

Mirror life: risks and implications for planetary protection

April 3, 2025

Summary

- Mirror bacteria could plausibly be created by scientists in 10-30 years
- Mirror bacteria would have limited practical benefit, but could plausibly pose **unprecedented risk** to humans, animals, plants, and ecosystems
- Global discussion and governance are needed now
- Mirror life should not be created

Confronting risks of mirror life

Broad discussion is needed to chart a path forward

KATARZYNA P. ADAMALA, DEEPA AGASHE, YASMINE BELKAID, DANIELA MATIAS DE C. BITTENCOURT, YIZHI CAI, MATTHEW W. CHANG, IRENE A. CHEN, GEORGE M. CHURCH,

VAUGHN S. COOPER, MARK M. DAVIS, NEAL K. DEVARAJ, DREW ENDY, KEVIN M. EVELT, JOHN I. GLASS, TIMOTHY W. HAND, THOMAS V. INGLESBY, FARREN J. ISAACS,

WILMOT G. JAMES, JONATHAN D. G. JONES, MICHAEL S. KAY, RICHARD E. LENSKI, CHENLI LIU, RUSLAN MEDZHITOV, MATTHEW L. NICOTRA, SEBASTIAN B. OEHM,

JASPREET PANNU, DAVID A. RELMAN, PETRA SCHWILLE, JAMES A. SMITH, HIROAKI SUGA, JACK W. SZOSTAK, NICHOLAS J. TALBOT, JAMES M. TIEDJE, J. CRAIG VENTER,

GREGORY WINTER, WEIWEI ZHANG, XINGUANG ZHU, AND MARIA T. ZUBER

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[Authors Info & Affiliations](#)

Technical Report on Mirror Bacteria: Feasibility and Risks

December, 2024

A 'Second Tree of Life' Could Wreak Havoc, Scientists Warn

Research on so-called mirror cells, which defy fundamental properties of living organisms, should be prohibited as too dangerous, biologists said.

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'Unprecedented risk' to life on Earth: Scientists call for halt on 'mirror life' microbe research

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Scientists warn of mirror bacteria risks

Broad discussion essential to put guardrails in place before organisms developed further

By Sabana Ghosh

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Tackling antimicrobial resistance and the looming threat of mirror life require global action

Microbacteria in a laboratory (Photo: iStock)

By Wilmot G James and Vaughn S Cooper

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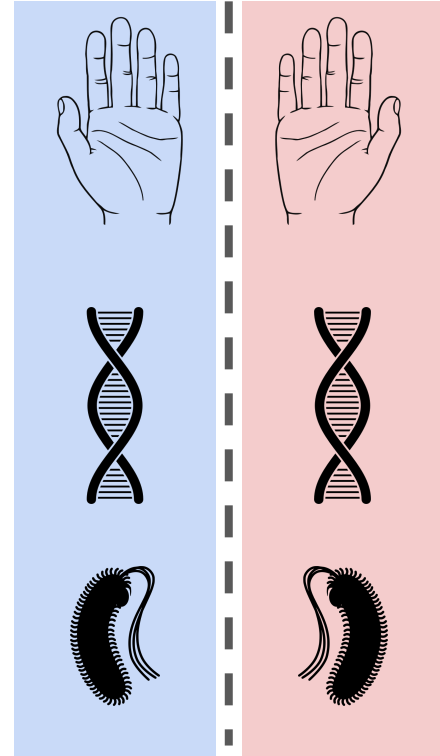
Our coauthors

Kate Adamala, University of Minnesota
Deepa Agashe, Bangalore Nat. Centre for Biological Sciences
Yasmine Belkaid, Institut Pasteur *
Daniela Bittencourt, EMBRAPA Brazil
Patrick Cai, University of Manchester
Matthew Chang, National University of Singapore
Irene Chen, University of California Los Angeles
George Church, Harvard University *
Vaughn Cooper, University of Pittsburgh
Mark Davis, Stanford University *
Neal Devaraj, University of California San Diego
Drew Endy, Stanford University
Kevin Esvelt, Massachusetts Institute of Technology
John Glass, J. Craig Venter Institute
Timothy Hand, University of Pittsburgh
Tom Inglesby, Johns Hopkins University *
Farren Isaacs, Yale University
Wilmot James, Brown University
Jonathan Jones, Sainsbury Laboratory *

Michael Kay, University of Utah
Richard Lenski, Michigan State University *
Chenli Liu, Shenzhen Institute
Ruslan Medzhitov, Yale University *
Matthew Nicotra, Johns Hopkins University
Sebastian Oehm, J. Craig Venter Institute
Jassi Pannu, Stanford University
David Relman, Stanford University *
Petra Schwille, Max Planck Institute *
James Smith, J. Craig Venter Institute
Hiroaki Suga, University of Tokyo *
Jack Szostak, University of Chicago *
Nicholas Talbot, Sainsbury Laboratory *
James Tiedje, Michigan State University *
Craig Venter, J. Craig Venter Institute *
Gregory Winter, Cambridge University *
Weiwen Zhang, Tianjin University
Xinguang Zhu, CAS-MPG Partner Institute
Maria Zuber, Massachusetts Institute of Technology *

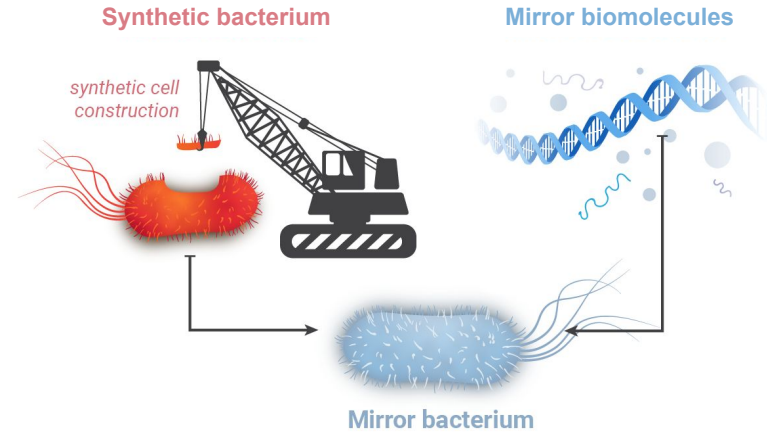
Introduction to mirror bacteria

- All life relies on molecules with **chirality** (“handedness”)
- Living organisms use only one of the two possible configurations, but “mirror life” using the opposite chirality could be constructed in the lab
- One of the simplest viable mirror lifeforms would be mirror bacteria
- Our work considers synthetic mirror life created here on Earth—not extraterrestrial mirror organisms



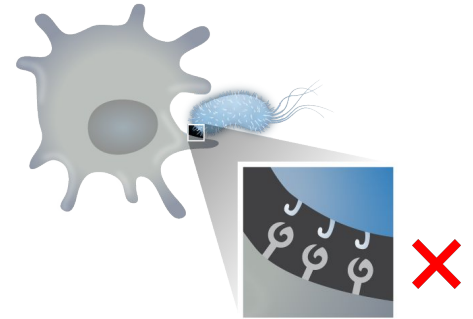
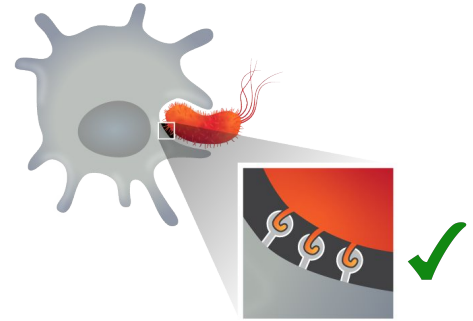
The creation of mirror bacteria is increasingly feasible

- Most likely pathway would combine work on synthetic cells and mirror biomolecules
- Primarily motivated by technical challenge and curiosity with few concrete benefits
- Few researchers are actively working toward mirror bacteria
- Timelines are highly uncertain:
 - 15-30 years away by default
 - >10 years with \$500m–\$1b effort (c.f. Human Genome Project)



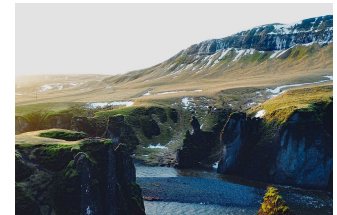
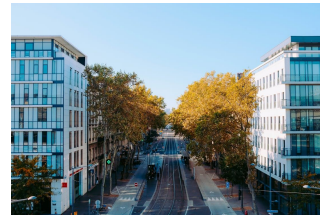
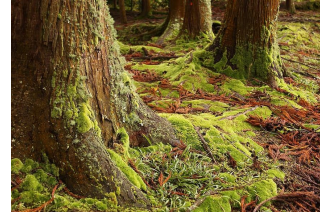
Mirror bacteria could evade most immune responses

- Across multicellular life, immunity depends on **chiral molecular interactions** that would likely be evaded by mirror bacteria
- In humans and other vertebrates, mirror bacteria could plausibly be lethal
- Many invertebrates and possibly plants would also likely be vulnerable



Mirror bacteria could disrupt global ecosystems

- Mirror bacteria would likely have:
 - **A somewhat lower reproduction rate** because of fewer food sources
 - **A *substantially* lower death rate** because of inherent resistance to predators
- Without ecological controls, mirror bacteria populations could expand and invade diverse environments
- The potential result: massive ecological harms through extinctions, degradation of habitats, and effects on nutrient cycling



Containment that is robust to misuse is not feasible

- Biocontainment is plausible but could be deliberately undone
- Physical containment often fails due to human error and can be deliberately evaded
- Malicious or ill-informed actors could replicate methods to construct mirror bacteria and likely make them more robust

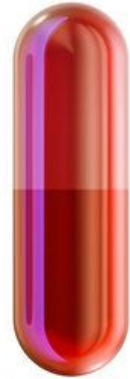


Medical countermeasures (MCMs) may be possible but will be insufficient

Some antibiotics may be effective against mirror bacteria and further MCMs could plausibly be developed

However:

- Distributing (novel) MCMs globally and equitably during a pandemic would be extremely difficult
- Medical countermeasures cannot plausibly prevent harms to plants, animals, and ecosystems



Our conclusions and initial recommendations

1) Mirror bacteria should not be created

- Our view is that research whose goal is the creation of mirror life or the establishment of key enabling technologies **should not** be funded or conducted
- Broad agreement at a recent conference: “no one argued that the potential benefits of creating mirror life [...] outweigh the risks”¹

2) Additional scrutiny and discussion is needed

- Participation will be needed from a variety of stakeholders

(1) Cohen, 2025. “Fifty years after ‘Asilomar,’ scientists meet again to debate biotech’s modern-day threats.” *Science*. doi: 10.1126/science.zw9idfw

Mirror life and planetary protection

- We consider synthetic mirror life—not naturally occurring extraterrestrial mirror life
- Planetary protection frameworks (e.g., COSPAR) offer a foundation for considering biological risks on a global level and how to manage them
- Current governance is not equipped to prevent, detect, or respond to synthetic mirror life



Further considerations for governance

- Consider governance of enabling technologies
 - Roadmapping of enabling technologies
 - Preventing mirror genomes
- Consider systems for monitoring purchase of mirror oligonucleotides
- Additional research on risk, including:
 - Immune system effects
 - Detection and biosurveillance



Recent and future events

The recent **Spirit of Asilomar** conference hosted a productive discussion on mirror life (February 2025)

There will be various workshops and conference side-events throughout 2025 to further the conversation on mirror biology:

- NASEM workshop on mirror biology (2025)
- Institut Pasteur (June 2025)
- University of Manchester (Fall 2025)
- National University of Singapore (Early 2026)



Q&A / discussion

Mirror bacteria could pose a risk to a substantial fraction of multicellular life.

The **reversed chirality** of mirror bacteria could allow for:

- 1) Evasion of many immune mechanisms, in humans, other animals, and plants
- 2) Evasion of ecological control mechanisms

They could plausibly be created in the next 10-30 years

Our view: mirror bacteria should not be created and key enabling work should not be funded

A broad discussion about this risk needs to be initiated

Q&A + Discussion