



According to multiple studies, one in three pregnancies results in miscarriage and one in 33 babies that are born will have a birth defect, due to the embryo forming incorrectly in the womb. Studying how the embryo develops can help us find ways to bring these numbers down. In 2022, we will see advances in this research thanks to stem-cell-based, embryo-like structures that can be grown in the lab.

Stem cells offer a powerful way to study the early development of the embryo. They can be grown in the lab in vast numbers and pushed towards making a huge assortment of cell types, including brain, blood, bone and muscle.

Recently, several researchers have found ways to join stem cells together into small 3D balls of cells, which

two and four weeks old. The International Society for Stem Cell Research, which represents researchers in this field, has called for a public dialogue about whether this limit should be changed. It is proposing that human embryo culture should be extended on a case-by-case basis. How regulatory bodies will respond to this remains to be seen.

In the meantime, stem-cell embryo-like models might mitigate some of the need to use “real” human embryos at all. They will allow researchers to perform precise studies of embryonic development, seeing how they react when a gene is mutated, for example, or when they are exposed to dangerous chemicals. Because they are made from stem cells, they could even be generated by taking blood or skin samples from patients with a birth defect themselves and winding back the clock to an embryo-like state. This could help us figure out how the defect occurred, and perhaps even take steps to reduce the incidence of such disorders in the future.

The development of embryo-like models will raise many new ethical questions. Other than a potential for moving down a slippery slope towards cloning, stem-cell-based embryo models begin to blur the line between what we regard as human or not. Is an early-stage human embryo, when it’s just a small group of 16 cells, more valuable if it comes from the union of sperm and egg? Or is it the same as if it is derived in the lab from stem cells? Should the moral status often applied to human embryos also apply to groups of cells, even in arrangements that might only vaguely mirror elements of actual embryo development?

As we push further towards models that could alleviate the devastating conditions faced at the very start of life, we will also find ourselves challenged as a society to ask big questions, including the fundamental issue of what it means to be human.

## LAB ETHICS

# STEM-CELL SCIENCE WILL RAISE QUESTIONS

Studying embryos will be more useful than ever, if we can resolve the moral conundrum

By Naomi Moris

facilitate the creation of tiny embryo-like structures. These are currently rudimentary – the structures can be variable, they are inefficient to create and are unable to develop much further. Next year, we are likely to see improvements, with more advanced embryo-like structures made from stem cells. And we are also likely to see scientists using these models to investigate specific problems, such as how the embryo implants into the uterus, how organs start to develop or how the embryo ensures that cells are in the right positions.

Such research has traditionally been difficult to perform with human embryos. Parents using IVF are able to donate their surplus embryos, but regulation (upheld internationally and enshrined in law in the UK) prevents researchers from culturing them beyond 14 days. This makes it impossible to study the progress of the human embryo directly as it changes from a cluster of cells to a structure with the organisation of a rudimentary body – when it is between



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# WE WILL GET AHEAD OF DISEASES

Data-driven predictive healthcare  
will become the standard in 2022

By J. Craig Venter

If the Covid-19 pandemic has taught us one thing, it is that it is far better to prevent a disease than try to treat it. In 2022, we will build on this insight to deal with other “pandemics” of disease – obesity, heart disease, cancer and dementia – which we can now address by investing in prevention through the intelligent use of science.

Wellness – feeling healthy with an apparent lack of symptoms of disease – is a self-determination made without true knowledge of the state of our bodies. For most of human history, that was all we had to go on. We only went to the doctor when we seemed unwell. Now, health professionals can tell us if we are disease-free or not, when we cannot do so for ourselves. Research we have done over several years at Human Longevity and at the Venter Institute has shown through MRI scans that three per cent of individuals over 50 have a significant tumour of which they were unaware. The majority of those, including myself, are now cancer free, more than five years after diagnosis and treatment. This is the likely maximum lifespan I would



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have had, had my cancer not been detected when it was.

Next year, MRI scans will become even more powerful when combined with new computer algorithms that post-process the raw MRI data. This will allow us to detect even smaller tumours, particularly when coupled with new lab tests that can recognise tumour DNA in someone’s blood before they become visible. In 2022, these new tests will even indicate from which organ the DNA came. The combination of MRI with circulating tumour DNA tests will begin to replace mammograms for breast cancer – removing exposure to dangerous radiation, improving both safety and breast-cancer diagnosis.

We will also be able to detect cases of Alzheimer’s disease a lot earlier. Increased risk of developing Alzheimer’s can be, in part, predicted from the genetic code but, without other information, those predictions are not diagnostic. In 2022, genome tests will be combined with MRI brain scans, which can reveal early brain deterioration, and PET scans, which can detect the amount of amyloid in the brain. Human Longevity has been able to detect early Alzheimer’s disease prior to the onset of symptoms. Numerous studies have shown that changes in brain activity, diet and preventive pharmaceuticals enable the slowing of disease progression. MRI brain scans have also proved to have an unexpected benefit. One per cent of all “healthy” tested individuals had a brain aneurysm, something usually only discovered when someone has a massive brain bleed.

In 2022, we will combine human genomics with extensive phenotype data – such as whole-body MRI scans, metabolomics, microbiome data, blood DNA cancer tests and data from wearable diagnostic devices – to make the practice of medicine much more predictable, thereby preventing disease. It will be up to us humans to acknowledge that we don’t always know when we are unwell and to make use of the continuous improvements in diagnostic tools that the world now offers us.



## Pre-pandemic plans

In 2022, Dr. Anthony Fauci will initiate a “prototype” vaccine programme in anticipation of the next pandemic – an idea originally pitched by Dr. Barney Graham in 2017. Using methodologies and research capabilities similar to those that produced the Covid-19 vaccines, it would draw on existing research to create protection against viruses from 20 virus families. By 2027, Dr. Fauci aims to have prototype vaccines for ten of the 20 virus families targeted. **SV**

**More than 300 million people worldwide** suffer from some form of infertility. Many are opting for parenthood at a later stage in life – in their thirties and forties – when the quality of their gametes (the egg and sperm) is no longer at their biological prime. Recent studies also show that we are simply not as fertile as our grandparents. According to Shanna Shaw, an environmental and reproductive epidemiologist at the Icahn School of Medicine, and author of the book *Count Down*, the average men's sperm concentration – that is, the number of sperm per millilitre of semen – has decreased by more than 50 per cent in the past four decades, with the blame placed on factors such as environmental pollution and unhealthy lifestyles.

Increasingly, couples have been forced to resort to assisted reproductive

techniques such as in vitro fertilisation, commonly known as IVF. According to the US Centers for Disease Control and Prevention, about nine million babies have been born using IVF since the first such case in 1978. It estimates that number will reach 200 million in 2100. In 2022, we will see the increased use of robotics and automation to meet that demand, while also improving the effectiveness of IVF for couples who are struggling to conceive.

Many of the protocols involved in an IVF procedure, from sperm analysis to embryo selection, are still conducted manually and without any regulatory oversight. IVF remains not only expensive (a full treatment typically costs up to £50,000) but also dismally ineffective, with a success rate of merely 25 per cent.

We are now seeing a new generation of startups dedicated to changing this with robotics and machine learning. San Francisco-based Alife Health, for instance, is using AI to study massive sets of historical data and eventually learn to identify the most viable treatment for couples undergoing IVF, improving chances of a successful pregnancy.

New York-based TMRW is automating IVF storage. It has built a robotic platform that automatically tags the vials used to store eggs and embryos with radio-frequency identification (RFID) chips. They are then stored in liquid nitrogen tanks with sensors that constantly monitor variations of temperature and nitrogen.

Mojo, the startup I co-founded in 2017, has developed a smart micro-

scope that uses AI to scan sperm samples and automatically count the number of sperm cells, and analyse their motility, morphology and DNA integrity. Independent clinical trials have shown that our technology has a 97 per cent agreement with the gold-standard analysis performed according to the WHO guidelines. The only difference is that our small robot can do in four minutes what it takes a skilled lab technician 30 minutes to do.

Ultimately, for many of these startups, including Mojo, the goal is to remove the human factor entirely, and replace IVF fertility clinics with an integrated lab of intelligent embryologist robots. In 2022, we will see the first-ever successful IVF procedure – from the gamete selection to egg fertilisation – carried out without human intervention. The hope is that this AI embryologist will not only increase the probability of IVF success to about 75 per cent, it will also make the process faster, cheaper, safer and more accessible. With no humans involved, artificial fertility will no longer be a painful, heartbreaking and often financially costly experience, but instead a hopeful and humane one.

#### SMARTER FERTILITY

## EMBRYOLOGIST ROBOTS WILL TRANSFORM IVF

The odds of conception will be boosted for many couples, as artificial intelligence, data and automation give nature a helping hand

By Mohamed Taha



**Mohamed Taha**

is co-founder and chief executive officer of fertility startup, Mojo