

# Science AMA Series: We authored a recent report on future products of biotechnology for the National Academies of Sciences, Engineering, and Medicine, Ask Us Anything!

NAS-AMA <sup>1</sup> and r/Science AMAs<sup>1</sup>

<sup>1</sup>Affiliation not available

April 17, 2023

## Abstract

Hi reddit, I'm Steve Bradbury, a professor of environmental toxicology at Iowa State University. My research spans pesticide resistance management, pollination services and monarch butterfly conservation, and sustainable agriculture. I also had a long career at the Environmental Protection Agency. I served on the National Academies committee that wrote the report on future biotechnology products. I'm Farren Isaacs, assistant professor of molecular, cellular, and developmental biology at Yale University. My research focuses on using foundational genomic and biomolecular engineering technologies to develop new genetic codes. I served on the National Academies committee. We're talking about the landscape of future biotechnology products and the capacity, expertise, and tools of the U.S. regulatory system that oversees those products. We will be back at 1 pm ET to answer your questions, Ask us anything! You can read about more about our committee's work and download our report here.

[REDDIT](#)

# Science AMA Series: We authored a recent report on future products of biotechnology for the National Academies of Sciences, Engineering, and Medicine, Ask Us Anything!

NAS-AMA [R/SCIENCE](#)

Hi reddit,

I'm Steve Bradbury, a professor of environmental toxicology at Iowa State University. My research spans pesticide resistance management, pollination services and monarch butterfly conservation, and sustainable agriculture. I also had a long career at the Environmental Protection Agency. I served on the National Academies committee that wrote the report on future biotechnology products.

I'm Farren Isaacs, assistant professor of molecular, cellular, and developmental biology at Yale University. My research focuses on using foundational genomic and biomolecular engineering technologies to develop new genetic codes. I served on the National Academies committee.

We're talking about the landscape of future biotechnology products and the capacity, expertise, and tools of the U.S. regulatory system that oversees those products. We will be back at 1 pm ET to answer your questions, Ask us anything!

You can read about more about our committee's work and download our report [here](#).

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Do you feel that CRISPR/Cas9 is a landmark discovery for biotechnology that will remain in use, or will the excitement over it soon fade out like other past technologies?

[moonlightstreetlamp](#)

From Farren: Great question! I think CRISPR certainly is a landmark discovery for biotechnology and expect its use and impact to grow over the coming years. Like past technologies, I also think that other genome engineering technologies -- genome synthesis, Zinc Fingers, TALENs, MAGE -- have and will be used alongside CRISPR to enable targeted modification of genomes across diverse species, ranging from bacteria to archae to multi-cellular eukaryotes, including plants and animals.

Professor Bradbury, what have your interactions been like with members of the pesticide community / over the years and do you see them starting to change their perspectives on how they are negatively impacting the environment?

Also, are you still in touch with any colleagues from the EPA and can you share what any of them are saying about the recent changes there since the election?

Lastly, do you see a bright future with wide ranging buy-in for sustainable agriculture?

Assistant Professor Isaacs, what is your take on the future of genetic engineering in humans? There is

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a lot of fear out there of the kind of thing you are working on. Are you fine with the old answer of "any technology can be good or bad based on how you use it"? Or do you spend a lot of time conflicted in your thoughts of the implications of it?

And for the both of you, in an age where regulation is seen as government excess and a problem by a large portion of the public and politicians, do you feel regulatory agencies are adequately equipped to deal with the pace of the science of biotechnology and how it applies to many industries? Is it possible for them to prepare for the pace of change or will they hold progress back by being unable to keep up?

Thanks to both of you for dedicating your lives to worthy work and moving us forward toward a better future.

[biotechknowledgey](#)

I'll start with the last questions first. Our report concluded that with number of novel products under development and the expanding diversity of groups developing new products the regulatory agencies could be challenged to keep up. We recommended that the agencies could use horizon scanning and pilot new approaches for risk analysis and public participation to be prepared. We also suggested that could pilot approaches to optimize use of resources on unfamiliar products and complex risk analyses vs. products that are similar to previously evaluated products.

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[biotechknowledgey](#)

From Farren: Although your question on genetic engineering in humans was explicitly not part of the scope of our NASEM study, given the number of human diseases that can be reversed through targeted genetic engineering, I think many believe that we have an obligation to pursue these strategies to enhance quality of life of people who are suffering. Clearly such work has not and will not be pursued without close guidance and integration of ethical, legal and societal implications (ELSI), and this is something that myself and many, many scientists proactively pursue in the broad context of any research that involves genetic modifications. In this spirit, I enjoy interacting with diverse audiences to hear people's thoughts and discuss the virtues and concerns of such work. I believe this is part of a continuing conversation that will be enhanced by engagement from diverse stakeholders. Regarding your questions on regulation, we do provide a number of recommendations to enhance the existing

regulatory infrastructure in anticipation of the profusion of new and diverse biotechnology products that are emerging and will continue to emerge over the coming decade.

Given our existing ability to edit the genome as well as future potential, what sorts of regulations are in place or could be imposed on the research process and perhaps clinical usage of these technologies?

[RhyDonCorleone](#)

From Farren: As I mentioned above, use of these technologies in the clinic was beyond the scope of our study and I recommend reading another recent NASEM report on genome editing and the following commentary in Science on this topic: <http://science.sciencemag.org/content/348/6230/36.long>

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[RhyDonCorleone](#)

Our report (Chapter 3) notes that NIH guidelines are in place for oversight of basic and clinical research involving recombinant or synthetic nucleic acid molecules - and even though these guidelines don't govern all public and private funded research they are a tool the entire research community can employ

What biotechnology products are the most likely to be well-funded in the future and why? Which products are more likely to be held back by either regulation or lack of funds?

[puffleninja](#)

Chapter 2 of our report summarizes the technological, economic and societal drivers for a diverse universe of potential future biotech products. Developers range from large companies to small start-ups, to the do-it-yourself community. The resource base includes crowdfunding. Future products being designed for open release in the environment will, in general, likely require greater investments for development and more complicated risk-benefit analyses than those products manufactured/used in confined/indoor facilities

Hello I am a recent high school grad and I am attending college with the hopes of earning a Biotechnology degree. My question is: Is the field of biotechnology growing in terms of jobs?. Thanks.

[NorthernYankee](#)

From Farren: I hope you are excited to begin college and to earn a degree in biotechnology. It is wonderful to hear about young people excited to pursue a career in STEM, particularly because we need a growing workforce that is educated in these disciplines to tackle the defining challenges of today and tomorrow. In this regard, I strongly believe that the number of biotechnology jobs will explode in the future. Enjoy, persevere and participate in the biotechnology revolution of the 21st century!

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[NorthernYankee](#)

While I can't speak directly to the future job market, our report certainly indicates significant public and private investments in the area and a diversity of future products are under development. One of our recommendations going forward was to include courses and educational materials on regulatory science and systems in biotech programs/majors

Can you comment on whether or not there is enough scrutiny, in your opinions, on the environmental impact of nanoparticles and other nano-sized technologies? Right now a huge, hidden problem are the amounts of pharmaceuticals that end up in our waterways due to either people flushing their old medicines down the toilets or sinks, waste runoff or disposal, and simply from the billions of people on this planet taking medications and excreting them out.

So what happens in the future when billions of people will be taking nanoparticle packed drugs? I realize a lot of nps are designed to degrade, but what about other things that will be used, such as quantum dot technologies that will be used for medical imaging that also might not degrade so easily-- people will excrete them out after they are done at the hospital. What'll happen to the environment when we start finding NPs and other nano sized technologies persistently in our waterways, food, and possibly in the air we breathe?

[xSialicAcidx](#)

From steve: Although our report didn't address NP we did think about the possibility that some biotech products in the future could be created and used in people's homes - and how this could create challenges assessing risks due to releases in waterways, for example. Stewardship of the products and their development will be everyone's responsibility

Have you commented on the new regulations that are due June 19, and can you link to a couple of good sample comments like yours or some other colleagues?

[mem\\_somerville](#)

From steve: Our report didn't comment on the specific proposals the agencies were putting out for comment while we were writing - although we acknowledged they were working! mem\_sommerville points out that we can all go the public dockets (regs.gov) and see what folks are suggesting to the agencies.

Hi Drs. Bradbury and Isaacs!

My name is Marie Gibbons and I'm a Physiology graduate student at NCSU, [New Harvest Research Fellow](#), and cultured meat scientist! I am currently working on [large-scale production of chicken and turkey meat without animals](#), and was very excited to find that the Future of Biotechnology report saw cellular agriculture (animal products w/o animals) as something with high growth potential.

As one of many interests students and researchers working in the field, I was hoping to learn more about what you thought of cellular agriculture, and how we might find support through the NSA.

Given the tremendous benefits cellular agriculture can have on our population, the environment, public and individual health, and animal welfare, I am hopeful that the NSA will be open to getting involved, and would love to hear what you think :)

Thank you!

[hugthegiraffe](#)

from steve: all the best with your research. I hadn't fully appreciated the efforts in this area until learning more while on the committee. schrodingersCat24 had a question on risk and consumer preferences that's probably relevant to your area of interest too. In addition to developing the 'know-how' to create these products thinking about consumer values and trying to analyze the costs-and benefits of different meat production systems may be useful.

The report seems to do a fantastic job of highlighting the position of various products in their path to reaching the market, as well as their potential risks. With so many products covered, from organisms entirely created via synthetic DNA to fragrant moss and do-it-yourself glowing plants, which anticipated products in particular are you excited to see come into the public eye in the future?

Thank you again for doing this.

[Captain\\_Starshield](#)

From Farren: "Captain\_Starshield" -- love the name, but please do explain its meaning...To your question -- there are so many exciting and innovative biotech products emerging that its hard to pick one. We are already reaping the benefits of biotech products (antibiotics, drugs, biofuels, biochemicals, etc) and will continue in the future where they will be pervasive in our every day lives. A few that particularly excite me: engineered photosynthetic organisms (using sun light as the sole energy source) to sequester the accumulation of toxic compounds (eg, elevated Carbon dioxide in the environment) that can also cleanly produce biofuels, new drugs and completely novel bioproducts that cannot be made through conventional petroleum-based processes or natural biological systems. In brief, imagine a world where biotech products solve multiple defining global challenges -- climate change, new medicines, energy -- using free sunlight in one shot. This exciting, transformative and emerging!

I recently read an article about a fungus that had been weaponized to kill mosquitoes with toxins from spider and scorpion venom. What safeguards exist to prevent or limit the weaponization of biotech? Is it even possible to prevent the biosphere from turning into an environment similar to cyberspace where there is an escalating conflict between black hat and white hat operators and no one is really "safe"?

[canvascanyons](#)

From Farren: You raise an interesting question on safeguarding biology and one that myself and many people - scientists and non-scientists - take seriously and are proactively addressing. Thankfully, a number of government funding agencies, e.g., NIH, DOE, DOD, have established programs to develop research, both scientific and ethical, legal, societal, have established opportunities for diverse stakeholders in biotechnology to address. Simply put, there are a number of important safeguards that have been developed -- e.g., engineering GMOs that are genetically isolated and resistant to viruses and biocontained such that their growth is limited to defined synthetic environments. Developing such safeguards at this stage of biotechnology development will enable broader use, acceptance and adoption in broader society and will result in improved quality of life. Much like seat belts - a common safeguard we take for granted in planes, trains and automobiles - secured the transportation industry, so too, will biological safeguards transform the emerging biotech revolution!

Professors - How can the public be better educated on the benefits of biotechnology products, particularly to address fears and concerns. The science is available but for those who are still skeptics, what can be done?

Second question if time, what role should Office of Science and Technology Policy, in the Executive Office of the President, play in preparing a strategic-level national biotech policy? Do you see the need for a update to the Bioeconomy Blueprint?

[Jenza2](#)

From Farren: Great question! The public can start by reading our NASEM report here: <https://www.nap.edu/catalog/24605/preparing-for-future-products-of-biotechnology> ...and then reading a lot of great documents written by diverse experts from a number of different sources. A few good examples: 1. Reviews in the scientific journals (Nature, Science, Nature Biotechnology) on many aspects (science and non-science) of the biotech field 2. Reports from government agencies on biotechnology related topics, e.g., DOE, DOD, NIH 3. The Science section of the NY Times and lots of other news outlets have great articles and commentaries by astute and insightful science writers 4. Lastly, many of us participate in outreach programs to discuss and engage the public about the excitement of scientific concepts and how these discoveries can transform our lives and the environment.

The Bioeconomy blueprint was recently updated last year -- take a look!

Regarding your question on the role of OSTP in the White house on national biotech policy. This is quite simple: First, I implore President Trump to fill positions in OSTP as a priority of national strategic, economic and security interest. Prioritizing science, technology and innovation, in large part, enabled the US to thrive during the cold war and made her great. Let's keep those values in place and enable our generation to truly be the greatest generation!

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[Jenza2](#)

from steve: Well I think we can all become better educated on the diversity of viewpoints and perspectives on biotech. While I think there will always be a diversity of perspectives, our report felt it was really important for the regulatory agencies to include public participation and input in formulating and working through their risk-benefit analyses. The agencies have to make decisions (and making no decision is a decision) and not everyone will agree with all the decisions - but it's important over the long haul to have these discussions.

Our report didn't specify how the government could address our recommendations - there are usually a variety of approaches that can reach the same goal

What is the most futuristic biotechnology you've seen that is just around the corner from becoming part of everyday life?

[RagingSmurfon](#)

From Farren: Biotechnology is already a part of our every day lives, but so often we're unaware -- its used to enhance lots of diverse products that go far beyond drugs -- commodity chemicals, fuels, detergents, novel materials, ... around the corner are biosensing plants, pets, bio-based water and

toxic purification systems, photosynthetic biofactories...we are only at the beginning of the biotech revolution!

I am currently doing a Biomedical Science/Engineering degree in Australia and this field is definitely something I have great interest in. Despite this 'profession' being quite new, what advice would you give an undergraduate student in establishing themselves in this field and "getting a foot through the door"?

Many thanks!

[dbp333](#)

From steve: Nofame33 had a similar question. going forward I think development to oversight to application and use of safe and effective products will be the result of folks with diverse talents and skills in the natural and social sciences, policy and the law. So while having to do a deep dive in your engineering etc. try and maintain breadth. And see if your school has some classes in regulatory science/risk-benefit analyses. having some exposure to these topics will likely be useful down the road

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Many thanks!

[dbp333](#)

From Farren: Great to hear and sounds like a similar degree to mine in bioengineering. Actually the profession is not that new, but is gaining momentum and interest. Its fun, challenging and meaningful. Get your foot in the door by jumping in and actively pursuing exciting work. Have fun and make an impact!

Do you feel like organic chemistry will ever pick back up? It has been harder and harder to get a job and it is expected to have a low paying with low fruits (and of course with crazy hrs for synthesis. I wonder if organic chemist will have some other directions to turn to and what that will be?

[NoFame33](#)

From Farren: Yes, we need you guys, the world needs you guys. Biotechnology is, in part, inspired by the revolution in synthetic organic chemistry revolution that started in the 1960s:

[https://www.nobelprize.org/nobel\\_prizes/chemistry/laureates/1965/](https://www.nobelprize.org/nobel_prizes/chemistry/laureates/1965/)

Biotechies still need organic chemistry and we're just augmenting these great advances by integrating biology. Stay, we need you!

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[NoFame33](#)

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How promising is the technology for 3D printing human organs? Will it ever be sophisticated enough to replace the need for organ donors?

[puffleninja](#)

From Farren: Great question and beyond the scope of the NASEM study but such an exciting space! There have been such amazing advances in the development of organoids over the past few years that I think have great potential to make an impact in organ donation. In this regard, there have been great advances that have stem from genome editing of pigs that could also solve big problems in xenotransplantation and also make a big impact in organ donations. See: <http://science.sciencemag.org/content/350/6264/1101.long>

Which product are you most anxious to come to fruition?

What, in your view, is the most important current or soon to be breakthrough in the field, excluding CRISPR?

[geak78](#)

From Farren: For some of the products that I'm most excited about, see my answer to "Captain\_Starshield" above. So often the biggest breakthroughs are often the most surprising...I'm reluctant to venture a guess, but rest assured more big breakthroughs in biotech are in progress...enjoy the ride!!

If I remember correctly, the Center for Biologics Evaluation and Research hasn't approved any gene therapy products for sale in the United States. As someone interested in pursuing this field, what would it take for companies/researchers to convince the CBER to approve their product? Is it a matter of some quantity of successful clinical trials?

[Commandaux](#)

from steve: our committee's scope didn't include these types of products. and I don't have direct familiarity with their evaluation. sorry.

If I were say an investor where would you point me to making money through technology?

[Bumbleblock](#)

From Farren: Gosh, when you figure this one out, let me know, too! Thanks!

Can you tell me anything about the state of the art in carbon sequestration? Is anyone trying to design a fast-growing tree, for example, that stores more carbon than natural trees?

[jerkstate](#)

From Farren: Great question and thanks to support from the Department of Energy and others, people

are working on carbon sequestration in trees, plants and even micoorganisms... Stay tuned for some breakthroughs in this exciting space!

What future biotechnologies are you most excited for?

[DeepPurpleDevil](#)

From Farren: See above...

Do you think we will make any breakthroughs into genetic engineering of humans any time soon? There is always the ethical battle but is there actually research being done to create "superior" humans that are immune to diseases, higher muscle growth potential, etc.?

[Mortis206](#)

From Farren: Great question and beyond the scope of our NASEM study, but I couldn't resist! I do believe we are on the cusp of exciting breakthroughs in genetic engineering. There are genome editing drugs in clinical trials to treat important diseases (eg, HIV-AIDS) and the focus should be on reversing human disease to prolong high quality of life.

Hi Prof. Issacs, I was in 370 (and 200 last year) this semester and I'd like to say how great it is to see you here on reddit. What is the largest risk that comes with the explosion of synthetic biology and genome engineering. What can we do to prevent it? What was your reaction after the Jimmy Kimmel skit and would you consider showing that video in either MCDB 200 or MCDB 370 next year?

[Rayvan121](#)

From Farren: Great! I hope you enjoyed both course (for those not in the know at Yale, MCDB200=molecular biology and MCDB370=Biotechnology). We and others are developing important safeguards (eg, genetic isolation, biocontainment) to enable safe and pervasive use of synthetic biology and genome engineering.

Regarding Jimmy Kimmel, that one caught me by surprise and I thought it was great. In addition to a good laugh, I was particularly impressed with Jimmy's message of how important scientific breakthroughs are... Want to start a movement for Jimmy to invite me, "the real Farren Isaacs", on his show in person?

Please do identify yourself and do you think future classes would enjoy the parody?

My question is for Steve (and go Cyclones).

When I converse with the average person without much experience with agriculture they assume pesticide resistance is isolated to glyphosate and GMO's and many don't realize that there's plenty of plants that are or become pesticide resistant. There's even examples I use like sunflowers that were bred to resist glyphosate through traditional means rather than genetic modification as an example I use. How would you converse to explain to the average person on how pesticide management is monitored and managed?

A quick second question is what future biotechnology products have peaked your interest at this time?

[kofclubs](#)

From steve: Active listening seems to be helpful and tends to result in discussions that lead to everyone learning something new - and helps you figure out where to start from, In Iowa we're working on a state-wide pest resistance management program for biotech and non-biotech products and it involves a whole of people all from different backgrounds and roles in the production chain.

while we were working on the report I was struck by a number of ideas in the works - engineered consortia of microbes is intriguing

hey !

i d like to know the implications of rational de novo protein design. there are many powerful molecular tools found in nature like polymerases that turned into technology. but what if we design these tools ourself. i am a fan of david baker and his lab... but how can we improve the designing process? is quantum computing necessary for calculating really fast how aminoacid chains fold? and is this approach the key to real nanotechnology? (bionanotech)

[jean-alain](#)

From Farren: Great question and one that myself and many others ask on a daily basis. David Baker and many others (eg, Rama Ranganathan at UTSW, Vatsan Raman at U. Wisconsin, Tanje Kortemme at UCSF, Sarel Fleishman at the Weizmann, and the list goes on...) have made great advances in this space... My take: I believe that, particularly for biological systems, an approach that combines rational and irrational (eg, evolutionary) processes will be key for the big breakthroughs where we should employ as much knowledge (rational) as we can while also harnessing the evolutionary and adaptive power of biology.

How is biotechnology as a feild to go into? I like science, engineering, and a billion other things. How would you suggest someone learn about the feild before committing to a degree?

[Hunter62610](#)

From Farren: The field is incredibly exciting, dynamic, and challenging with great potential to make an impact in the world. Its great that you enjoy science, engineering, etc, because people with diverse interests and skill sets are all needed in biotech. Immerse yourself, learn and follow your passion. All of the formalities (eg, degrees) will fall into place. Good luck!

As a professor, what sets a student apart in the lab for you? I'm an undergrad who will be doing microbio research and want to stand out!

Also, what made you choose your degree and do you feel that your area of work is threatened by CRISPR advancements?

[Quizerd](#)

From Farren: This is very simple. The students who are committed, persistent and passionate about their work do exceedingly well. I love discussing new and non-incremental ideas with my lab because I truly believe that the most difficult questions are truly the ones worth pursuing.

I chose to study bioengineering as an undergraduate and graduate student because of my love for many fields -- biology, engineering, chemistry, physics, math, medicine -- bioengineering lied at the interface of all of them and provided rigorous training to tackle the interdisciplinary challenges of today and the future.

We use CRISPR technology in lots of our projects; CRISPR doesn't threaten our work at all; it only enhances it and allows us to develop more creative ways of engineering genomes and cells. But, stay tuned for more, exciting genome engineering (& other) technologies to emerge soon also..

What do you think of American labelling verses other nations?

We get mad if anyone wants to point out gmos are in our food however other nations share all nutritional facts and origins and sometimes won't let companies use the word "healthy" unless it is actually beneficial to a human diet.

What are your thoughts on what we should make huge corporations share with their consumers?

[RenAndStimulants](#)

from steve: in chapter 3 of the report we discuss consumer education in terms biotechnology foods and a US law passed in 2016 that requires USDA to establish labeling requirements for foods containing bioengineered organisms. Let's see how implementation of that law plays out.

Off the tops of your heads what are some of your favorite or most interestint potential future products and technologies? Ill try and read the full report when i get home!

[Thesource674](#)

From Farren: See chapter 2 of the report and a few of my responses above where I list a few exciting future products...exciting times!

What role does research on other forms of life around the world (animals, plants, bacteria, etc.) play in the development of biotechnology products?

[puffleninja](#)

From Farren: Studying all forms of life is not only so important for biotechnology products, but incredibly fascinating, challenging and fun! Very important!

What role does research on other forms of life around the world (animals, plants, bacteria, etc.) play in the development of biotechnology products?

[puffleninja](#)

from steve: as our committee was looking into the future, I was struck by the diversity life forms that could play into development of biotechnology products - it includes what you've noted as well as totally synthetic entities.

What are the main areas or issues that biotechnology is focused on

[paletothbone](#)

From Farren: Read our report...the short answer: EVERYTHING!

What efforts are out there to integrate biotechnology and space exploration?

I know there are research programs like Bioastronautics at Boulder, but are there any private companies which are working towards dealing with myriad of problems which will come with the commercialization of space, and eventual space tourism?

[serious\\_sarcasm](#)

From Farren: Short answer: Yes...check out the Mars club and NASA...

What do you see as the role of regulators vs the market in determining which products get built and sold? How much risk is allowable and who decides? Thanks!

[SchrodingersCat24](#)

from steve: well ... it depends... in part on the law(s) that are relevant for a specific product. For some products, like pesticides, the product can't enter the market until EPA reviews required information and data to undertake a risk analysis. Even if EPA determines the product is 'safe' (as defined by the law and subsequent regulations) it doesn't mean the consumers will use the product. Other products, like cosmetics, can enter the market with out a review by FDA, but FDA can make a post market assessment if problems arise. To varying degrees the agencies use public comment, public participation, and peer-review to help inform their decisions. Chapter 3 in the report goes over this in detail.

What do you see as the role of regulators vs the market in determining which products get built and sold? How much risk is allowable and who decides? Thanks!

[SchrodingersCat24](#)

From Farren: Good question and please do read our NASEM report to learn about the current and proposed recommendation for biotech product regulation in the future. Our report dedicates several chapters to answer this profound question.

How accurately can you really predict the future of these sorts of projects? Have you checked whether past reports have been at all accurate (if they exist)? Do you feel under any pressure to make concrete declarative statements where the truth would be closer to hopes and maybes?

[I\\_lectrup](#)

From Farren: Although I do not have knowledge of the prognostic outcomes of prior reports, the composition of this NASEM committee brought to bear people with diverse expertise who performed exhaustive literature searches and conducted interviews with external experts (see presentations here: <http://nas-sites.org/biotech/>) that inspired spirited debate on the issues and manifested in the published report. In this context, our recommendations reflect the thoughtful synthesis of current knowledge sourced from many data points. The National Academies tasked us to establish the most informed predictions for anticipated biotechnology products in the future. Like any endeavor such as this, our predictions of the future won't be perfect and requires horizon scanning (see more details in the report), but that's ok because we'll learn and hopefully establish a productive and healthy course to realize the profusion of biotechnology products in the future.

Whats your thought on Global warming?

[4HitmaN7](#)

From Farren: Rather than sharing my thoughts, just look at the data, particularly the very rigorous studies that correlate the rise in temperature and atmospheric CO2. For those who live in southern CA, Scripps has a great exhibit that beautifully explains this in an accessible way for everyone. We should all learn the facts and then be active participants in doing our part to protect the planet.

What is your stance on the precautionary principle applied to biotechnologies? Will we ever know enough about life to disprove the existence of a risk?

[Funktapus](#)

From Farren: This is more of a philosophical question. We take on many more risks by getting up in the morning, crossing the street, riding bikes, driving cars, flying planes, wearing clothes produced from chemicals...There is risk inherent in everything we do. The challenge is to conduct a balanced risk-benefit analysis, maximize benefit, minimize risk and proceed. I believe regulation and the approach to these questions in biotechnology is rigorous and will continue to be rigorous to ensure safety across the board.

When can I get translucent skin & Firefly ATP so that my muscles glow when they move and I can feel safe going for night runs.

[Bannedfromfun](#)

from steve: now that's a question! we hadn't identified that as a future product. probably need to think of way to not glow in daylight. if some one was going to sell it to you they may have to get FDA approval depending on their claims

Can you help me in understanding transcription of DNA? (with detail, I am a medical student)

[ImSKan](#)

From Farren: Sure, come take MCDB200: molecular biology at Yale where you can learn these details in a class that I co-teach with my great colleague, Anna Pyle!