed that one person from each couple – a total of three people – required a wisdom tooth extraction, at which point they were formally approached as volunteers for tissue engineering research. That is, the oral surgeon provided them with information about the project and explained what would happen to their donated bone cells. The couples then returned home to think things over.

Three weeks later, the couples came back to Guy's for a final discussion. All were happy to sign a consent form and underwent the surgery, however one was unable to have a bone chip removed.

What will happen to me if I take part?

If you consent to take part in this study you will have your wisdom teeth removed as planned. The treatment and procedure will be carried out in the same way as if you were not part of the study. When we remove wisdom teeth, we may require to remove some bone from around the tooth so as to free the tooth and allow us to remove it more easily. This small amount of bone is normally sucked away with the sucker that the assisting nurse uses and is disposed of. Consenting to take part will simply mean that we retain these bone fragments that are generated.

If consenting, the Oral Surgeon who has contacted you will arrange for your visit and remove your wisdom teeth as normal. We will keep the fragments and grow the bone cells that are contained within it.

We are requiring ten patients to consent to the project. All of those who consent will be kept informed about what the research outcomes are. It is also expected that the experiments will be publicised in the wider media, but you will not be named. At the end of the experiment, after approximately two years, all cells will be destroyed. If you wish to leave the study at any point your bone samples along with any test materials will be destroyed.[3]

[3] Extract from patient information sheet for 'Use of bone, collected during routine wisdom tooth removal, in the study of Bone Tissue Engineering'

The bone chips were immediately cut into very small fragments and placed in culture medium. This provides nutrients for cells, which move out from the fragments and adhere to the culture dish.

CULTURING BONE TISSUE

From the operating theatre to the lab

Once the bone sample had been extracted from the patient, it was placed in a sterile container full of a fluid called culture medium, and taken to a cell culture laboratory. (One of the biggest challenges in the past, before tests could be performed on the cells, was determining how to receive and transport them so as to prevent contamination.)

In the laboratory the samples were placed in a sterile dish inside a sterile cabinet, cut into very small fragments and placed in culture medium in an incubator set at 37°C and with a 5% carbon dioxide level, simulating body conditions. After three to five days, cells moved out of the bone fragments into the culture medium. Using chemicals and enzyme, it was possible to extract these cells from the dish. The cells were then expanded, resulting in a large number of cells. Using this method, it is possible to grow millions of bone cells from tissue explants which initially provide only thousands of cells.

Once the cells had been expanded to provide a large number of cells, about half were used immediately to seed onto the scaffold rings. The remaining half of the cells were frozen. If any problems arose these could be resuscitated.

A word about bone cells (because things are getting technical)

It is only in the last 30 years that it has been possible to extract the living cells that exist in all bones of the body. Throughout our life time, bone forming cells called osteoblasts are active within our bones, repairing and replacing the white bone mineral.

Among the many tissues in the body, bone has the highest potential for regeneration. Found in the bone marrow, bone stem cells give rise to pre-osteoblast cells which in turn give rise to osteoblast cells. The transition period between a pre-osteoblast and a differentiated osteoblast cell is approximately two to three days. The osteoblasts are generally found on surfaces where the bone is in the process of growth and remodelling. These cells are responsible for the creation of the hard white material that we all recognise as bone, and were used to create Biojewellery.

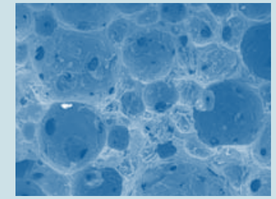
The tissue cultures are kept in culture medium to provide nourishment for the growing cells. The medium is changed every four days to remove waste and replenish nutrients. The samples are kept in a sterile incubator at 37° centigrade.

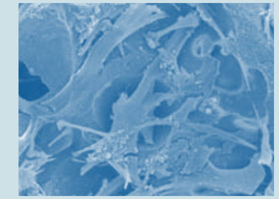
The complexity of cell culturing

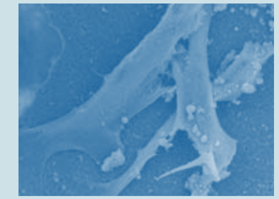
Cell culture is carried out under aseptic conditions, i.e. free from contaminating organisms. The techniques and methods used are designed in such a way as to minimize the risk of introducing any contaminating microorganisms, such as fungi, mould, bacteria or viruses. However, culturing cells means dealing with 'living cells' and, however carefully the work is done, it always carries an element of risk.

As it takes time to grow enough cells to run a useful experiment, and even longer to create the amount of tissue required for Biojewellery, this renders the cells susceptible to infection. It is therefore essential that the cells are checked on a regular basis to ensure that there is no sign of infection.

Despite aseptic conditions, a bacterial infection did occur in our first batch of cells. The consequences of a contaminated culture are devasting: the results are invalidated, cultures have to be discarded and work has to cease until the source of the infection has been identified and eradicated. Therefore all our cultures had to be destroyed to prevent further outbreaks of infection, and frozen cells (which we had stored earlier) had to be resuscitated and expanded in order to continue the study.







Images captured with a scanning electron microscope shows Harriet's cells growing on the scaffold at day 8 at three levels of magnification. Cells can be seen adhering and stretching over the surface of the scaffold.

Seeding the osteoblast on to the hydroxyapatite

Once the resuscitated osteoblast cells had expanded in sufficient numbers, they were detached from the culture dish using special chemicals and enzymes. The cells were resusupended in medium and seeded on to the test scaffold hydroxyapatite (HA) rings.

The cell-seeded HA scaffolds were incubated in cell culture medium containing special nutrients for five weeks, allowing the osteoblast to differentiate and release matrix proteins and begin to form new bone mineral on the HA ring.

After six weeks, the completed rings were removed from the culture medium and fixed using a mix of chemicals. They were then washed and left to air-dry prior to being infiltrated with epoxy resin and fashioned into rings. Normally, when engineering such structures for a patient, the cell-seeded scaffold would not be allowed to dry as the body requires living cells.

The value of this collaboration

All research projects taking place in the cell biology laboratory pose challenges and the opportunity to learn new skills and techniques. They also provide a useful teaching tool, as students can master important techniques, experience the pressures of working to a deadline and come to understand the necessity of thorough planning.

This gold frame from about 1850 contains a photographic portrait of a man, and is attached to three lengths of cord woven from human hair. The jewellery may have been worn as a choker, and may have been a gift from husband to wife. *Photo source: Ingenious science picture library*

DESIGNING THE JEWELLERY

Why jewellery?

The germ of this project was our fascination with the idea of finding an alternative use for cultured bone. We imagined using this material to make an object that could be held or worn, or perhaps closely examined. We also wanted the object to be familiar, to be somehow evocative of our own experience. That was the point – to intensify the meaning of an everyday object. The element of novelty was a given. The cutting-edge technologies involved in the project virtually guaranteed it a public reaction, whether positive (excitement about the possibilities offered by Biojewellery) or negative (disquiet about the broader implications), or, like our own feelings, a compelling mix of the two.

And so we began to consider jewellery, which led us to think about rings. Although the products of jewellery are tiny objects, they are often imbued with great importance and complex meaning, and none more so than the ring. In terms of symbolism and ceremonial value, the ring is one of the most significant items of adornment. It has a long and involved social history, having been used for many centuries (and in many different parts of the globe) to mark key occasions – birth, matrimony, mourning.

As we discussed the meaning and history of rings, a design question soon took shape: could we combine the symbolic power of the form of the ring with the symbolic power of a love one's bone material? What might such a ring look like? And what might it *feel* like?

Mementos and rituals of exchange

Embedding part of the body within jewellery is not a new idea. In many ancient cultures both human and animal bone were used to represent fertility and status. For example, amulets made from bone provided protection and evoked a connection to the past. More recently – and perhaps of more relevance – nineteenth-century mourning jewellery made from the hair of a deceased relative was fairly commonplace in Britain. You could say that Biojewellery represents a continuation of this Victorian tradition, but with a difference – here, the ring is a memento of a living person.

The role that rings perform in the marriage ceremonies of many cultures is, of course, particularly relevant to this project. The bride and bridegroom perceive the exchange of rings as a symbol of their relationship, even when the exchange is not part of a traditional marriage ceremony. The following Celtic wedding verse celebrates this exchange in terms that hint at the potential emotional power of Biojewellery:

'Ye are Blood of my Blood, and Bone of my Bone. I give ye my Body, that we Two might be One. I give ye my Spirit, 'til our Life shall be Done.' [a]

In their own words

Each couple had strong feelings about the use of their bones to make rings:

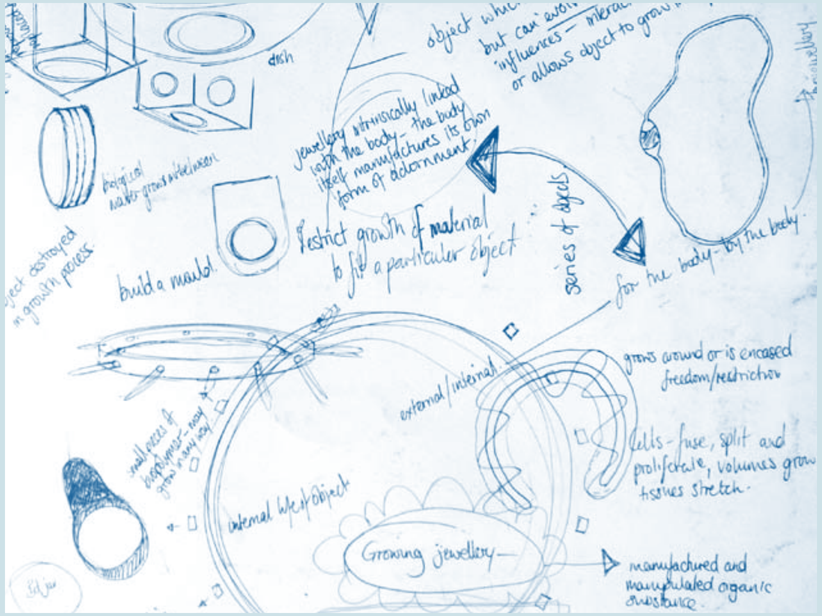
'This is an opportunity to create a piece of jewellery that has a significance ... much deeper than traditionally manufactured rings — even if they are bespoke.' Matt

'I think this is far more ethical than exploitative mining for diamonds or hunting of rare animals or other 'precious' materials. If we can grow precious materials that mean an awful lot to individuals through a deep physical connection, then this is far more positive than demonstrating love through the magnitude of a shiny rock.' Harriet

'We just have a deep love and respect for each other, and have been looking for an unusual but beautiful way to show this love. We intend to spend the rest of our lives together, and the rings sound like the perfect seal to our love and devotion. We have talked about this at length and feel very strongly that we would like to participate.'

'We have discussed signing the civil partnership register and having some form of commitment ceremony, and have been looking at rings that, we feel, best suit us and hold greater meaning for us. We feel that these rings would be an ideal way for us to show our love for each other.' Trish and Lynz

[a] Celtic wedding verse



Early designs from Nikki Stott's sketch book

Initial designs

Early sketches experimented with many different forms. The first models made to illustrate the Biojewellery project were composed of etched silver and solid bone. At this stage, we were working on the premise that the cultured bone would be completely compact.

Testing scaffolds

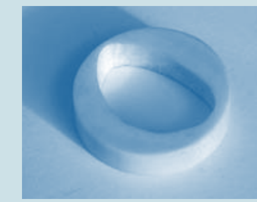
As our knowledge of tissue engineering developed, we began to understand that the scaffold would form the structure of the ring. These materials are similar in appearance and texture to cancellous bone. Our initial scaffold was made of foam derived from bioactive glass. Carving this delicate substance into a ring form proved difficult and it was not able to withstand the tissue engineering process. The initial experiments resulted in partial disintegration of the scaffold which broke down before the tissue had a chance to mineralise and create its own structure.

Preparing the scaffold

After our failed attempts at carving the bioactive foam into a simple ring, we realised that ring form should be shaped by an engineer who understood the tolerance and structure of the material. The initial shape and size approximated the finger size of the eventual owner. After it left the laboratory, we then worked on it in more detail, customising the final form for the wearer.


Experimenting with carving an early scaffold, and an image of the final rings before the protective resin is applied

Models made to communicate the project at a very early stage. A ring of cow bone (left) illustrates the final tissue engineered sample, and an example ring (right) made with a combination of cow bone and etched silver.




Out of the lab and into the studio

The outcome of the cell growth over and through the biofoam scaffold was successful. Although the samples did not yield the thick cortical bone envisioned in the initial models (designed using a solid band of cow bone) large nodules of bone were clearly visible in a mineralised from. A cross-section of a test sample showed that the tissue had formed deep into the scaffold, as well as around the surface.

The final cultured rings comprised a set for Harriet and Matt grown from Harriet's cells, and a set for Trish and Lynz grown from Lynz's cells. After the samples left the laboratory, they were taken to the jewellery studio and encased in epoxy resin (for strength). The rings were then carved to create a final form – dependent on the owner's finger size – and finished. They were cleaned thoroughly to remove any traces of oil, and painted with a electrically conductive paint which was applied in a surface pattern chosen by the participants.

The rings were placed in the electroforming tanks where a low voltage electrical current plated the paint with a layer of metal – silver for Trish's and Lynz's rings, and gold for Harriet's and Matt's. During electroforming, an electric charge carried to the object causes it to 'attract' silver or gold ions from the solution. These ions deposit on the surface of the object where paint has been applied. The process only takes a day but we left the rings overnight, to ensure a good deposit. The thicker the gold or silver pattern, the better it will protect the bone and resin.

WHAT DO YOU THINK?

Afterthoughts

It seemed a simple idea: we invite couples to put a bit of themselves into the rings they wear. But the rings that we made symbolise complex issues and provoke complex responses, about the meaning of technological change and the meaning of love. These issues emerged only gradually through the design process, as one practical step led to another...

There were the technical challenges posed by the properties and behaviours of the materials used to grow the rings of tissue. Would the scaffold stay intact? Was it sufficiently like bone to encourage the tissue to grow well? Then, once the couples stepped forward, the designs had to be adapted to suit their requirements: the value and meaning of the rings became personalised by their motives. How would their intentions change the project and push it in unexpected directions? Then came the donation of cells by the couples, and all the associated legislative and ethical issues. How could we balance the couples' willingness to give cells with the requirements of the medical institutions? The next step was the culturing of the cells, a difficult task as we were dealing with living cells, and the problems associated with this. And finally there was the construction of the rings themselves. Would the bone be robust enough, and how would the couples receive their rings?

Of course, many aspects of the process didn't go according to plan. This is not surprising given that it was a project dependent on novel technical flexibility, resources and the skills of those involved. We hope that, by presenting as much of this process as possible, we have managed to give you a fair impression of the difficulties and achievements – the highs and lows – that attended the realisation of a seemingly simple idea.

At the Dana Centre Nikki Stott answers questions from members of the public about the making of the rings

What next?

Biojewellery was envisioned as a collaboration that would encourage people from within different disciplines to learn from one another, and also to stand back and reflect on their own work. Others outside the project have also been stimulated by it, like this astute businessman from the States who came across Biojewellery on the internet:

'We would like to find prospective clients and set up a complete package of experiences, where these individuals fly to the UK, participate in the surgical biopsies, enjoy the UK as a vacation destination for a period after the bone is harvested, and then work with the custom jeweller in the final production of the piece.' [5]

So, what next? We have no plans to commercialise Biojewellery. We are more interested in exploring new avenues than mining them for gold. Emerging technologies excite our sense of design and, to return to Robert Doubleday's thoughts at the beginning of this booklet, key to our work is a desire to provoke discussion about science and technology, 'even though the eventual applications of the science aren't yet clear'. When this exhibition closes, the rings will go to their owners (on Valentine's Day!) and we can start looking for new ways to get people talking to each other.

We would like to hear what you think about any of the issues raised by the exhibition. Please let us know by answering the questions on the form provided, and drop it in the slot. If anything else occurs to you, especially about an aspect of science or technology that you feel strongly, jot it on the back of the form.

[5] Extract from an email, 5 October 2005 09:37:25 BDT

Credits

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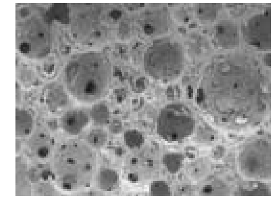
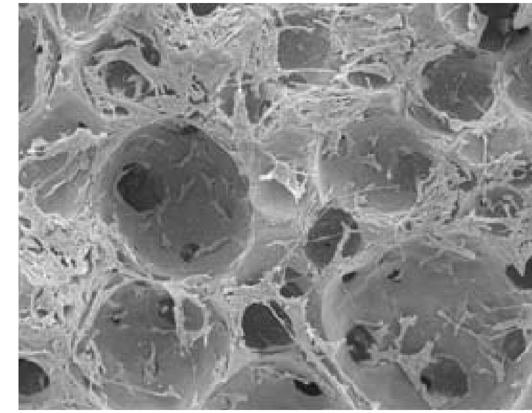
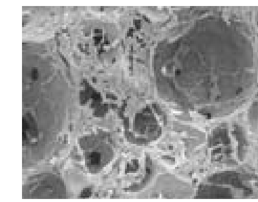
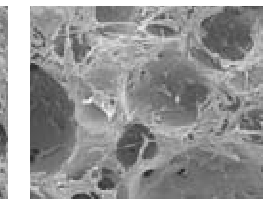
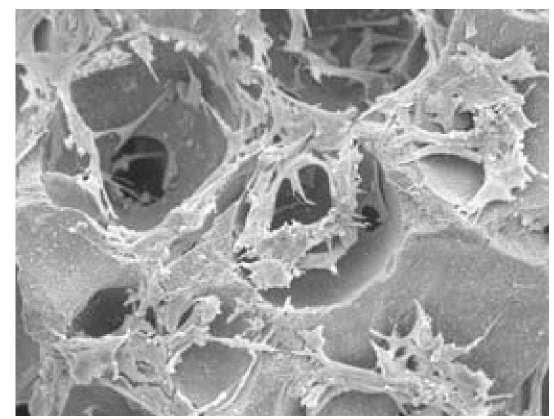
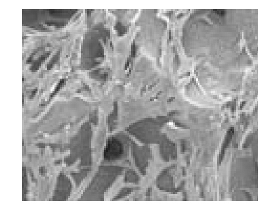
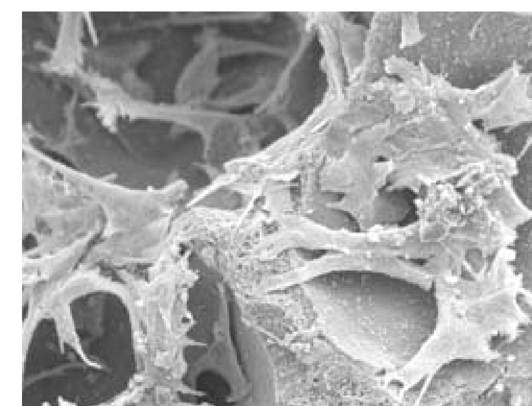







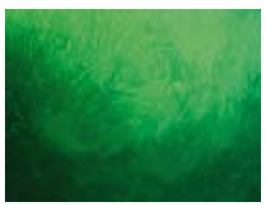
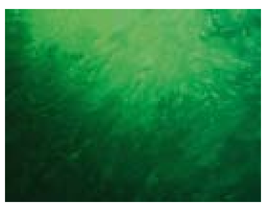
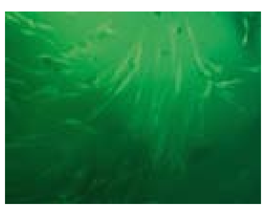


Images captured with a scanning electron microscope show Harriet's cells growing on the scaffold on the eighth day. Cells can be seen adhering and stretching over the surface of the scaffold.

Stains are applied to the culture to show cell viability. A green stain indicates live cells whilst a red stain reveals dead cells. Harriet's osteoblast cells can be seen attached to the surface of the scaffold after eight days.



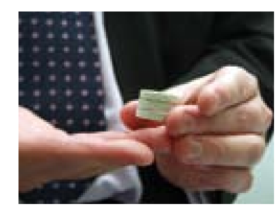
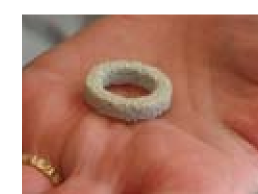



Stains were also applied to cultures from Lynz's cells



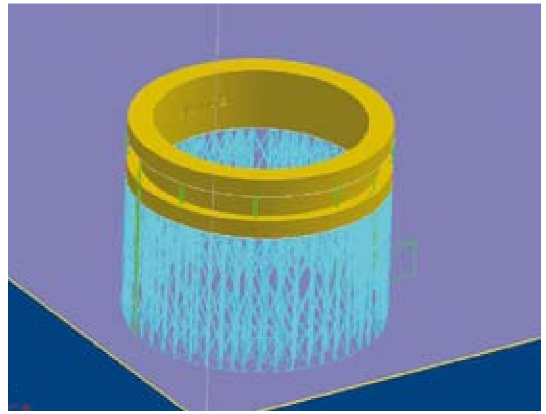


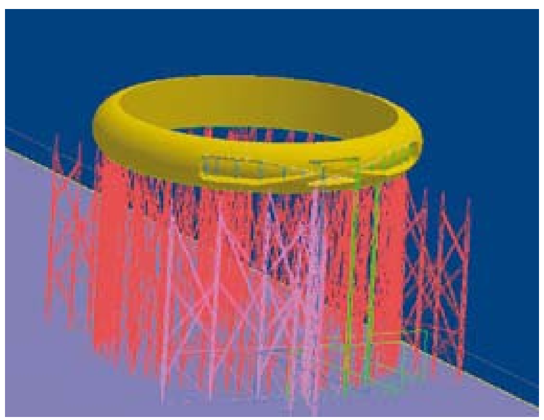




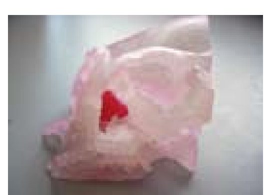
Harriet's and Lynz's cell cultures were chemically fixed before being taken by Nikki to the jewellery studio. The cultures were made inert and stable so they could be filed to the correct size.







There were unexpected similarities between the tools used to make jewellery and facial surgery implants. Computer drawings of a ring (centre) were transformed into solid objects (bottom left) by the same machine that produced the model of a patient's skull (bottom right).