Should animal organs and tissues be used for human transplants?

What they said…

'Animal-to-human transplants are unethical, dangerous, and a tremendous waste of resources that could be used to fund research that might actually help humans'
Statement from PETA (People for the Ethical Treatment of Animals)

'If human organs are imagined as the fossil fuel of the organ supply, then pig kidneys are the wind and solar: sustainable and unlimited'
Robert Montgomery, head of the Transplant Institute at New York University Langone Medical Center

The issue at a glance

On January 11, 2022, it was reported that a patient in the United States was doing well three days after becoming the first recipient of a genetically modified pig's heart.
Doctors at the University of Maryland Medical Center said the transplant showed a heart from a genetically modified animal could function in a human body without immediate rejection. Prior attempts at such transplants – or xenotransplantation – have failed, largely because patients' bodies have rapidly rejected the animal organs.
https://www.abc.net.au/news/2022-01-11/pig-heart-transplanted-into-us-man-in-world-first/100513728

On October 20, 2021, surgeons in the United States attached a pig kidney to a pair of large blood vessels outside the body of a deceased recipient kept on life support so they could observe the kidney's function for two days. The kidney continued to filter waste and produce urine and did not trigger rejection. https://tinyurl.com/3f7mr3zd

These developments have renewed worldwide debate around the practical and ethical issues raised by transplanting animal organs into human beings. https://www.bbc.com/news/world-59951264

Background

The full text of the extracted information below can be found at the Wikipedia entry titled Xenotransplantation. It can be accessed at https://en.wikipedia.org/wiki/Xenotransplantation
Animal to human organ or tissue transplants
Xenotransplantation (xenos- from the Greek meaning 'foreign' or strange), or heterologous transplant, is the transplantation of living cells, tissues or organs from one species to another. Such cells, tissues or organs are called xenografts or xenotransplants.

History
The first serious attempts at xenotransplantation (then called hetero-transplantation) appeared in scientific reports in 1905, when slices of rabbit kidney were transplanted into a child with chronic kidney disease. In the first two decades of the 20th century, reports of several subsequent efforts to use organs from lambs, pigs, and primates were published.
Scientific interest in xenotransplantation declined when the immunological basis of the organ rejection process was described. The next wave of studies on the topic came with the discovery of immunosuppressive drugs. Even more studies followed Dr. Joseph Murray's first

successful renal transplantation in 1954 and scientists, facing the ethical questions of organ donation for the first time, accelerated their effort in looking for alternatives to human organs.

In 1963, doctors at Tulane University attempted chimpanzee-to-human renal transplantations in six people who were near death; after this and several subsequent unsuccessful attempts to use primates as organ donors and the development of a working cadaver organ procuring program, interest in xenotransplantation for kidney failure largely evaporated. Out of 13 such transplants performed by Keith Reemtsma, between 1963 and 1964, one kidney recipient lived for 9 months, returning to work as a schoolteacher. At autopsy, the chimpanzee kidneys appeared normal and showed no signs of acute or chronic rejection.
An American infant girl known as 'Baby Fae' with hypoplastic left heart syndrome was the first infant recipient of a xenotransplantation, when she received a baboon heart in 1984. The procedure was performed by Leonard Lee Bailey at Loma Linda University Medical Center in Loma Linda, California. Fae died 21 days later due to a humoral-based graft rejection thought to be caused mainly by an ABO blood type mismatch, considered unavoidable due to the rarity of type O baboons. The graft was meant to be temporary, but unfortunately a suitable allograft replacement could not be found in time.

Potential animal organ donors
Since they are the closest relatives to humans, non-human primates were first considered as a potential organ source for xenotransplantation to humans. Chimpanzees were originally considered the best option since their organs are of similar size, and they have good blood type compatibility with humans, which makes them potential candidates for xenotransfusions. However, since chimpanzees are listed as an endangered species, other potential donors were sought. Baboons are more readily available, but impractical as potential donors. Problems include their smaller body size, the infrequency of blood group O (the universal donor), their long gestation period, and their typically small number of offspring. In addition, a major problem with the use of nonhuman primates is the increased risk of disease transmission, since they are so closely related to humans.

Pigs (Sus scrofa domesticus) are currently thought to be the best candidates for organ donation. The risk of cross-species disease transmission is decreased because of their increased phylogenetic distance from humans. Pigs have relatively short gestation periods, large litters, and are easy to breed making them readily available. They are inexpensive and easy to maintain in pathogen-free facilities, and current gene editing tools are being adapted to pigs to combat rejection and potential zoonoses. Pig organs are anatomically comparable in size, and new infectious agents are less likely since they have been in close contact with humans through domestication for many generations. Treatments sourced from pigs have proven to be successful such as porcine-derived insulin for patients with diabetes mellitus.[30] Increasingly, genetically engineered pigs are becoming the norm, which raises moral qualms, but also increases the success rate of the transplant. Current experiments in xenotransplantation most often use pigs as the donor, and baboons as human models. In 2020 the United States Food and Drug Administration approved a genetic modification of pigs, so they do not produce alpha-gal sugars. Pig organs have been used for kidney and heart transplants into humans.

In the field of regenerative medicine, pancreatogenesis- or nephrogenesis-disabled pig embryos, unable to form a specific organ, allow experimentation toward the in vivo generation of functional organs from human stem cells in large animals. Such experiments provide the basis for potential future application of stem cell technology to generate

transplantable human organs from the patient's own cells, using livestock animals, to increase quality of life for those with end-stage organ failure.

Internet information

On January 22, 2022, ABC News published a report titled ‘Pig heart transplants: ethics, regulations and why we shouldn't expect to see them in Australia soon’
The report gives the point of view of a range of Australian bioethicists on the ethics of animal to human organ transplantation. The article also notes the quarantine regulations which would prevent Australia importing the genetically modified pigs necessary for these transplants.
The full text can be accessed at https://www.abc.net.au/news/science/2022-01-22/organ-transplant-pigs-humans-heart-kidney-ethics-regulations/100769786

On January 19, 2022, the World Economic Forum published a detailed report titled ‘In a medical first, a gene-edited pig heart has been transplanted into a human patient’. The article explains the gene-editing used to help prevent organ rejection and discusses some of the ethical issues the procedure raises.
The full text can be accessed at https://www.weforum.org/agenda/2022/01/gene-edited-pig-heart-transplanted-into-human-patient/

On January 14, 2022, Nature Magazine published an article titled ‘First pig-to-human heart transplant: what can scientists learn?’
The article examines the ethical implications of offering a human patient an experimental procedure and considers some of the practical and cost factors that currently restrict the use of pig organs.
The full text can be accessed at https://www.nature.com/articles/d41586-022-00111-9

On January 14, 2022, RGA (Reinsurance Group of America) published a report by Hilary Henly, a global medical researcher, titled ‘Xenotransplantation – The Future of Organ Transplants in Humans’. The report promotes the future benefits to be derived from animal organ transplants. It details the early history of xenotransplantation and some of the gene-editing processes required to make it successful.
The full text can be accessed at https://www.rgare.com/knowledge-center/media/articles/xenotransplantation-the-future-of-organ-transplants-in-humans

On January 12, 2022, Deseret News published an opinion piece titled ‘“I want to live” — Why even in an age of animal rights, human beings come first’ The piece discusses why in the most recent ground-breaking case of the transplantation of a pig’s heart into a human recipient, the human life takes precedence. However, it argues that animal welfare considerations remain important.
The full text can be accessed at https://www.deseret.com/opinion/2022/1/12/22878815/the-terrible-blessing-of-using-pigs-as-organ-donors-heart-transplant-bioethics-peta-animal-rights

On January 11, 2022, BBC News published a report titled ‘Three ethical issues around pig heart transplants’
The report considers some of the ethical considerations raised by the most recent animal to human transplant.
The full text can be accessed at https://www.bbc.com/news/world-59951264

On November 1, 2021, Forbes published an article titled ‘A Big Step Forward In Solving The Organ Shortage’

The article gives an overview of the work, especially in the area of genetic modification, over the last 35 years to produce pigs whose organs are suitable for transplantation into human beings.
The full text can be accessed at https://www.forbes.com/sites/williamhaseltine/2021/11/01/a-big-step-forward-in-solving-the-organ-shortage/?sh=517af3bf1f3a

On October 28, 2021, Vox published a discussion titled 'Is it okay to harvest pig kidneys to save human lives?'
The piece addresses the questions, 'Is it morally justifiable to slaughter thousands of pigs annually to keep humans alive? And is it more morally justifiable than other methods that could also end the kidney shortage?'
The full text can be accessed at https://www.vox.com/future-perfect/22738680/pig-kidney-human-transplant

On October 21, 2021, PETA (People for the Ethical Treatment of Animals) updated a previous publication titled 'Pigs Aren't Spare Parts! PETA Slams Latest Organ 'Transplant' Stunt as Junk Science'. The piece was originally prompted by an experiment involving attaching a pig's kidney to a dead human body attached to life-support. It was updated to address the later transplantation of a pig's heart into a living human recipient. It outlines PETA's objections to both procedures.
The full text can be accessed at https://www.peta.org/blog/pig-kidney-attached-human-problems-frankenscience/

On April 3, 2019, The Guardian published a report titled 'Using animal organs in humans: "It's just a question of when"' The report details the gene-editing techniques employed to prevent rejection and infection when transplanting pig organs into a human recipient.
The full text can be accessed at https://www.theguardian.com/science/2019/apr/03/animal-global-organ-shortage-gene-editing-technology-transplant

In June 2018, Stanford Medicine published an article titled 'Growing human organs: Caution surrounds the use of animals to solve donor shortages' This article considers the work currently being done to grow subject-specific human organs with animals such as pigs, that used the genetic material of the human recipient.
This work is highly experimental, and the article discusses some of the practical and ethical considerations it raises.
https://stanmed.stanford.edu/2018winter/caution-surrounds-research-into-growing-human-organs-in-animals.html

On December 14, 2011, The Conversation published a report by Peter Cowan co-director of the Immunology Research Centre, St Vincent's Hospital Melbourne. The report is titled 'Xenotransplantation: using pigs as organ and tissue donors for humans'. The report explains why pigs have been preferred over primates as sources of organs for human transplants.
The full text can be accessed at https://theconversation.com/xenotransplantation-using-pigs-as-organ-and-tissue-donors-for-humans-4291

In 2008, Bio (Biotechnology Innovation Organization) published a summary paper titled 'XENOTRANSPLANTATION: The Benefits and Risks of Special Organ Transplantation'

The article supplies a brief history of xenotransplantation, considers appropriate animals for transplantation and ways of addressing the risk of rejection and infection. It also considers several ethical issues raised by the process.
The full text can be accessed at https://archive.bio.org/articles/xenotransplantation-benefits-and-risks-special-organ-transplantation

In June 2004, the United States Department of Health and Human Services Advisory Committee on Xenotransplantation released a draft report titled 'Informed Consent in Clinical Research Involving Xenotransplantation'. The document details the protocols needed to protect the rights of human patients and subjects at the same time as allowing researchers to work to develop cures.
The full text can be accessed at https://www.tts.org/images/stories/pdfs/SACX-informed-consent.pdf

On March 30, 2001, PBS current affairs program Frontline televised the first of two episodes titled 'Organ Farm' which supplied detailed information from all both sides of the issue on attempts to use transplants of animal organs and tissues to treat human recipients.
A transcript of the programs can be accessed at
https://www.pbs.org/wgbh/pages/frontline/shows/organfarm/

Arguments in favour of using animal organs and tissues for human transplants

1. Human organs for transplants are in too short supply
One of the primary arguments offered to support the use of animals to supply organs for human transplantation is that there are simply too few human organs available to meet the present need.

In the United States as of January 2019, there were over 113,000 people on the national waiting list in need of an organ. Every 10 minutes another person is added to the waiting list, and every day 20 people on the waiting list die before they can access the organ they need. https://lifepassiton.org/the-organ-shortage-the-need-for-donors/ In the United Kingdom at the end of 2021, there was estimated to be 7,000 people on the transplant waiting list and over 470 people died while waiting for a transplant. https://tinyurl.com/yckvcn83 Germany had the highest number of patients waiting for a lung transplant in Europe in 2019 with 731 individuals on the waiting list during the year, while 45 died on the waiting list for a lung transplant. In Austria, five people requiring a lung transplant died during 2019. https://www.statista.com/statistics/537912/lung-transplant-rate-in-europe/ According to the statistics, the deceased organ donation rate in China currently is only about 0.6 per 1,000,000 China citizens, one of the lowest in the world. There are about 1 to 1.5 million people in China needing organ transplant every year and only 10,000 people can get a new organ successfully. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4820883/ In 2019, 4419 Canadians were on a waiting list for a transplant. Of those, 77 percent were waiting for a kidney. Wait times can range from a few months to several years, during which time many would-be recipients die or become too ill to be given an organ. https://tinyurl.com/2p8tvdk5 The picture is similar in Australia. In 2020, there were 1,270 organ transplant recipients from 463 deceased organ donors. As of 2021, more than 1,600 people are waiting for a life-saving transplant. There are also 12,000 people on dialysis, many of whom would benefit from a kidney transplant. https://tinyurl.com/yckht347

The pandemic has worsened the situation around the world for those waiting to receive a human organ. In the United Kingdom., 474 patients died by the end of 2021 while waiting for organs compared with 377 the year before. Most patients who died were waiting for kidney transplants. There were 3,391 transplants performed in 2020-2021 compared with 4,820 the previous year - a fall of 30 percent. https://www.bbc.com/news/health-57839024 Those who argue for access to animal organs for transplants highlight figures like those above and note the vulnerability of organ transplant programs to complicating factors such as the current pandemic.

Many transplant specialists are enthusiastically awaiting the time when animal organs can be used to replace diseased or faulty human organs. Unlike human organs, where patients must wait for someone else to die, the supply of pig organs and cells would be virtually unlimited. Devin Eckhoff, a liver transplant surgeon at the University of Alabama at Birmingham Medical School, has said that if the procedure were approved, he could be producing 50 pigs for transplant within nine months. He has referred to the frustration of watching his patients become critically ill and then die waiting for replacement organs. He has stated, 'With organs available from pigs, think of how many more lives we could save.' https://www.theguardian.com/science/2019/apr/03/animal-global-organ-shortage-gene-editing-technology-transplant

David Cooper, who co-directs the xenotransplantation program at the University of Alabama at Birmingham, has stated, 'It'll revolutionise medicine when it comes in. You'd have these organs available whenever you want them … If somebody's had a heart attack, you could take their heart out and put a pig heart in on the spot. There is huge potential here.' David Cleveland, a heart surgeon at the University of Alabama at Birmingham, wants to use xenotransplantation to save babies born with congenital heart defects. Dr Cleveland has stated, 'At the moment, newborns can wait on the organ transplant list for more than three months for a new heart, often facing a mortality rate above 50 percent.' https://www.theguardian.com/science/2019/apr/03/animal-global-organ-shortage-gene-editing-technology-transplant

2. Using animal organs and products has the potential to treat many serious human conditions
Those who support the use of animal organs and tissues to treat human diseases and other conditions argue that they can be used to address both life-threatening health issues and many others. Currently, human organs that can be donated after death include the heart, liver, kidneys, lungs, pancreas, small intestines, hands, face and uterus. Tissues include corneas, skin, middle ear veins, heart valves, tendons, ligaments, bones, and cartilage. http://www.americantransplantfoundation.org/about-transplant/facts-and-myths/ It has been argued that animal organs and tissues could be used to address all these needs.

Researchers and transplant surgeons have pointed out the large number of organs that could be harvested from pigs to save human lives or treat non-life-threatening conditions. It is widely proposed that one day, genetically modified pigs could supply hearts, kidneys, lungs and livers to transplant centres to save patients from death. https://www.technologyreview.com/2019/11/01/132110/meet-the-pigs-that-could-solve-the-human-organ-transplant-crises/ Dylan Matthews, writing for Vox in an article published on October 23, 2021, stated, 'Genetically engineered pig hearts that could work for humans could dramatically extend lifespans for people with heart disease, and the same goes for lungs, liver, and other organs.' https://www.vox.com/future-perfect/22738680/pig-kidney-human-transplant

Transplant-ready pigs could do more than just provide organs. Already, tissue taken from pigs is being used to treat human conditions. Pig heart valves have been used successfully for decades in humans. The blood thinner heparin is derived from pig intestines and Chinese surgeons have used pig corneas to restore sight. https://apnews.com/article/animal-human-organ-transplants-d85675ea17379e93201fc16b18577c35
It has also been suggested that pig tissues could be used to treat diabetes. Until the 1980s, humans with type I diabetes or insulin-dependent diabetes relied on animal insulin to control their blood glucose levels. Insulin is a hormone produced by the pancreas. People with type 1 diabetes make little to no insulin. This is because their immune system attacks this hormone. In 1921, Frederick Banting and his assistant Charles Best extracted insulin from dogs for the first time. In the years that followed, experts began extracting this hormone from the pancreas of pigs and cows. Currently, human-derived insulin is also available in the market. https://www.downtoearth.org.in/news/health/pig-heart-transplant-a-history-of-the-animal-s-contribution-to-medical-sciences-81085 It is hoped that soon, a transplantation from genetically modified pigs could remove the need for these patients to take insulin at all. These pigs could be used to produce the islet cells – clusters of hormone-producing pancreatic cells – needed by people with diabetes. A 2011 review in the medical journal The Lancet is optimistic that clinical xenotransplantation may soon become a reality, particularly for cellular grafts such as islets. https://theconversation.com/xenotransplantation-using-pigs-as-organ-and-tissue-donors-for-humans-4291

Pig blood could also be used to give transfusions to trauma patients and people with chronic diseases like sickle cell anemia, who often develop antibodies against human blood cells because they have had so many transfusions. David Cooper, who co-directs the xenotransplantation program at UAB. the University of Alabama at Birmingham, has stated, ‘Even dopamine-producing cells could be made by pigs, and transplanted into patients with Parkinson’s disease.’ https://www.theguardian.com/science/2019/apr/03/animal-global-organ-shortage-gene-editing-technology-transplant

Jeremy Goverman, the principal investigator of Massachusetts general’s skin trial, has explained how pig skin could also help burn patients. He often cannot find swatches of human skin big enough to cover large wounds. He believes a patch of skin from a pig would be more cost-effective than one from a cadaver. For countries that cannot maintain human tissue banks, pig skin might be a life-saving alternative. This is already being done in some places. https://www.theguardian.com/science/2019/apr/03/animal-global-organ-shortage-gene-editing-technology-transplant In October 2019, the united States Food and Drug Administration authorised human trials on the use of porcine (pig) skin tissue to treat human burns patients. https://www.advisory.com/en/daily-briefing/2019/11/18/pig-transplant

3. Experimental surgery is necessary, while guidelines, including informed patient consent, ensure it is ethical
It has been argued that all medical treatments applied to human beings were once experimental and that without patients being willing to undergo experimental treatments there would be no advances in medical practice. Supporters of the use of animal organs, tissues and cells to treat human beings stress that initial trials should only take place with the informed consent of patients and their families.

A range of international organisations have established guidelines and procedures describing how experimental medical treatments should take place. The World Health Organisation

states, ‘Clinical trials are a type of research that studies new tests and treatments and evaluates their effects on human health outcomes. People volunteer to take part in clinical trials to test medical interventions including drugs, cells and other biological products, surgical procedures, radiological procedures, devices, behavioural treatments and preventive care. Clinical trials are carefully designed, reviewed and completed, and need to be approved before they can start. People of all ages can take part in clinical trials, including children.’ https://www.who.int/health-topics/clinical-trials#tab=tab_1

The World Medical Association similarly states ‘Medical progress is based on research that ultimately must include studies involving human subjects.’ The Association further states, ‘While the primary purpose of medical research is to generate new knowledge, this goal can never take precedence over the rights and interests of individual research subjects.’ The Association also stresses the importance of the research subject having given his or her informed consent. Its guidelines state, ‘Participation by individuals capable of giving informed consent as subjects in medical research must be voluntary. Although it may be appropriate to consult family members or community leaders, no individual capable of giving informed consent may be enrolled in a research study unless he or she freely agrees.’ The guidelines further state, ‘In medical research involving human subjects capable of giving informed consent, each potential subject must be adequately informed of the aims, methods, sources of funding, any possible conflicts of interest, institutional affiliations of the researcher, the anticipated benefits and potential risks of the study and the discomfort it may entail, post-study provisions and any other relevant aspects of the study. The potential subject must be informed of the right to refuse to participate in the study or to withdraw consent to participate at any time…’ Where an individual cannot give informed consent, for example in the case of a minor, the guidelines state that the child’s permission must also be received where he or she can express it The guideline state, ‘When a potential research subject who is deemed incapable of giving informed consent is able to give assent to decisions about participation in research, the physician must seek that assent in addition to the consent of the legally authorised representative.’ https://www.wma.net/policies-post/wma-declaration-of-helsinki-ethical-principles-for-medical-research-involving-human-subjects/

A range of transplant surgeons and ethicists have explained the circumstances under which animal-to-human transplant surgery is ethical. Professor Julian Savulescu, Uehiro Chair in Practical Ethics at the University of Oxford, has stated, ‘You can never know if the person is going to die catastrophically soon after the treatment - but you can't proceed without taking the risk. As long as the individual understands the full range of risks, I think people should be able to consent to these radical experiments.’ https://www.bbc.com/news/world-59951264 David Bennett, the 57-year-old patient who recently received a pig’s heart at the University of Maryland Medical Center, stated before the surgery, ‘It was either die or do this transplant. I want to live. I know it's a shot in the dark, but it's my last choice.’ https://www.abc.net.au/news/2022-01-11/pig-heart-transplanted-into-us-man-in-world-first/100513728 A spokesperson for the University of Maryland Medical Center stated after the surgery was performed, ‘This patient came to us in dire need and a decision was made about his transplant eligibility based solely on his medical records. This patient made the extraordinary decision to undergo this groundbreaking surgery to not only potentially extend his own life but also for the future benefit of others.’ https://www.abc.net.au/news/2022-01-14/son-calls-fathers-pig-heart-transplant-a-miracle/100756060

4. Organ rejection issues and the transmission of infections carried by the donor animal can be substantially overcome

Supporters of animal organs being used in human transplants argue that the major obstacles that formally prevented these transplants have been overcome. They claim that organ rejection and the transmissions of diseases carried by the donor animal have been virtually eliminated by new developments in gene technology.

It is claimed that the problem of organ or tissue rejection by the human recipient has been largely overcome. Modifications can now be made to the organs or tissues to be transplanted to cause the recipient's body to fail to recognise them as foreign. Researchers can now make targeted changes to the genes of the pig supplying an organ to remove markers that identify cells as foreign so the human immune system will not reject them. https://www.theguardian.com/science/2019/apr/03/animal-global-organ-shortage-gene-editing-technology-transplant In the case of David Bennett, the 57-year-old patient who recently received a pig's heart at the University of Maryland Medical Center, the Maryland surgeons used a heart from a pig that had undergone gene editing to remove a sugar in its cells that is responsible for the rapid organ rejection that would normally occur. https://www.abc.net.au/news/2022-01-11/pig-heart-transplanted-into-us-man-in-world-first/100513728 The donated heart came from a pig developed by United States firm Revivicor. The animal had ten genes modified. Four of those were inactivated, including one that causes an aggressive immune response and one that would otherwise cause the pig's heart to continue growing after transplant into a human body. To further increase the chances of acceptance, the donor pig had six human genes inserted into its genome and Bennett is taking immune-suppressing medications.
https://www.newscientist.com/article/2304167-how-a-pig-heart-was-transplanted-into-a-human-for-the-first-time/#ixzz7ImT8fiBf

Similar genetic technology has also been used to reduce the risk of porcine (pig) viruses being transmitted to the recipients of transplants and then to medical carers, family, friends, workmates, and others. Gene-editing technology can enable researchers to eliminate from the pig genome a group of viruses that some worry could jump to humans after a transplant. Porcine endogenous retroviruses (Pervs) are permanently embedded in the pig genome, and research has shown they can infect human cells, posing a potential hazard. Researchers in the United States have used the precision gene editing tool Crispr-Cas9 combined with gene repair technology to deactivate 100 percent of Pervs in a line of pig cells. These have been used to clone pigs that do not carry these retroviruses. Dr Luhan Yang, co-founder and chief scientific officer at the biotech company eGenesis, has stated, 'This research represents an important advance in addressing safety concerns about cross-species viral transmission.' https://www.theguardian.com/science/2017/aug/10/gene-editing-to-remove-viruses-brings-transplant-organs-from-pigs-a-step-closer Dr Luhan further noted, 'Our work dispelled the shadow PERVs cast on the field more than a decade ago when the virus was discovered, while renewing our faith in xenotransplantation.' https://www.ndtv.com/health/gene-editing-removes-major-barrier-to-pig-to-human-organ-transplant-1231896 Professor Ian McConnell, from the University of Cambridge, has similarly stated, 'This work provides a promising first step in the development of genetic strategies for creating strains of pigs where the risk of transmission of retroviruses has been eliminated.' https://www.bbc.com/news/health-40886600

5. Using animal organs for transplants is ethically responsible
Those who support animal organs being used for human transplants argue that these transplants, especially when they involved domestic animals such as pigs, are ethically responsible.

One of the fundamental claims made by those who support animal organ transplantation is that human life is of greater value than animal life. Many ethicists maintain that human beings automatically privilege human life over animal life because of the greater intelligence and moral and emotional awareness of human beings. Juan Carlos Marvizon, a Professor of Medicine at the University of California, Los Angeles (UCLA) has presented a range of reasons as to why human life should be valued more highly than animal life. He has outlined in detail the aspects of human intelligence that place human beings in a higher category to all animals. He has also focused on the qualities of human emotion, stating, 'Mammals, birds and some other animals have a set of six basic emotions listed by Ekman: anger, fear, disgust, joy, sadness and surprise. However, we humans are able to feel many other emotions that regulate our social behavior and the way we view the world: guilt, shame, pride, honor, awe, interest, envy, nostalgia, hope, despair, contempt and many others. While emotions like love and loyalty may be present in mammals that live in hierarchical societies, emotions like guilt, shame and their counterparts pride and honor seem to be uniquely human.' https://speakingofresearch.com/2016/12/06/not-just-intelligence-why-humans-deserve-to-be-treated-better-than-animals/ The greater intellectual, moral and emotional complexity of human beings is claimed by many to make their lives of greater worth than any animals. Proponents of animal transplants argue that this superiority of human beings justifies them in using human organs and tissues to extend their lives.

It is also claimed that the animals used to supply transplant organs or in experiments to develop successful transplant procedures are not subjected to unnecessarily cruel or painful treatment. Those who defend animal testing and the use of animals in medical procedures that help human beings note that most countries have protocols and regulations designed to reduce the amount of suffering these animals endure. On October 8, 2021, Justice published a discussion of the use of animals in medical treatments and scientific experiments. The piece was written by animal rights activist Grace Hussain who stated, 'Laboratories attempt to mitigate this suffering with the use of pain medications, sedation, and anesthesia. Another mitigation technique employed is that researchers set a limit to the level of suffering animal subjects will endure prior to euthanasia. Once an animal reaches the predetermined level of suffering the animals will be humanely euthanized.' https://sentientmedia.org/animal-testing/

It is further argued that in using domestic animals such as pigs for transplants, animals such as apes and chimpanzees, which are endangered in their natural habits, are not having their species survival further put at risk. The Foundation of American Scientists has made a comparison between the use of primates and pigs to supply organs for human transplants. It suggests that the use of pigs raises fewer ethical concerns. It states, 'Although non-human primates such as chimpanzees are genetically closest to humans, reducing the chances of graft rejection, primates are endangered in the wild and their use as a source of replacement organs raises ethical concerns because of their high level of intelligence. As an alternative, some have proposed using pigs as a source of organs because they have large litters (up to 10 offspring) and a short gestation time (four months), are anatomically and physiologically similar to humans, are already produced as a food source, and provide some replacement tissues, such as heart valves.' https://biosecurity.fas.org/education/dualuse-agriculture/2.-agricultural-biotechnology/pigs-source-of-replacement-organs-for-humans.html

Arguments against using animal organs and tissues for human transplants

1. Using animal organs for human transplants risks organ rejection
Opponents of animal-to-human transplantation stress the high risk of organ rejection, that is, the immune system of the human body receiving the animal organ will mount a massive immune response against the foreign tissue.

Large numbers of current studies have noted the great danger to patient survival posed by the human body's immune response. A report published in Science Daily on March 14, 2019, noted the significant problems that organ rejection currently poses for patients receiving human organs. The report notes, 'One third of organ transplants are lost to transplant rejection. Although acute transplant rejection responds relatively well to steroids, chronic rejection (which is mainly mediated by antibodies) has no effective treatment.' https://www.sciencedaily.com/releases/2019/03/190314101312.htm The problems of organ rejection associated with transplanted animal organs are potentially greater. In 2020 Bernard Rollin, emeritus professor of philosophy, animal sciences, and biomedical sciences at Colorado State University, stated, 'The most significant issue with using animals for a source of transplanted organs (xenotransplantation) for humans is immunological rejection of the organ, with the human immune system recognizing the foreign organ as "not-self" and…rejecting it. In what is known as "hyper-acute rejection", the body begins to reject the organ virtually as soon as it is implanted.'
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7552641/

The same problem was described in the 1996 Nuffield Council on Bioethics report 'Animal-to-Human Transplants: the ethics of xenotransplantation'. The report states, 'The major hurdle in the way of successful xenotransplantation is preventing the rejection of transplanted animal organs. This is a problem even with human organ transplantation: the recipient's immune system mounts an attack on the transplanted organ, which it sees as foreign. The immune response to organs or tissue from a different species is much stronger. Two main approaches are being used to overcome this problem. First…the use of baboons is being investigated, on the basis that baboons are closely related to human beings and so the immune response to baboon organs or tissue will not be too strong. The second approach is to use pigs that have been modified genetically so that their organs do not cause such a strong immune response when transplanted into human beings.'
https://www.who.int/ethics/en/ETH_Nuffiled_xenotransplantation.pdf

Critics note that the long-term effectiveness of genetic modification to reduce the likelihood of rejection has not been demonstrated. It has been claimed that the problems associated with acquiring a genetically modified organ grown within an animal (usually a pig) have not all been solved. In 2018 , EMBO, the journal of the European Molecular Biology Organization published a report titled 'Ethical rejections of xenotransplantation? The potential and challenges of using human-pig chimeras to create organs for transplantation.' The report states, 'To prevent tissue rejection, the transplanted organ has to contain at least 90 percent human cells, which will make it necessary to generate a human organ with a human vascular system. Second, we do not know how many pig chimeras [pigs with genetically modified organs] will be needed to ensure that a proper patient-specific organ is obtained for transplantation. Finally, heart transplant candidates require intense medical care and usually receive a transplant within 6 months. Will it be possible to generate a human heart in human-pig chimeras within 6 months or will more time be necessary that may place these patients at a higher mortality risk while waiting for the donor heart?'
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6073069/

2. Using animal organs for human transplants risks animal diseases entering human populations

Those who oppose animal organs being transplanted into human beings stress the risk of currently animal-specific diseases being acquired by transplant recipients and the people with whom they come into contact.

On January 18, 2022, The Australian published a report from Rhys Blakely, the science correspondent for The Times which examines some of the negative consequences associated with animal organ transplants. Blakely explains, 'Pig DNA contains viruses that have become embedded inside the animal's genetic code. These porcine [pig] endogenous retroviruses (abbreviated, memorably, to "Pervs") could potentially break out of the pig's DNA to become independent infectious pathogens. Retroviruses can lurk in the body for years, decades even, before they cause symptoms. They're not to be trifled with: another pathogen in the same class is HIV.' https://www.theaustralian.com.au/science/harvesting-pig-organs-can-cut-transplant-lists-but-risks-viruses/news-story/61f80d82b55551661356ccfb90e9925b

Many medical authorities have stressed the potential for disease transmission when human beings receive transplant organs from animals. The United States Food & Drug Administration (FDA) has stated, 'The use of xenotransplantation raises concerns regarding the potential infection of recipients with both recognized and unrecognized infectious agents and the possible subsequent transmission to their close contacts and into the general human population. Of public health concern is the potential for cross-species infection by retroviruses, which may be latent and lead to disease years after infection. Moreover, new infectious agents may not be readily identifiable with current techniques.' https://www.fda.gov/vaccines-blood-biologics/xenotransplantation In January 2001, the American Society for Microbiology published a paper titled 'Infectious Disease Issues in Xenotransplantation'. The paper states, 'Infectious diseases passed from animals to humans under natural circumstances are called zoonoses…[T]he breaches of normal host defenses inherent in xenotransplantation may enable infectious agents that are unable (or poorly able) to infect humans under normal circumstances to cause infections… The risk for such infections would presumably increase with both increased immunosuppression [treatment to reduce the immune response so as to avoid organ rejection] and possible introduction of potentially pathogenic microorganisms through the xenotransplantation product, bypassing the normal defensive mechanisms.' The same point was made in a paper published by The American Journal of Transplantation on October 1, 2017. The paper states, 'From a theoretical standpoint, PERV (porcine endogenous retrovirus) represents the most serious challenge because it is present at multiple copies in the pig genome, and thus unlike other viral pathogens cannot be eliminated by breeding.' https://minerva-access.unimelb.edu.au/bitstream/handle/11343/292877/ajt.14311.pdf?sequence=1&isAllowed=y

Other, non-medical commentators have expressed similar concerns. In a statement first released by PETA (People for the Ethical Treatment of Animals) on October 21, 2021, the organisation states, 'Even before the COVID-19 pandemic, public health experts—including a Centers for Disease Control and Prevention researcher and researchers with the World Health Organization—raised concerns about the potential of xenotransplantation to spread zoonotic and other infectious pathogens. Their warning? These transplants are dangerous to humans, as pigs carry viruses and other infectious pathogens that could potentially be introduced into human populations.' https://www.peta.org/blog/pig-kidney-attached-human-problems-frankenscience/

3. Using animal organs for human transplants treats human patients as test subjects
Critics of animal organs being transplanted into human beings argue that this procedure is too dangerous, and the human patients are being used as test subjects in what are merely experiments.

Critics point to earlier periods of animal to human transplantation and highlight the experimental and unsuccessful nature of the procedures. They suggest they were not undertaken with the real intent to cure the patient or prolong their lives and instead were experiments. It is further suggested that patients were not adequately informed about the procedures and other options which may have existed.

In the 1960s, Louisiana surgeon, Keith Reemtsma, transplanted 13 human kidneys into human patients. Twelve of these patients died of either infection or rejection within two months and the thirteenth died nine months later of acute electrolyte disturbance. Despite a lack of success, such animal to human transplants continued sporadically until the 1980s. https://www.medicalnewstoday.com/articles/282690#-Where-does-research-currently-stand?- On October 26, 1984, Dr. Leonard Bailey and his associates at the Loma Linda University Medical Center in California implanted a heart from a seven-month-old baboon in a human infant born with a life-threatening heart condition. Baby Fae, as the newborn child has become known to preserve anonymity, lived for twenty days before dying on November 15 due to rejection of the foreign tissue and kidney failure. Ethical reviews following the child's death raised questions about the experimental rather than therapeutic nature of the transplant; expressed doubts that the procedure offered a greater chance of survival than any less radical alternative; and questioned the quality and extent of information provided to baby's mother regarding other treatment options, the risks of the procedure, and prognosis for the child. https://repository.library.georgetown.edu/bitstream/handle/10822/556905/sn5.pdf;sequence=1 Dr. Paul Terasaki, director of the California Regional Organ Procurement Agency, has stated, 'My feeling is that they should have tried harder to get a human heart. I think they did not make any effort to get a human infant heart because they set on doing a baboon.' https://www.washingtonpost.com/archive/politics/1984/11/17/baby-fae-case-leaves-tremors/2d100f96-01bc-498a-afc5-f680e334c9e8/ Concerns about the effectiveness and ethics of animal to human transplants following the Baby Fae transplant saw such procedures all but cease.

A related concern regarding animal to human transplants is that the organ recipient, as well as being inadequately informed, may not be able to consent freely to the transplant. It has been noted that patients are generally only offered an animal organ as a transplant when they are in immediately life-threatening ill health. In these circumstances, their desperation for a treatment may make it difficult for them to make a fully considered decision. The United States Department of Health and Human Services outlines some of the information that must be available to the patient if consent is to be reasonably given. These include: background and history of the particular procedure, including previous related trials and outcomes and relevant results from animal studies; a description of the procedure(s) to be followed, including identification of those that are experimental; a description of the risks and potential benefits, if any, of the procedure; available alternatives (both accepted medical practices and other experimental approaches), including their comparative risks and benefits; possible social, economic, psychological, and/or medical consequences to the subject and his or her family. https://www.tts.org/images/stories/pdfs/SACX-informed-consent.pdf It has also been noted that because animal-to-human transplants involve the risk of the recipient contracting

one or more diseases which can then be passed on to family, friends and other contacts, these people should be informed of the risks they are facing.

4. Using animal organs for human transplants transgresses animal rights
Those who oppose transplanting animal organs into human recipients also stress that this practice is morally questionably because it ignores the rights of animals and often involves inflicting pain upon them in addition to taking their lives.
One of the major arguments against using animals to supply organs for human transplants is that this is a total violation of animals' right to life. It treats animals as though they exist only to provide materials for human beings. It reduces them to the level of objects or apparatus with no right to their own existence. This is made even more the case because most animals likely to be used for transplantations will have been breed expressly for this purpose. Clare Palmer, a British philosopher, theologian, and scholar of environmental and religious studies, is currently a professor in the Department of Philosophy at Texas A&M University. Professor Palmer has explained, 'From a rights perspective, this treats pigs merely as means to our ends, almost as a kind of mechanism, whose entire life is created and disposed of for human use.' https://liberalarts.tamu.edu/blog/2021/12/13/are-pig-to-human-kidney-transplants-ethical/

Another objection to the use of animals for human transplants is that the process involves suffering for the animals concerned. Before animals such as pigs are used to supply transplant organs for human beings, they are used in cross-species transplant experiments. To lay the groundwork for pig organ-to-human transplants, xenotransplantation researchers and regulatory agencies agree pig organ transplants must first show survival rates of three to six months in nonhuman primates. Thousands of monkeys, chimpanzees and baboons have been experimented on and killed in the course of this cross-species transplant research. https://www.pbs.org/wgbh/pages/frontline/shows/organfarm/rights/ The BUAV (British Union Against Vivisection) claim that primates used in xenotransplantation research will experience a large number of traumatic procedures, including major surgery, from which many will die; internal haemorrhages; isolation in small cages; repeated blood sampling; wound infections; nausea, vomiting and diarrhoea because of immunosuppressant drugs and kidney or heart failure.
https://www.pbs.org/wgbh/pages/frontline/shows/organfarm/rights/primates.html Dr. Gill Langley, a Fellow of the Royal Society of Medicine and a member of the Animal Procedures Committee since 1998, has stated, 'It's not just the suffering they [the primates] endure in the laboratories and research establishments. Just getting there can be torture. Studies of primates show them to have complex mental abilities which may increase their capacity to suffer. Supplying the laboratories in the UK imposes huge suffering on the animals. It involves capturing wild individuals, usually in Africa. They're then contained in small, single cages, and transported for very long distances causing deaths, distress, and suffering. A number of inquiries have said that the use of primates was unacceptable and should be limited to very small numbers. Our view is that any number is unacceptable.'
https://www.pbs.org/wgbh/pages/frontline/shows/organfarm/rights/primates.html

Other animal rights activists have explained the suffering that will be imposed on those pigs bred in specifically engineered, hygienic conditions to be donor animals. Daniel Lyons is the chief executive officer of the Centre for Animals and Social Justice, a British animal protection charity. He is an honorary research fellow at the University of Sheffield and the author of The Politics of Animal Experimentation. Lyons has explained, 'One of the most important natural behaviors of pigs is rooting and foraging behavior, and they spend about

three-quarters of their waking lives rooting and foraging for food. And obviously, in nature, they would have a virtually infinitely complex environment to explore; they would have room to socialize with their fellows. They're at least as intelligent as dogs. We're talking about very, very intelligent, sensitive animals. But none of this will be afforded to them if they're being factory-farmed. Because of the needs for the relatively sterile conditions, they won't have any of this rooting and foraging behavior.

And the suffering starts way before that, because in order to minimize the bacteria that they'll be carrying, the piglets, or some of them at least, will be born by cesarean section, rather than being born naturally and having a bond with their mothers. The separation of the sow from the piglet normally wouldn't be allowed, because it's very important for the piglet's health, both psychologically and physically, for it to have an early relationship with its mother. But it'll be taken away and reared in incubators. It will be a very, very sterile production procedure.' https://www.pbs.org/wgbh/pages/frontline/shows/organfarm/interviews/lyons.html

5. Alternatives to animal organ transplants are being developed
Critics of animal transplants argue that technologies are being developed which will provide better alternatives without either the ethical or practical problems created by using animal organs. These 3D printed organ substitutes create no ethical concerns and do not create rejection or disease-transfer problems. Like animal organs, once developed they will also be available without any supply limitations.

Scientists have used variations of 3D printing techniques to print mini organoids and microfluidic models of tissues, also known as organs on chips. Some of these models are used by pharmaceutical companies to test drugs before moving on to animal studies and eventually clinical trials. One group, for example, printed cardiac cells on a chip and connected it to a bioreactor before using it to test the cardiac toxicity of a well-known cancer drug. https://www.the-scientist.com/news-opinion/on-the-road-to-3-d-printed-organs-67187
Some companies have had some success with 3D printing full organs. Robby Bowles, a bioengineer at the University of Utah, has stated, 'There are a number of companies who are attempting to do things like 3-D print ears.' Researchers have already reported transplanting 3-D printed ears onto children who had birth defects that left their ears underdeveloped. Bowles has noted, 'The ear transplants are kind of the first proof of concept of 3-D printing for medicine.' https://www.the-scientist.com/news-opinion/on-the-road-to-3-d-printed-organs-67187

Advances are being made toward constructing components of the kidney and the whole organ. In 2016, scientists from the Lewis Lab at Harvard University developed a novel bioprinting method that allowed the creation of small segments of the nephron, called proximal tubules. Nephrons are the most basic structure of the kidney and responsible for all the blood filtering in these organs. In 2019, American bioprinting company Organovo announced the successful automated production of kidney organoids. Organoids are self-organising stem-cell-based structures that can be produced in large numbers relatively quickly. In September 2020, the United Therapeutics Corporation partnered with Israeli regenerative medicine company CollPlant Biotechnologies to apply its material technology (rhCollagen) to kidney bioprinting development. https://all3dp.com/2/most-promising-3d-printed-organs-for-transplant/

Similar advances are being made toward the construction of other organs. In 2016, researchers from the University of California San Diego were able to 3D print organic tissue

that mimicked real liver structures both in architecture and function. Back then, such bioengineered tissues were used by the pharmaceutical industry for drug development and testing. Organovo (mentioned above with their kidney advancements) was also able to 3D bioprint liver tissue patches, and in 2018, it went further to implant them into living mice. The results were very positive, with tissue retention and functionality verified a month post-implantation. Brazilian researchers from the University of São Paulo reported successful bioprinting 'miniature livers' in late 2019. These organoid structures were from human blood cells and performed liver normal functions such as producing proteins, storing vitamins, and even secreting bile. According to the researchers, the entire process took approximately 90 days from collecting the patient's blood to the final maturing of the mini-livers. https://all3dp.com/2/most-promising-3d-printed-organs-for-transplant/

Supporters of this technology note that the most promising projects of 3D bioprinted organs are for the heart. The heart is one of the easiest organs to recreate because it does not employ any complex biochemical reactions. Rather, its primary function is to act as a hydraulic pump. The Wake Forest Institute for Regenerative Medicine (WFIRM) is an American research institute focused on tissue engineering for various applications, including transplantation. In 2018, a WFRIM research group claimed to have 3D bioprinted functional cardiac tissue using mice cells. In 2019 researchers from Tel Aviv University's (TAU) School of Molecular Cell Biology and Biotechnology produced the first fully-vascularised 3D printed mini human heart. This bioprinted organ was made from human cells taken from a patient and carrier gels. TAU's team is now working to mature the cardiac cells and make them fully functional. The Chicago-based company Biolife4D has also accomplished a similar breakthrough in 2019, announcing its own bioprinted heart. This one, however, shows extended functionally when compared to the one developed at Tel Aviv University and is much larger too. Specialists predict that a ready-to-transplant bioprinted heart could be available within the decade. https://all3dp.com/2/most-promising-3d-printed-organs-for-transplant/

Further implications

Currently, the transplantation into human recipients of organs taken from animals relies on gene-editing, manipulating the genes of the donor pig to remove certain qualities and adding human genes to create other qualities. These are the primary measures being used to prevent rejection of the transplanted organ and to help human recipients avoid certain diseases which pigs carry. Developments occurring now are taking these gene-editing processes much further. Key among these is the production of chimeras. A chimera is an animal carrying cells from two different species. In the context of transplantation, a chimera is an animal, such as a pig, which can be used to grow human organs.
https://www.statnews.com/2017/10/20/human-pig-chimera/

Scientists are now working on a technique that would allow human organs to be grown inside pigs. For example, the DNA within a pig embryo that enables it to grow a pancreas is deleted, and human stem cells are injected into the embryo. These stem cells can develop into any type of cell within the body, and previous experiments using rats and mice suggest that they will automatically fill the gap created by the missing pancreas genes and form a pancreas that consists of predominantly genetically human cells. https://theconversation.com/human-pig-chimeras-may-provide-vital-transplant-organs-but-they-raise-ethical-dilemmas-60648 It has been suggested that pigs could be used to grow many different types of transplant organ – kidneys, hearts, livers, and that these organs would have the particular advantage of being an

exact match for the recipient patient as they will have been grown from that patient's own genetic material.

However, despite the obvious potential of such developments to revolutionise transplantation and save human lives many practical and ethical concerns have been raised. Critics are anxious about research projects involving the implantation of human brain stem cells into other animals or aiming at the creation of human-animal admixed embryos. There are concerns that in producing these chimeras, researchers may create animals which have properties that make them 'part human'. Megan Munsie, Deputy Director - Centre for Stem Cell Systems and Head of Engagements, Ethics & Policy Program, Stem Cells Australia, at the University of Melbourne, has noted, 'Human-animal chimeras blur the line about what it means to be human, and this raises serious ethical questions about how we should use them.' https://theconversation.com/as-scientists-move-closer-to-making-part-human-part-animal-organisms-what-are-the-concerns-159049 Munsie goes on to suggest, 'Humans are widely (but not universally) thought to have a higher moral status than other animals. But human-animal chimeras blur this line. They are not fully human, nor fully non-human. So, the big question is whether (or under what conditions) we should be allowed to use them as a source of transplantable organs, in harmful research, or for other purposes we wouldn't use humans for.' https://theconversation.com/as-scientists-move-closer-to-making-part-human-part-animal-organisms-what-are-the-concerns-159049

Given the ethical dilemmas potentially raised by the creation of pig-human chimeras for organ transplantation, there are others who suggest that bioprinting may be a better source of transplantable organs which are compatible with the recipient and risk neither rejection nor infection. Bioprinting is an extension of traditional 3D printing. It can produce living tissue, bone, blood vessels and, potentially, whole organs for use in medical procedures, training, and testing. The cellular complexity of the living body has resulted in 3D bioprinting developing more slowly than mainstream 3D printing. However, bioprinting technology could provide the opportunity to generate patient-specific tissue for the development of accurate, targeted and completely personalised treatments. Despite its potential, there is still a long way to go before fully functioning and viable organs for human transplantation can be developed. https://www.science.org.au/curious/people-medicine/bioprinting

Both the breeding of chimera animals as organ sources and the creation of organs through bioprinting are extra-ordinarily expensive areas of research. If transplants of gene-edited organs, such as the heart recently received by David Bennett, prove to be successful, this area of research is likely to be preferenced over both chimeras and bioprinting as it is more developed and consequently less costly.