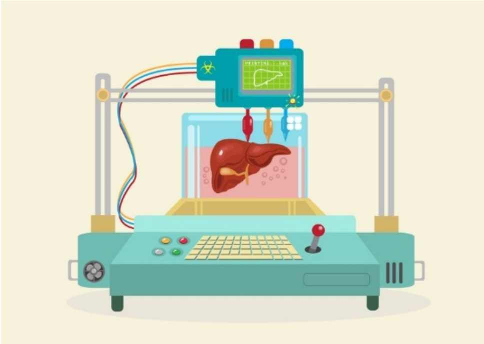
What if we could 3D-print our own body parts?

The 3D-printing sector has proven its commercial viability in recent years, reaching the high street and, indeed, many homes. The technology is already used in some medical domains, such as dentistry and prosthetics, and many scientists are now exploring methods of printing biological materials – even if reports about lifesaving 3D-printed hearts are certainly premature.

3D-printing is a well-known technique for producing objects by adding layers of material, usually plastic, according to a 3D design. The printers vary enormously in size, specification, complexity and price, but are accessible to most households and businesses. The technology can also be used to produce objects with an excellent external fit for individual bodies, which can be useful for making supports and other products worn by patients. Recent advances in the technology hint at the possibility of producing biological materials for direct integration within people's bodies.



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The full spectrum of 3D-printing methods and materials can be used to produce body-relevant objects. Building upon products derived from advanced 3D images, they open the possibility of fabricating highly-customised moulds and tools for patients and medical professionals alike. It is also possible to use 3D-printers to produce biological materials. The most advanced experimental methods involve producing skeleton structures that encourage cell growth. Such skeletons can then either be transplanted for integration in the patient's body, or used to develop biological systems outside the body. While there has been some clinical success with both methods, many technical and regulatory barriers remain. Other bio-3D-printers take biological and chemical materials as their input to produce food and pharmaceutical products.

Here, we draw upon the ongoing STOA scientific foresight study **Additive Bio-Manufacturing: 3D-Printing for Medical Recovery and Human Enhancement** to outline the possibilities and challenges that this emerging 3D-bioprinting technology presents.

Potential impacts and developments

3D-printed materials allow medical doctors to take advantage of detailed scans by using them to fabricate models of patients' bodies for practicing procedures or teaching purposes. They can build accurate frames on which to construct titanium parts for reconstructive surgery, as well as surgical guides, knives and other tools to support specific medical interventions. Orthoses (devices to support limbs) and prostheses (devices to replace limbs) could also benefit from 3D-printing technology, which is coupled with advanced imaging techniques to deliver products that are highly tailored to the individual patient and may offer better results than 'off the shelf' solutions. The same advantages apply to a wide range of moulds, supports and other items that are worn by the patient. Hearing-aid manufacturers were early adopters of 3D-printing technology. In the space of 500 days, the entire American hearing aid industry converted to 3D-printing.

3D-printing technology could also be deployed for individually tailored drug delivery, with tablets designed and printed using porous materials that disintegrate according to a well-defined schedule, releasing the active ingredients embedded within them according to an optimal pattern. In the future, pharmacists may be able to combine all the drugs in a patient's prescription into a single tablet, adapted to their specific situation.

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Authors: Philip Boucher
Scientific Foresight Unit (STOA)
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Appliances for 3D-printing food are already commercially available and have been used in nursing homes to offer more appetising fare to residents that have difficulties chewing and swallowing. While such printers face stiff barriers in market acceptance, customers may one day be able to print their own food that is tailored to their taste and texture preferences, as well as their nutrient (and perhaps even pharmaceutical) requirements.

The 3D-printing of tissues and organs is more complicated. While some reports are exaggerated, there has been some clinical success with 3D-printed scaffolds being transplanted directly in the patient to encourage bone, cartilage and skin growth, as well as more limited success in producing blood vessels, nerves, skin and bones outside the body. Known as 'organ printing', this is the least advanced of all 3D-bioprinting applications, yet minor advances can still yield substantial benefits in producing materials for training, testing, education and experimentation purposes. Further success in producing viable organs from a patient's own cells is not expected any time soon, but could one day resolve the challenge of timely identification of compatible organs for transplant.

As with many innovations in the biotech sector, 3D-bioprinting may raise questions about standards and accessibility. Standards and approval procedures for medical devices are often more demanding than those for other products. Higher innovation costs can make life difficult for smaller biotech businesses and inflate the costs of new medical products and services.

3D-printing is often considered a driving force in the decentralisation of manufacturing. Low costs coupled with speed, proximity and customisation make it an attractive option for many SMEs and individual households. In the context of 3D-printed surgical guides, prostheses and supports, for example, we might imagine local production at hospitals and doctors' surgeries rather than at distant laboratories. Such decentralisation could allow patients to benefit from more personalised treatment with fewer visits to the hospital and reduced waiting times. It may also see the emergence of a new generation of on-site 3D-printing medical professionals. On the other hand, the high levels of expertise required and tight controls over medical products may mean that 3D-printing capacity develops within the existing laboratory infrastructure, ensuring the survival of the centralised production model.

3D-printing has also been associated with the 'democratisation' of production, whereby substantial gains in accessibility are achieved through massive reductions in the financial and technical barriers to production. While some expertise and capital investment are required, they remain within reach of most enthusiastic amateurs. The same is true of 3D-bioprinting, and we are starting to see '3D-biohackers', that is, DIY biologists using 3D-printers to experiment outside the usual scientific, medical and commercial institutions.

Finally, it is worth noting that some of these same innovations in 3D-printing may also be used for non-therapeutic purposes. For example, cosmetic surgeons can produce implants for 'body enhancement' procedures, and show potential clients detailed 3D-printed models of their post-operative bodies. There might also be opportunities for novel body art procedures. Since food and drugs both present large global markets, 3D-printing could be deployed in non-medical contexts such as recreational drugs and gastronomy. The full range of biologically relevant 3D-printing procedures may also be deployed for artistic purposes, such as Diemut Strebe's living piece, a 'recreation' of Vincent van Gogh's ear.

Anticipatory policy-making

In regulating medical products and services, legislators are called upon to balance the need for high standards and responsible processes against the greater financial and technical barriers that these present to innovators in the sector. Higher costs can create challenges in ensuring equitable access to cutting-edge medical treatments. DIY 3D-bioprinting activities that occur outside professional laboratories are difficult to monitor and regulate, but could pose safety and security threats, and may even infringe principles of medical ethics.

This 'What if ...?' publication is a product of the Scientific Foresight Unit (STOA) of EPRS. More information on the unit's activities can be found at http://www.europarl.europa.eu/stoa/ and http://epthinktank.eu/author/stoablogger/