Humans could recolonize Earth after mass extinctions with ectogenesis

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Ectogenesis scheme for long-term human survival. Credit: Matthew Edwards

Lately it seems that every movie, book and video game we see is about future apocalypses. Science articles are also painting a grim future for Earth and its inhabitants. If it's not global warming that will get us, it will be nuclear weapons, pandemics or AI gone rogue. Even if we could overcome such threats, we must still contend with the many natural forces that have caused mass extinctions in the past. Could we actually divert the asteroids, squelch volcanic upheavals and find oases of food and warmth deep enough to survive severe ice ages? Despite the heroics that we see in disaster movies, the answers to these questions are more likely to be no, no and no.

But wait. Maybe you also saw movies about humans trying to muddle through extinction events in underground bunkers or in space colonies, maybe on Mars or the moon. Yes, these might serve as refuges for a decade or so, but against longer lasting extinction events they would be useless. Space colonies would protect their inhabitants only for so long as Earth continued to provide them with food, supplies and spare parts. It is precisely during a major extinction event that those shipments would come screeching to a halt. The physical conditions of space colonies are so daunting—freezing temperatures, severe space radiation and lack of water and oxygen—that refuges built on Mt. Everest or the ocean floor would be Edens in comparison.

What good would bunkers or space colonies be for extinction events lasting a million years? And what could be done to save Earth life a billion or so years from now, when the Earth itself is totally incinerated in the final solar expansion?

The lifeboats of ectogenesis

I suggest there is a way to save humanity and Earth life, not only from our present follies but from most or all of the natural disasters too—even ones in the far future. You might imagine this to be even more unlikely than the absurd rescue missions in apocalypse movies. Yet the critical first steps toward a successful long-term survival plan may already have been taken.

The core idea is this. While humans, animals and plants would perish in a sufficiently powerful mass extinction event, their cryopreserved embryos and plant seeds might survive. These could be stored in deep underground bunkers for short-duration events and in fully automated, orbiting spacecraft for long-duration and far future events. After favorable surface conditions had returned to Earth after an apocalypse event, the embryos would be thawed out and raised using the emerging assisted reproduction techniques of ectogenesis: development of embryos to neonates outside the natural womb. The newborn humans and animals would then be raised by android guardians and farmers.

We already know that human babies can be born from embryos that had been cryopreserved after in vitro fertilization for twenty years, but in theory, this period could be thousands or even millions of years. Arctic rotifers—microscopic, multicellular animals—have recently been revived after being in a frozen state for 24,000 years. Even more amazingly, unfrozen bacterial species recovered from anoxic, deep sea deposits were revived after existing in a suspended state for over 100 million years.

The key requirement for these embryo survival missions is an artificial uterus system capable of supporting complete ectogenesis. Remarkably, the operational cores of such systems have already been developed for animals and soon will be available for human babies. These systems conduct what is called partial ectogenesis. Their purpose is to support extremely premature infants who cannot reach full development in their mother's uterus. Systems such as Biobag and EVE operate by supplying all the substances to the fetus ordinarily supplied by the maternal placenta, such as oxygen, nutrients and electrolytes, and removing waste products from the fetus.

In human survival missions the cryopreserved embryos would be early-stage embryos—much too small to be surgically attached to one of these systems. The embryos must instead be able to implant directly in cryopreserved tissues mimicking the natural uterus, which in turn would be connected to one of these core systems. Though limited at present by bioethical issues, real progress has been made towards complete ectogenesis also. Here, the goals are to afford clinical assistance to infertile women and to prospective parents who would otherwise be incapable of natural reproduction. Uterine analogs made of sections of a natural uterus or sculpted endometrial cells have been used to grow mouse embryos for many days in a healthy state. While unforeseen obstacles could yet frustrate these efforts, it appears more likely that complete ectogenesis will be available in the near future.

A realistic survival plan should be comprehensive in scope

Once a suitable artificial uterus system is in place, I argue that the key to effective mission design is to plan for all possible future extinction events comprehensively in a single, unified scheme. In this way, maximal efficiency can be attained, as the same ground infrastructure can be used over and over again in follow-up missions.

A scheme of this type is shown in the figure above. It employs two familiar elements already discussed: conventional subterranean refuges and manned orbiting spacecraft (1 and 2). These would be used only for short-duration events lasting just a decade or so. For longer events, some adult crew members in the orbiters and bunkers would be replaced by cryopreserved embryos (3 and 4). The embryos permit longer missions, since their food, energy and maintenance costs would be drastically reduced compared to adult crew. With enough artificial uterus systems, the number of colonists could be expanded quickly once suitable surface conditions returned.

Where ectogenesis really shines, however, is for major or far-future mass extinctions. For those events, adult crews would be entirely replaced by embryos and androids. Embryos could be stored in very deep bunkers for as long as refrigeration equipment and energy supplies last, possibly up to a century (5). For still longer periods, spacecraft carrying frozen embryos and plant seeds would have to be kept in orbit, possibly around Mars, where they could use the natural refrigeration of space. Many spacecraft would be stationed there, each targeting specific periods of the far future Earth. At suitable times, species-specific modular craft would descend to Earth and start introducing plants and animals (6). Hundreds or perhaps thousands of years might be allowed to pass before the next species modules descended to the surface. Various plant and small animal modules would be followed some time later by more sophisticated ones for mammals. Modules holding human embryos would likely land last, after a stable, operating farm operation had already been set up by androids.

The challenges in developing AI to orchestrate all this would of course be immense. But if the last few decades have taught us anything, it's that the pace of AI's future development will be sharply exponential. If iPhones and DeepMind could appear during this short period, could the AI for raising infants from the embryo stage and running computerized farms be far off?

To preserve their functionality over thousands or millions of years, the orbiting spacecraft would need to be 'sleeping' most of the time. They would be like seeds themselves. Even their AI systems would be turned off completely, only powering up intermittently to make decisions and course corrections.

You might suppose that raising children in this manner—without parents or a supporting "village"— would be unfair to them. But here again, we must factor in the rapid pace of AI. We can't expect android parents to really be the same as Mom and Dad, but they might get pretty darn close to an "Aunt Lucy' or an "Uncle John." The children would also have siblings of a sort: the children born in their cohort. Together with farm animals and libraries—both physical and digital—the lives of these children could be rich, indeed.

I mentioned that the Earth will become totally uninhabitable one day due to the final solar expansion. To counter this threat—as well as any other utterly cataclysmic events—requires that human and animal embryos ultimately be sent to exoplanets and raised there by ectogenesis. You might be familiar with this aspect, as it has recently featured in some popular productions, such as "Interstellar" and "Raised by Wolves." These shows, however, did not do proper justice to the embryo approach. Embryo space colonization largely avoids the technical hurdles of manned space travel. For cryopreserved embryos, it makes no difference if spacecraft take thousands of years to reach their exoplanet destinations. They would once again be running 'dormant' most of the time. The fast spaceships of science fiction are but techie fantasies—nowhere on the drawing board and never likely to be.

Should humans be included?

In addition to the obvious bioethical questions concerning ectogenesis and android parents, you might be wondering if humans really have the moral license to be sending human embryos to colonize future Earths or exoplanets at all. Have we not inflicted enough damage on other species in our own time? Maybe we should just let evolution on Earth take its course and allow other intelligent species to have a go at it. And maybe we should just leave exoplanets alone—to evolve life or not, as they will.

In this regard, one nice feature of embryo arks compared to manned missions is that they can react with sensitivity and flexibility in situations where other lifeforms are detected. They could choose simply not to deploy at those times. They could just wait patiently in orbit until such a time as no one's rights were being infringed upon.

Then again, maybe you would feel comfortable sending species to future Earths and exoplanets so long as humans themselves were left out. Given our appalling ecological record, a case could certainly be made for banning humans from the future outright. While 'human-free' projects have been suggested in the past, I argue that it would be a mistake to leave us out. Humans alone have the unique capacity to serve as catalysts for Earth life. By including humans on board, we set up the possibility that a new civilization could arise on a future Earth or an exoplanet, which could then send out embryo missions of its own: to send Earth life to still later future Earths and still other exoplanets. The progress of life through the galaxy could then be exponential. Without humans, each successful seeding project would start and end there.

The take home message

Using the integrated, embryonic approach combining Earth-based and exoplanet-based missions that I have described, humans could eventually colonize distant parts of our galaxy and potentially the wider universe beyond. At the moment, cosmologists agree that the universe will end, but can't agree if it will be in a "Big Rip," a 'heat death' or yet something else. If no clear future 'killer' of the universe can be identified, a prudent detective might hold open the possibility that there is no killer—and that our universe could go on indefinitely. My own work in gravity and cosmology research suggests that this might well be so. In that case, there would be no theoretical limit as to how far humans and Earth life could actually go.

Time is of the essence in implementing the above approach. Our technical civilization is clearly fragile and could soon fail. If no missions have been sent prior to that time, we will very likely go extinct in a future extinction event.

Even after launching such missions, however, our work would not be done. The key to long-term survival is to keep on launching embryo missions—to always stay ahead of mass extinctions and planetary deaths. To paraphrase Darwin, long-term survival is a numbers game. If our civilization truly wants to secure its long-term survival we can never stop rolling the dice—by sending embryo arks to future Earths and other worlds.

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Bio: Matthew Edwards has worked for many years at the University of Toronto Library. He researches diverse theoretical topics, including the origin of life, gravitation physics, geophysics and cosmology. In 2002 he edited the book Pushing Gravity: New Perspectives on Le Sage's Theory of Gravitation.

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