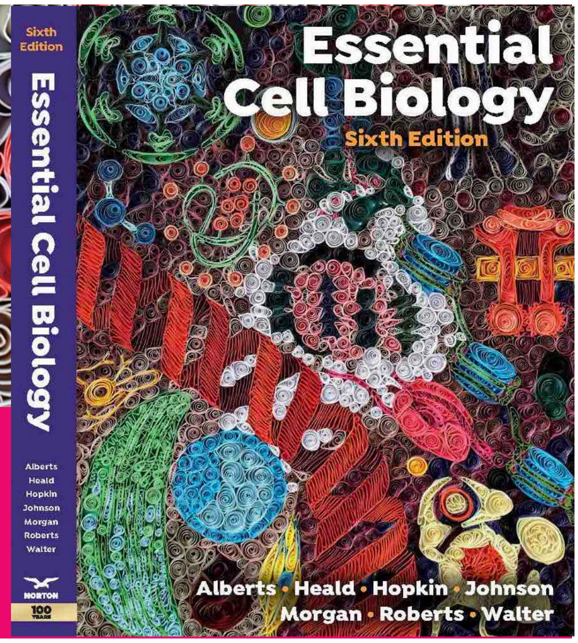


SPECIAL FEATURE

Why Trust Science?

If you're reading these words right now, you no doubt have access to the Internet. So much of our daily lives revolves around this technology—from our education and entertainment to our ability to interact with friends and family anywhere on the planet. We use the Internet to order groceries, keep abreast of the news, listen to music, make dinner plans, and access information.

In 1990, the Internet did not exist. At least not as we know it. Initially devised as a means for scientists to communicate and share data with one another, the Internet has since evolved into a worldwide network of information that anyone with access to a computer or smartphone can tap into.

It's nearly impossible to imagine (or to remember) what life was like before the Internet. And that's just one example of how the products of science—and the efforts of scientists—have changed our everyday lives in immeasurable ways. Think of electricity, phones, even toilets—not to mention the agricultural advances that provide the food we eat or the medicines and vaccines that help us to live twice as long as our ancestors did just a few hundred years ago (**Figure 1**).

We don't spend much time thinking about these things, because we don't really have to. We trust that they will work. We trust that when we plug in our phone, the battery will charge. We trust that when we hop in the car, the engine will convert the chemical energy of gasoline into the kinetic energy of motion. And we trust that we can navigate the Internet to find the goods, services, or information we seek.

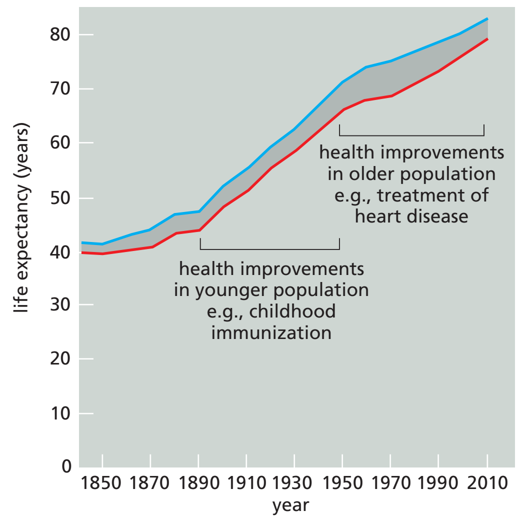


Figure 1 Robust and reliable science is a driving force behind human progress. Life expectancy, for both men (*red line*) and women (*blue line*), has nearly doubled in the past 150 years. Innovations based on scientific investigation—including sanitation, vaccines, and disease treatments—account for most of that increase. (Data from the UK Office for National Statistics, 2015.)

But why do we trust in these technologies that—let's be honest—most of us can't even begin to fully understand? How many of us know how a search engine works or how "packet switching" allows information to be sent from one computer to another? Do we understand how rechargeable lithium-ion batteries operate? Do we have any idea how Bernoulli's principle creates the lift that keeps a jet plane aloft?

Probably not. After all, few of us are experts on any of these subjects. But, generally speaking, we all trust that we can recharge our phones at the end of the day and that the aircraft that's taking us on a long-awaited vacation won't suddenly drop from the sky midflight. We trust that these things will work because we can trust the engineering that produced them—technological advances enabled by principles derived from scientific observation and experimentation.

But how can we tell when information is trustworthy? Many stories we hear on the news or encounter on the Internet begin with the phrase: "a new study shows…" And though we can rely on the infrastructure of the Internet—the hardware and programming that allow it to function—we certainly can't trust a great deal of the information we encounter there. So how do we know which studies are robust and reliable—especially when we often lack the expertise to analyze the experimental design and data ourselves?

In this feature, we address the question of why we can trust science—and how we identify what science we can trust. We begin by explaining how scientists work together, as part of a community, to generate knowledge that is reliable. We describe how the scientific process builds a consensus, and how new evidence can change the ways that scientists—and, ultimately, the rest of us—see the world. Last, but not least, we explain how, as informed citizens, we can all become "competent outsiders" who are equipped to evaluate scientific claims and are able to separate science facts from science fiction.

Science Creates Knowledge Through a Community Effort

When we imagine a scientist, we might picture someone working long, lonely hours at a laboratory bench (beakers boiling in the background). Or maybe we think of Gregor Mendel, toiling alone in his abbey garden, painstakingly breeding and recording the appearance of generation after generation of pea plants (as discussed in Chapter 19). But science, particularly modern science, is very much a team sport. In 2021, for example, investigators published a fully complete, "telomere-to-telomere" human genome sequence (as discussed in Chapter 9). The resulting paper included more than 100 authors from 20 different institutions around the world.

And that is only one of thousands of such studies published that year. In any field of science, from genome biology to subatomic particle physics, researchers labor within a broad scientific community. These investigators share their data in publications and debate their findings at conferences. They write research proposals that are reviewed by their scientific peers. They give seminars where others critique and question everything from their methods to how they interpret their results.

In response to such collegial criticism, scientists devise even more rigorous strategies for testing their models and verifying their observations. They contemplate the findings of others in the field and adjust their concepts to best accommodate all of the available data. In this manner, the scientific community strives to come to a consensus. Or as Ludwik Fleck—a Polish microbiologist who studied the sociology of science—put it, "A truly isolated investigator is impossible....Thinking is a collective activity."

Of course, individual scientists can make mistakes. Scientists are only human. But they are professionals who have dedicated their lives to trying to understand the natural world. So we should be able to trust their training and expertise like we trust a pilot to land our plane safely. As scientist and historian Naomi Oreskes notes in her book *Why Trust Science*, "We trust experts to do jobs for which they are trained and we are not....Scientists are our designated experts for studying the world. Therefore, to the extent that we should trust anyone to tell us about the world, we should trust scientists."

Science Is Self-Correcting Because Scientists Are Critical of Their Own Work

When we first learn about "the scientific method," we are told that scientists make observations and then develop a hypothesis—a proposal explaining those observations—that can be tested by some sort of experiment. If the results support the hypothesis, the hypothesis is confirmed and the investigators can then conduct additional research to further refine their model.

But that picture is vastly oversimplified. In reality, hypotheses are not primarily meant to be proven, but disproven. Scientists are trained to be skeptical—even (or especially) of their own hypotheses. Good scientists operate with the knowledge that their initial models may require revision or complete abandonment. Some might even argue that a major goal of science is to eliminate erroneous ideas and incorrect interpretations. In his book *If Science Is to Save Us*, astronomer and former president of the Royal Society Martin Rees argues that being critical is in a scientist's professional interest. "That's because the greatest esteem goes to those who contribute something unexpected and original," he writes, "and especially to those who can overturn a consensus."

Because science advances through a rigorous community-based testing of ideas, it effectively corrects its own mistakes—steering us away from misinformation and toward an increasingly accurate understanding of the world.

Skepticism allows science to progress. But it only does so because, as a community, scientists share a similar set of values. As Jacob Bronowski, a physicist and philosopher, noted in *Science and Human Values:* "Science confronts the work of one [investigator] with that of another and grafts each on each; it cannot survive without justice and honor and respect. . . . Only by these means can science pursue its steadfast object, to explore truth."

Shared Practices Increase the Accuracy of Scientific Findings

Shared values alone are not enough to make science self-correcting. Over time, the scientific community has developed a set of critical practices that facilitate the vetting of knowledge—enabling investigators to identify problems in their theories and experiments and allowing them and their colleagues to pursue the necessary corrections. These practices include:

1. **Independent replication:** When investigators publish their work, they provide comprehensive descriptions of the experimental procedures they followed. This sometimes excruciating level of detail—which can include not only the reagents they used, but where these ingredients were purchased, how they were prepared, and even what lot numbers appear on the side of the bottle—is meant to allow others in the community to reproduce the original experiment (or conduct one that is very similar). This independent examination is essential for either corroborating the original results or, alternatively, indicating that something is amiss.
2. **Randomized controlled trials:** How do researchers determine if a particular intervention—whether it's a new drug, vaccine, therapy, or even an overhauled high-school science curriculum—is more effective than the procedure or practice currently in use? They compare what happens to a group of people who receive the new treatment to a comparable collection of volunteers who do not. To make sure that this "control group" does not differ in some significant way from the experimental group, such studies randomly assign some participants to receive the new treatment and others to receive either the conventional, current treatment or a placebo—an inactive substance or "dummy" treatment. Such randomized controlled trials are expensive, but they represent the "gold standard" approach to determining, with certainty, whether a new treatment is both effective and safe.
3. **Blinded analysis:** In a blinded analysis, investigators attempt to remove any bias from their interpretation by "not looking at the answer" ahead of time. In clinical trials to test the safety and effectiveness of drugs or vaccines, for example, the investigators conducting the study typically do not know which participants are receiving a treatment and which are getting a placebo (nor, frequently, do the participants themselves). Such blinded studies are more trustworthy, because they minimize the possibility that investigators might "fudge" their data—whether purposely or unconsciously— to obtain the desired result.
4. **Statistical validation:** Scientific data will always exhibit some degree of variability, so scientists use statistical analyses to quantify this inconsistency. Statistics allow scientists to assess how likely it is that a particular result was obtained by chance rather than by the experimental manipulation or treatment. To avoid being misled, good scientists design their experiments with all the appropriate controls, replicate samples, and a total sample size that is large enough to assure them that their results are meaningful and not simply due to chance.
5. **Peer review:** Everything that scientists do is subject to review by others in the community. Before they even begin their research,

> investigators typically submit requests for funding to pay for their experiments, explaining what they intend to do and how they intend to do it. These applications are evaluated by other investigators in their field to ensure that only well-designed projects will receive financial backing. The articles that scientists write to describe their research are similarly assessed before being published in "peer-reviewed" journals. In this process, scientists with the required expertise (whose identities are traditionally not revealed to the study's authors) vet the paper before it is accepted for publication. And once research papers are published, all of the information they present is subject to critique by the broader scientific community.

By publishing their results and subjecting their methods and analyses to critical review, scientists facilitate the exchange of ideas, challenge hypotheses and interpretations, and encourage each other to continually reassess their theories and refine their conclusions. Thus, although individual scientists may get things wrong, community-driven corrections allow the field to progress toward an ever greater understanding.

Only those claims that have passed the rigorous testing of community-wide experimentation and critique are corroborated, thereby moving us toward a consensus that is reliable and in which we can trust. As Oreskes puts it: "...the basis for our trust is not in scientists—as wise or upright individuals—but in science as a social process that rigorously vets claims."

Science Is a System for Understanding the World That Generates Testable Predictions

Science does not generate consensus by simply corroborating the same experimental results, again and again. The beauty of the scientific enterprise is its ability to generate logical predictions about how the natural world will behave in the future by producing models that are derived from past observations and experiments. These models are then tested repeatedly by investigators in other labs—and even in other fields of science—to determine whether they always hold true. New experiments may confirm a model, lead to its alteration in small or large ways, or prompt its rejection and replacement with a model that accommodates all of the data. In this way, science has produced a vast web of interconnected, well-established knowledge that allows us not only to describe or account for the things we observe today—but to predict what will happen tomorrow, next Tuesday, and 100 years from now.

In the late 1600s, Sir Isaac Newton came up with his laws of motion to explain how physical forces affect the movement of objects. These laws are still valid today. Anywhere on the planet, we can use them to predict, say, where to stand to catch a ball. But they also apply in space, where they can predict, with almost uncanny accuracy, when an eclipse will take place, how often a comet will return to our skies, or whether detonating a precisely targeted explosion will provide enough force to alter the path of an asteroid that might otherwise collide with the Earth in five months, five years, or five centuries.

Scientific Thinking Is Continually Refined by New Evidence

Science is based on observations—and on verification of those observations. Yet observations alone, no matter how numerous, are rarely definitive. New information can always change the way we see the world. Thus, although we can believe or trust in theories that have passed rigorous testing, these ideas must always be subject to revision based on new evidence.

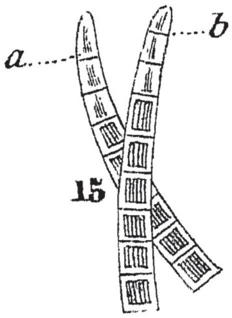


Figure 2 Improvements in microscopy allowed scientists to see, quite clearly, that cells arise from preexisting cells. The first distinct visualization of cell division in a multicellular organism came from an examination of a filamentous freshwater green alga. This drawing, which shows cells dividing at the very tips of a slender silkweed called *Conferva*, was published in 1832. (From B. C. Dumortier, Recherches sur la structure comparée et le développement des animaux et des végétaux. *Nova Acta Physico-Med. Acad. Caesar. Leopoldino-Carolinae Nat. Curios.* 16:217–312, 1832.)

The history of science reveals that even a major scientific consensus can occasionally be overturned by an accumulation of evidence that does not corroborate the current thinking. Although this does not happen often, a critical aspect of science is that even popular ideas are continuously scrutinized. In the 1830s, for example, few in the scientific community believed that cells arise solely from preexisting cells by the process of cell division. Prominent cytologists Matthias Schleiden and Theodor Schwann, whose extensive microscopic observations gave rise to the idea that cells are the building blocks of all living tissues (discussed in Chapter 1), insisted that new cells crystallize from a special slurry of sugar, gum, and mucus found within or between other cells. Ultimately, as microscopes became more powerful and biologists grew more adept at preparing tissues in a way that avoided introducing visual artifacts, the evidence that cells are the product of cell division could no longer be disregarded (**Figure 2**).

Similar fundamental shifts have taken place in the field of molecular cell biology. As we discuss in Chapter 2, at the beginning of the twentieth century there was a consensus among chemists that macromolecules—polymers composed of a very large number of atoms held together by covalent bonds—simply could not exist. Instead, molecules as large as proteins were believed to be formed as collections of loosely associated small organic molecules. Eventually, new methods for examining proteins and measuring their mass allowed chemists to prove definitively the existence of the macromolecules that make life possible (see How We Know, pp. 64–65).

Most Scientific Knowledge Builds Gradually Toward a Reliable Consensus

Although the process of scientific inquiry occasionally leads to remarkably dramatic changes in our understanding of the natural world, changes in the scientific consensus are commonly more gradual. As the collection of studies on a particular topic accumulates, the community moves closer to an accepted understanding in smaller steps, without drastic change, producing a refined model that better fits the data.

One example of this gradual refinement is the "fluid mosaic" model of cell membranes that is presented in all modern biology textbooks, including our own. A century ago, Dutch physiologists Gorter and Grendel proposed that cell membranes consist of a lipid bilayer (as discussed in Chapter 11). But not everyone agreed with this proposal. Most notably, in 1935, physical chemists Danielli and Davson came up with a membrane model that resembled a protein-lipid triple-decker sandwich: a lipid bilayer stabilized by a twin layer of proteins on either side (**Figure 3A**).

This model was revised when subsequent biochemical and structural studies indicated that membrane proteins are hydrophobic and come in different sizes. Hence they would not be expected to form uniform layers on either side of a lipid bilayer. And fluorescent tagging revealed that membrane proteins are highly mobile (see Figure 11-30). Thus, rather than forming a fixed, static, rigid outer layer on either side of a cell membrane, membrane proteins are embedded within a flexible lipid bilayer. The fluid-mosaic model, proposed in 1972, accommodated these observations, and by 1975, the determination of the structure of bacteriorhodopsin by electron microscopy provided unambiguous evidence that membrane proteins can span the bilayer (**Figure 3B**).

The gradual approach to the truth that is characteristic of science can also be seen in the cell biology textbooks that we have written, the first of which was published in 1983. Over the past 40 years, our illustrations of many

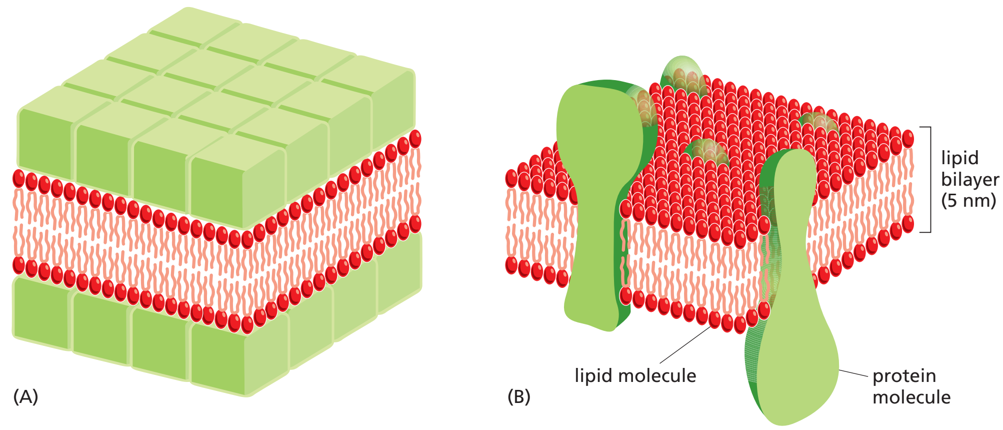


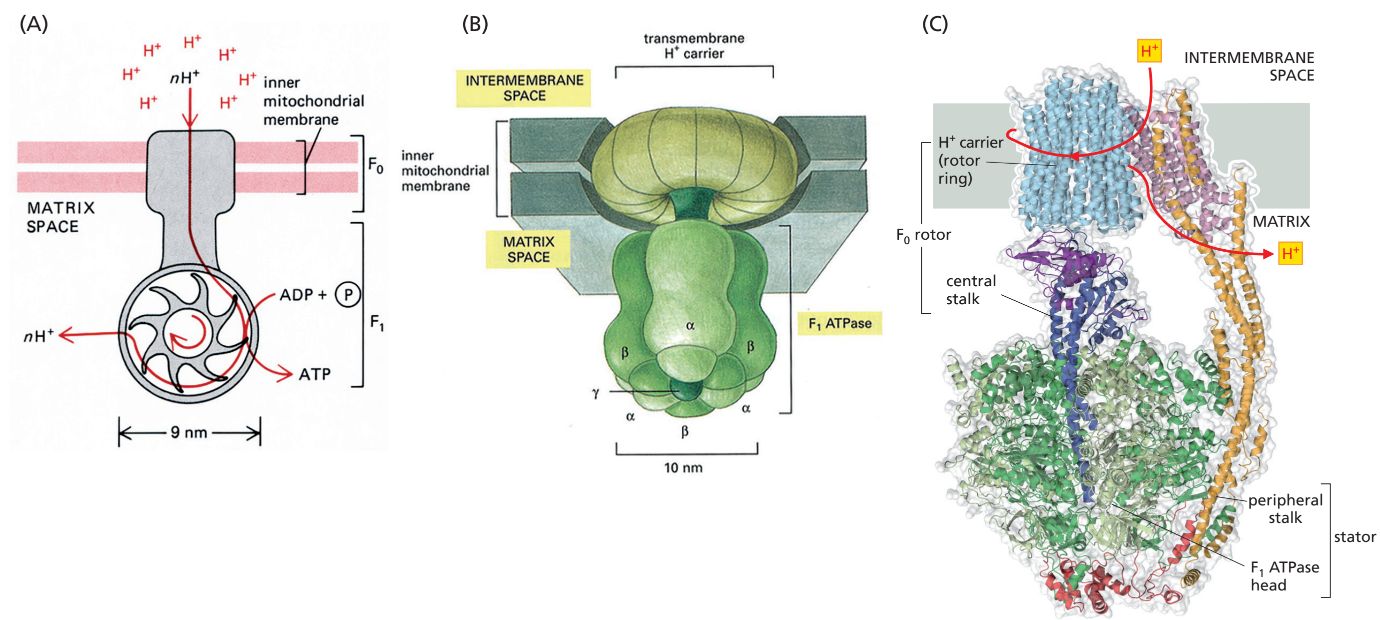
Figure 3 Models of membrane architecture have evolved over time. After a consensus emerged that membranes contained a lipid bilayer as a basic structural component, there was still uncertainty about how proteins were involved in their structure. An early model envisaged a triple-decker structure (A) in which a pure lipid bilayer is tightly sandwiched between two layers of protein molecules. It took another 40 years of experiments to arrive at the current model of membrane architecture, the fluid-mosaic model, that is still generally accepted (B).

biological molecules (**Figure 4**) and processes (**Figure 5**) have become increasingly (and noticeably) more accurate with each successive edition.

Understanding the Scientific Process Can Help Us Differentiate Between Misinformation and Legitimate Science

When the Internet and its collection of publicly accessible web pages was launched in the 1990s, no one could have predicted how central this global system of shared resources would become in our lives. With the rapid expansion of the Internet and the unforeseen proliferation of social media, all of us have unlimited access to a virtual tidal wave of information—and misinformation. Today, anyone can promote products or ideas to hundreds or thousands or even millions of people with the click of a button. Sadly, a great deal of this information is not legitimate. Influencers can produce or publicize dubious or unconfirmed

Figure 4 Refinements in the structure of ATP synthase led to a deeper understanding of how this protein complex functions. It required a collective effort of many scientists over time to produce our increasingly detailed knowledge about ATP synthase—the protein machine that makes ATP. (A) In the First Edition of our textbook *Molecular Biology of the Cell*, published in 1983, all we knew was that the protein complex was embedded in a membrane and that, based on electron microscopy studies, it had the rough shape of a lollipop. (B) By the time the First Edition of *Essential Cell Biology* was published in 1998, more was known about the various protein subunits and their relative abundance, but precise structural detail was still lacking. (C) By 2023, when this Sixth Edition was published, the molecular architecture of the complex had been progressively refined in many laboratories by cryo-electron microscopy, and its detailed mechanism of action deduced and accepted.



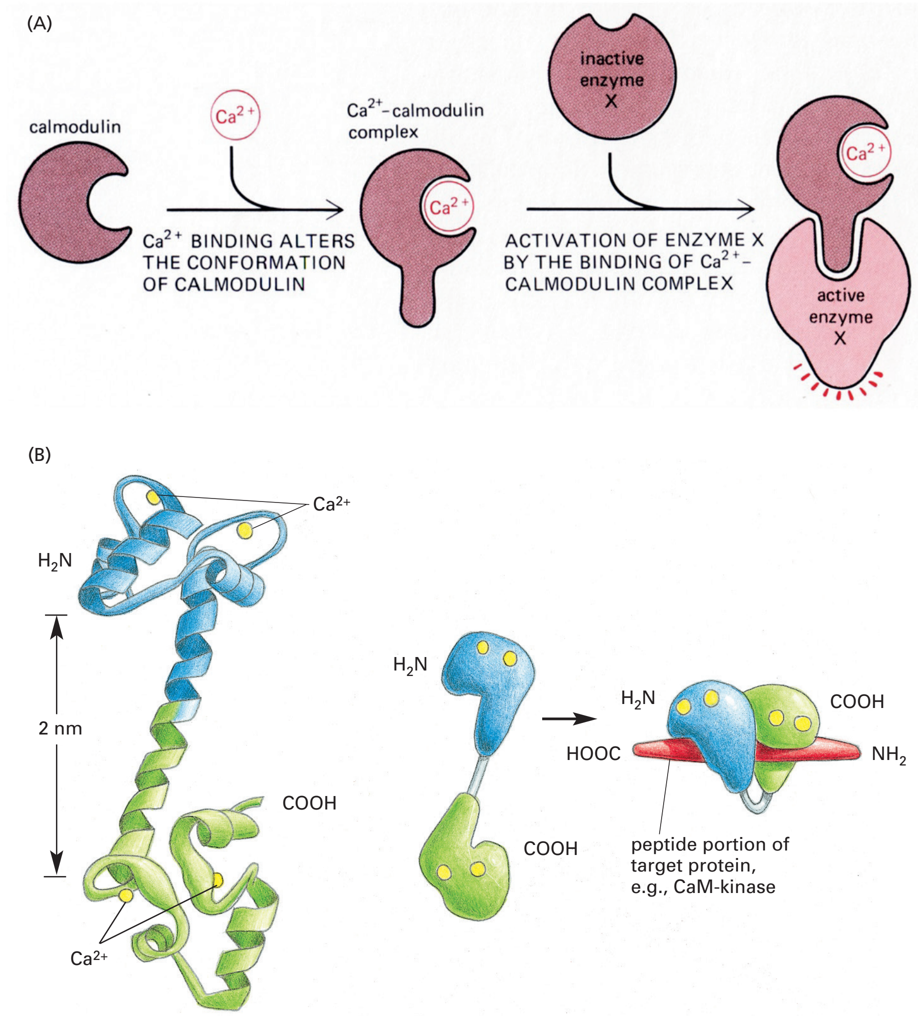


Figure 5 Improvements in methods for studying protein structure have also provided insights into how calcium drives many important biological processes. (A) In 1983, when the First Edition of *Molecular Biology of the Cell* was published, calcium was known to act as a second messenger through activation of the protein calmodulin. With no available structural information, we knew little more about this activation step than depicted in this simplified drawing. (B) A few years later, the molecular structure of calmodulin was determined by X-ray crystallography, and additional studies using nuclear magnetic resonance revealed that calcium induces a dramatic change in the conformation of calmodulin, allowing it to wrap around its target proteins. With this new information, we were able to present the figure found in the First Edition of *Essential Cell Biology* in 1998. This model is still accepted and continues to be confirmed by additional experiments—as reflected by the figure that appears in the Sixth Edition (Figure 16-25).

studies—or even fabricate them out of thin air. Some promote sincere but unscientific beliefs, like a link between autism and childhood vaccines. Others might do so for financial gain, like an oil company lobbyist denying the role of fossil fuels in global climate change. Misinformation is also spread for political reasons—with nations or politicians devoting major resources to sowing confusion and enmity to disadvantage their competitors. In this informational free-for-all, false claims often become quickly sensationalized and disseminated to millions of people.

We all need to think critically when we read or see stories on the web or in the popular press. However, given that we can't be experts in most fields of science, how can we discern whether a particular study or story is trustworthy? How can we inoculate ourselves against being fooled by scientific falsehoods? A recommended three-step process is outlined in Figure 6.

The first step involves evaluating the source of the claim. Who is providing the information? How did they come up with their conclusions? Do they have economic or political reasons to spread these views? What, if anything, might they be selling? It is also critical to learn whether the source of the information has the expertise and credentials needed to validate the assertion. Does that individual have the appropriate training (an MD or PhD degree, for example)? Do they conduct research in the field? Are their views respected by their scientific peers? Note that the use of ivermectin to treat or prevent COVID-19 was ceaselessly promoted by a small but vocal group of physicians, some of whom had previously been criticized by their peers in the medical community for advocating other unproven and ineffective treatments. These unsupported claims were then amplified by influencers with no scientific or medical training at all.

If the source of the information seems credible, one can consult the websites of reliable organizations, such as the National Academy of Sciences (in the United States) or the Royal Society (in the United Kingdom), to

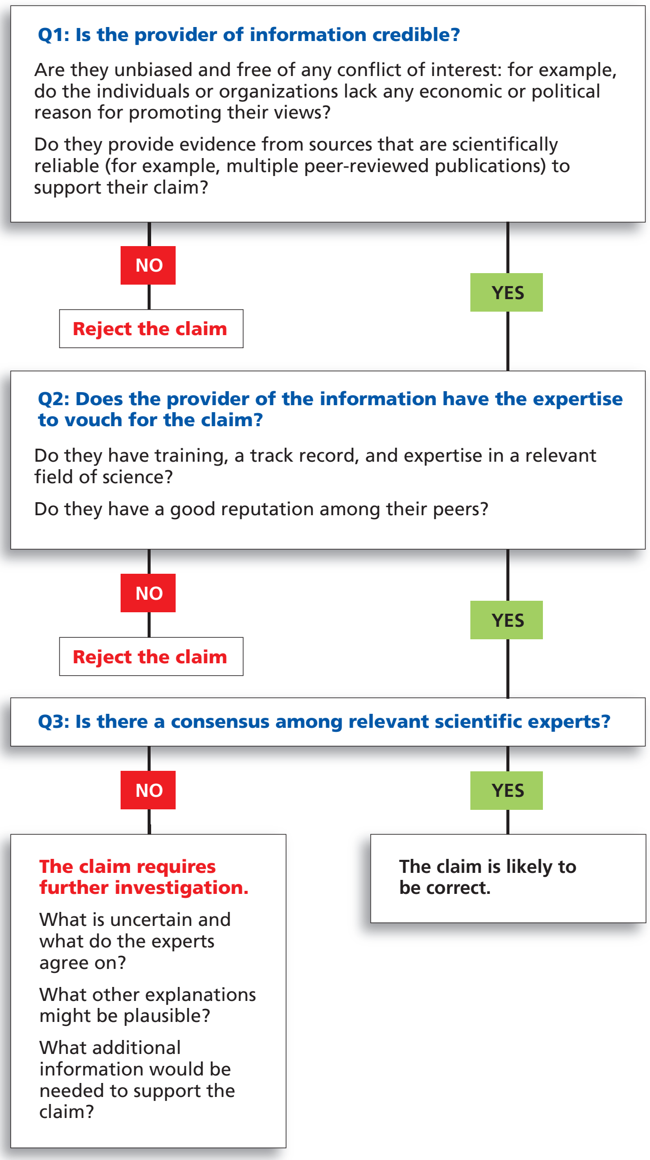


Figure 6 A simple, three-step process can be used to evaluate scientific information. This "fast and frugal" method uses three filters to differentiate between claims that are not supported by science and those that are. Adapted from J. Osborne and D. Pimentel, *Science* 378:246–248, 2022. Reprinted with permission from AAAS.

investigate whether there is a scientific consensus on a contentious issue. In the case of climate change, for example, it is clear that the community of climatologists speaks with a broad consensus when it concludes that human activity is contributing to global warming. The evidence is undeniable and overwhelming.

Even highly respected scientists can be wrong when they venture too far from their areas of expertise. Much damage was done in the recent past by small groups of senior distinguished physicists who first insisted that it was uncertain that smoking caused cancer, later cast doubt that acid rain was caused by smokestack emissions, and until their last breaths opposed the idea that greenhouse gases cause climate change—all heavily promoted by financial support from the industries that would benefit from their "expert" testimonials.

False or exaggerated claims are often made for products aimed at improving health and wellness. For example, billions of dollars are made each year through the sale of dietary supplements that are unlikely to be of any use. A truly scientific study of these supplements would be very expensive and difficult to conduct—volunteers can't be sequestered in a laboratory where their diets can be rigorously controlled for years. But huge profits can be made by selling supplements that are supposedly "backed by science." The so-called experts promoting these products might even insist that they have been "proven 100% effective." Of course, anyone claiming to know something with absolute certainty should always be viewed with suspicion. One does not have to be an expert in any field of science to know that such an assertion is literally too good to be true.

Ensuring That Science Remains Trustworthy Requires Constant Vigilance

By now it should be clear that the entire scientific enterprise is built on trust. Scientists must trust one another to adhere to the standards and practices that the community has established to enable researchers to rely on—and build on—each others' findings. This confidence is a foundational component of the iterative process of investigation that allows scientists to come to a consensus and provide us with knowledge that we can trust.

At the same time, scientists have an obligation to be open and honest with all of us. Much of the authoritative research we encounter in the news is supported by our tax dollars. And lives can depend on whether scientific studies are rigorously conducted and accurately presented. Scientists therefore have an ethical responsibility to communicate their findings in a clear and straightforward manner, honestly explain what their conclusions mean (and what they don't mean), and, as much as possible, make their data available for public scrutiny.

This policy of openness did not arise spontaneously. Worldwide, the institution of science has long worked to establish a system of values and incentives that strongly encourage investigators to be meticulous with their methodology and scrupulous when it comes to disseminating their results. The scientific community actively discourages various forms of "bad behavior," such as the publishing of fraudulent or misleading data or the promotion of unverified research. Failure to adhere to community values and practices represents a severe threat to a scientist's entire career, inasmuch as success in science requires the respect of one's fellow scientists—both to have one's ideas considered by others and to obtain the funding needed to carry out research.

Even with such safeguards, maintaining the cultural values of science requires a continuous input of energy and attention. When it comes to shoring up the pillars of the scientific edifice, venerable scientific academies, such as those mentioned earlier, often lead the charge. The Royal Society in England has long been the model for this type of honorific organization; established in 1660, the Royal Society set standards for scientific excellence by choosing outstanding scientists as its members and creating effective mechanisms for their frequent interactions. In the United States, the National Academy of Sciences performs a similar function. Established in 1863 by an Act of Congress approved by Abraham Lincoln, the Academy is charged with "providing independent, objective advice to the nation on matters related to science and technology." To continue to fulfill this obligation, a key mission of this institution has been to educate young investigators: instilling in them the cultural values that are required for science to remain healthy and offering guidance on how they can mentor future generations of scientists—fostering in them the love of learning that is the cornerstone of a life in science (**Figure 7A**).

The academies also labor to identify and eradicate threats to scientific integrity. One such threat comes from hundreds of for-profit publications that have proliferated in recent years. For a fee, these "fake" or "predatory" journals promise extremely rapid publication, while falsely claiming that they engage in a legitimate peer-review process. Honest peer review, as we have discussed, is vital for the health of science, and its absence ultimately erodes the reliability and trustworthiness of research. These journals are therefore being actively challenged by the InterAcademy Partnership (IAP), a collaboration of more than 140 science, medicine, and engineering academies across the world (**Figure 7B**).

In these ways, the continued vigilance of individual investigators, scientific academies, and other organizations ensures the ongoing integrity of the scientific enterprise—demanding that researchers carry on operating with openness and honesty while maintaining the trust of their fellow scientists, the broader community, and the public at large.

Trust in Science Is Essential for Our Future as a Civilization

Science has produced such a vast array of knowledge about how the natural world operates that it not only allows humanity to foresee likely future calamities—such as climate change or a catastrophic collision with a far-away asteroid—but to take actions today to prevent them. By producing reliable predictions about future events, science makes all of our lives safer.

The need to make decisions that are based on reliable scientific predictions has never been more urgent. With the human population topping 8 billion, the demands we make on the planet's finite resources cannot be sustained and threaten the entire biosphere. Science can offer solutions to the concerns we face, from avoiding the perils of climate change and pandemics to addressing the ethical concerns raised by the development of ever more powerful techniques for engineering genomes, including our own. But as individuals, voters, and consumers, we all need to be able to identify good science to make sound, well-reasoned decisions on the issues that affect our personal lives—as well as to protect the health, integrity, and very future of society as a whole.

A variety of institutions are doing their part to provide resources we can all use to process challenging and conflicting torrents of information. Social scientists, science historians, and experts in fields from psychology to communications are conducting active research on science culture, the spread of misinformation, and public trust in science. These efforts

Figure 7 Scientific academies educate young scientists about proper scientific practice and also strive to protect the scientific enterprise. (A) The US National Academies produced this guide, which can be downloaded for free, to describe what responsible conduct in science looks like and to encourage good practice for scientists-in-training. (B) "Bad actors" exist in the scientific community (as they do in any large group), and their activities can erode public trust. One such threat is represented by the recent proliferation of for-profit journals and conferences that do not subscribe to the accepted principles of sound science. In 2022, a consortium of the world's science academies launched a project aimed at ferreting out these predatory entities and practices and providing recommendations on how to identify and avoid them. This type of vigilance is key to rooting out scientific malpractice and keeping the scientific enterprise healthy. (A: National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. 2009. On Being a Scientist: A Guide to Responsible Conduct in Research: Third Edition. Washington, DC: The National Academies Press. https://doi.org/10.17226/12192. B: This work is copyright of the InterAcademy Partnership (IAP) and is licensed under Creative Commons Attribution 4.0 International https://creativecommons.org/licenses/by/4.0/. The full report (in English) can be found at https://www.interacademies.org/publication/predatory-practices-report-English.)

are guiding the development of tools we can use to determine which information we can trust.

The University of California, Berkeley, offers an entire course aimed at making students better equipped to think critically. "Every day we make decisions that can and should be informed by science," reads the course description. "The problem is we don't do it so well." To minimize these errors to which all humans are prone, the course reviews "what makes science such an effective way of knowing, how both non-scientific thinking and scientific thinking can go awry, and how we can reason more clearly and successfully as individuals, as members of groups, and as citizens of a democracy."

In the spring of 2023, the National Academy of Sciences, in partnership with the Nobel Foundation, sponsored a three-day summit to discuss how to stop misinformation from eroding public trust in science and scientists. At this conference, Nobel Prize–winning scientists were joined by leaders in information technology, policy makers, journalists, and educators to explore solutions for curbing the spread of misinformation that weakens public deliberation and undermines trust in science and in democracy itself. Underway is the development of a course, designed for high school students around the globe, that has the same aim as this "Why Trust Science" feature.

As textbook authors, we attempt to point out how the information we present is the product of decades of discoveries. In the How We Know panels in each chapter, *Essential Cell Biology* has long showcased how scientists think, outlining the elegant logic and experimental approaches behind some of the most fundamental concepts in cell biology. Now, in the Sixth Edition of *Essential Cell Biology*, we introduce a new feature, "Why Trust Science." This brief primer on the process of science represents our response to an urgent need to reorient the teaching of science at all levels, so as to enable students to discern the truth in a world intensely bombarded by misinformation.

We sincerely hope that this discussion will broaden our readers' appreciation of how science leads to new knowledge—and thereby help them to become more critical consumers of scientific content and better informed, more confident thinkers and citizens.

ESSENTIAL CONCEPTS

- **Science produces reliable knowledge as a broad community effort, guided by a critical set of standards and values.**
- **Critical scientific values include an insistence on evidence, honesty, a healthy dose of skepticism, and an openness to new interpretations and ideas.**
- **Community standards that support these values include publishing the experimental details needed for others to replicate or refute one's findings, randomized control trials, blinded analyses, statistical validations, and peer review.**
- **A scientific consensus represents humanity's best approach to the truth, but it can never be certain, as it must be kept open to change based on new evidence and ideas.**
- **A good scientific explanation makes logical and testable predictions about the system being studied; thus, science not only accounts for current observations, but also predicts what will happen in the future.**
- **Most scientific knowledge improves gradually, with refinements that bring it ever closer to the truth.**
- **The pervasiveness of social media has vastly expanded the influence of fake science, exposing us all to massive amounts of misinformation to tragic effect.**
- **A solid understanding of science as a community-driven process can enable all students to discern the truth and become "competent outsiders."**