A scientific approach to life: A science toolkit

Trans-fat free! Ethanol production: an eco-nightmare? Cancer researchers discover new hope. Major petroleum company acknowledges reality of global warming. Clinically proven to reduce the appearance of wrinkles! These aren't exactly the headlines you'd find in a scientific journal, but they are examples of the sorts of scientific messages that one might encounter everyday. Because science is so critical to our lives, we are regularly targeted by media messages about science in the form of advertising or reporting from newspapers, magazines, the internet, TV, or radio. Similarly, as discussed in Science and society, our everyday lives are affected by all sorts of science-related policies—from what additives are allowed (or required) to be mixed in with gasoline, to where homes can be built, to how milk is processed. But you don't have to take these media messages and science policies at face value. Understanding the nature of science can help you uncover the real meaning of media messages about science and evaluate the science behind policies.

Understanding Science

Untangling media messages and public policies

Everyday, we are bombarded with messages based on science: the nightly news reports on the health effects of cholesterol in eggs, a shampoo advertisement claims that it has been scientifically proven to strengthen hair, or the newspaper reports on the senate's vote to restrict carbon dioxide emissions based on their impact on global warming. Media representations of science and science-related policy are essential for quickly communicating scientific messages to the broad public; however, some important parts of the scientific message can easily get lost or garbled in translation. Understanding the nature of science can make you a better-informed consumer of those messages and policies. It can help you:

- separate science from spin
- identify misrepresentations of science, and
- find trustworthy sources for further information.

To demonstrate how this works, we'll look at a set of questions that you can use to get to the science behind the hype:

Your Science Toolkit: Evaluating Scientific Messages

- Where does the information come from?
- Are the views of the scientific community accurately portrayed?
- Is the scientific community's confidence in the ideas accurately portrayed?
- Is a controversy misrepresented or blown out of proportion?
- Where can I get more information?
- How strong is the evidence?

As an example, we'll apply these to a hypothetical article relating to global warming that might have appeared in a major newspaper in the early 1990s …

Understanding Science

Ice cores offer clues to global warming question

An international group of researchers working in Tibet have recovered new clues about Earth's ancient climate. These clues come in the form of ice cores taken from the Guliya ice cap, which are believed to contain information about the components of the atmosphere over the last 200,000 years.

The scientists are beginning analysis of one of the three cores recovered by the expedition last summer. Lonnie G. Thompson, leader of the research team, said that this core could reveal new insights about Earth's climate through the last four ice ages.

A better understanding of these climate patterns will inform the so-called "global warming" debate.

Some scientists believe that human-produced carbon dioxide is causing Earth to warm dangerously. This view is supported by some ice core studies. However, skeptics question this opinion, arguing that we lack evidence that the warming is not simply a natural part of the planet's climate fluctuations.

Ice cores contain atmospheric "fossils"—bubbles of preserved gases and dust from different times in Earth's history. Thompson explained that "These long-term archives will let us look at the natural variability of the climate over long periods …."

Another ice core taken from Antarctica has suggested that carbon dioxide levels and temperature have increased and decreased in sync over the past 160,000 years, rising to unprecedented levels today.

However, scientists have not yet come to a conclusion regarding the main question inspired by the ice core data: Do higher carbon dioxide levels actually cause temperature increases?

To see how the article measures up against our set of tips, read on …

Who dunnit: Where does the information come from?

In paperback mysteries, the answer to this question is withheld until the last page …

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… but when evaluating a media message about science, it's one of the first things to consider:

- What is the source of this message? Is it a sensational article in *Cosmopolitan*, a report from the *New York Times*, a feature in a science publication aimed at the general public like *Discover*, or an original journal article? Each of these sources will provide you with a different level of information—and probably, a different level of fidelity to the original science. So if you are reading a short summary in your local newspaper, don't assume that you've got the whole story!

- Does that source have an agenda or goal? All media messages have goals, which can affect the information presented. For example, scientific messages that appear in advertising (e.g., "Clinically proven to reduce wrinkles") are aimed at selling a product and are unlikely to give the full story. Some publications are aimed at rallying readers around particular issues, like environmental activism, anti-environmentalism, or health issues, and so may present a skewed view of the science. If you really want the whole scoop on a scientific issue, it's best to look for a source whose main goal is to explain the science involved. Science publications aimed at the general public provide this sort of information. As we've seen in other sections of this website, scientists strive to be unbiased in their scientific work, but occasionally the media's interpretation of this work introduces bias.

An original piece of scientific research may be interpreted many times over before it reaches you. First, the researchers will write up the research for a scientific journal article, which may then be adapted into a simplified press release, which will be read by reporters and translated yet again into a newspaper, magazine, or internet article—and so on. Just as in a game of telephone, errors and exaggerations can sneak in with each adaptation.

GETTING IT WRONG EVERY WHICH WAY

In 2004, an international group of researchers modeled the effect of predicted climate change over the next 50 years, and reported that this amount of change might *eventually* cause 15-37% of a select group of terrestrial species to go extinct. It was simple, straightforward science. However, much of the press coverage that followed was both sensational and inaccurate. For example, the *Guardian* ran the headline:

An unnatural disaster:

- *Global warming to kill off 1m species*
- *Scientists shocked by results of research*
- *1 in 10 animals and plants extinct by 2050*

In fact, most newspaper reports got it wrong, frequently suggesting that over a million species would go extinct *by* 2050—and not, as the science implied, that over a million species would be sentenced to extinction by 2050 and would actually die off afterwards. In addition, many websites picked up the story, and as one might expect, conservation-oriented websites tended to run more sensationalized versions of the story, and websites with an anti-environmental bent tended to dismiss the story. In this case, it's clear that the media source of the story made a big difference in the information offered to readers.

Our sample article on global warming seems to have been based on an interview with a key scientist and possibly also a press release. However, no specific scientific publication (e.g., a journal article) is cited, which makes it difficult to learn more about this work. On the plus side, we have no particular reason to believe that a major newspaper or the author would have any agenda other than to inform readers of an interesting development in science.

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Beware of false balance: Are the views of the scientific community accurately portrayed?

Balanced reporting is generally considered good journalism, and balance does have its virtues. The public *should* be able to get information on all sides of an issue—but that doesn't mean that all sides of the issue deserve equal weight. Science works by carefully examining the evidence supporting different hypotheses and building on those that have the most support. Journalism and policies that falsely grant all viewpoints the same scientific legitimacy effectively undo one of the main aims of science: to weigh the evidence.

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Our sample article on global warming, for example, balances its report like this:

> *Some scientists believe that human-produced carbon dioxide is causing Earth to warm dangerously. This view is supported by some ice core studies. However, skeptics question this opinion, arguing that we lack evidence that the warming is not simply a natural part of the planet's climate fluctuations.*

and then ends it with more uncertainty:

> *However, scientists have not yet come to a conclusion regarding the main question*

inspired by the ice core data: Do higher carbon dioxide levels actually cause temperature increases?

This report maintains journalistic standards for balance, but it's not a very accurate depiction of the state of science at the time. Even in the early 1990s, scientists who studied the issue had weighed the evidence and concluded that global warming could likely be traced to humanity's increased production of greenhouse gases, like carbon dioxide. Yet the newspaper article seems to give equal weight to the few skeptics. And this false balance is not unusual. A survey of articles in topnotch U.S. newspapers published between 1988 and 2002, found that 52.6% of those that dealt with global warming balanced the human contribution to global warming with a skeptical viewpoint. Meanwhile, the scientific evidence for the human contribution to global warming became ever more convincing. A survey of 928 scientific journal articles published between 1993 and 2003 found that *none* of them disagreed with the idea that human activities are causing global warming! Such a disconnect between the true views of the scientific community and those represented in the popular press make it difficult for a casual reader to get an accurate picture of the science at stake.

WHO'S THE EXPERT?

Some popular science stories provide journalistic balance by including the views of two scientists—one on each side of an issue. For example, a magazine article about the origins of life might quote Scientist A, who argues that we have a good understanding of the chemical reactions that led up to the origin of life, and Scientist B, who argues that we don't know much about these reactions now and that we never will. In untangling such conflicting messages, it pays to investigate each scientist's area of expertise. Knowing that Scientist A is a biochemist who studies the origins of life and that Scientist B is a physicist who works on electricity and magnetism could factor into your assessment of the controversy. Scientific knowledge is immensely deep and varies widely across fields. No single scientist can be an expert on everything. Also, beware of science stories that quote Dr. XYZ without explaining Dr. XYZ's area of expertise. Plenty of scientists don't have Ph.D.s, and plenty of doctors (e.g., those with Ph.D.s in English) don't necessarily have a strong scientific background.

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Too tentative: Is the scientific community's confidence in the ideas accurately portrayed?

Contrary to popular opinion, science doesn't prove a thing …

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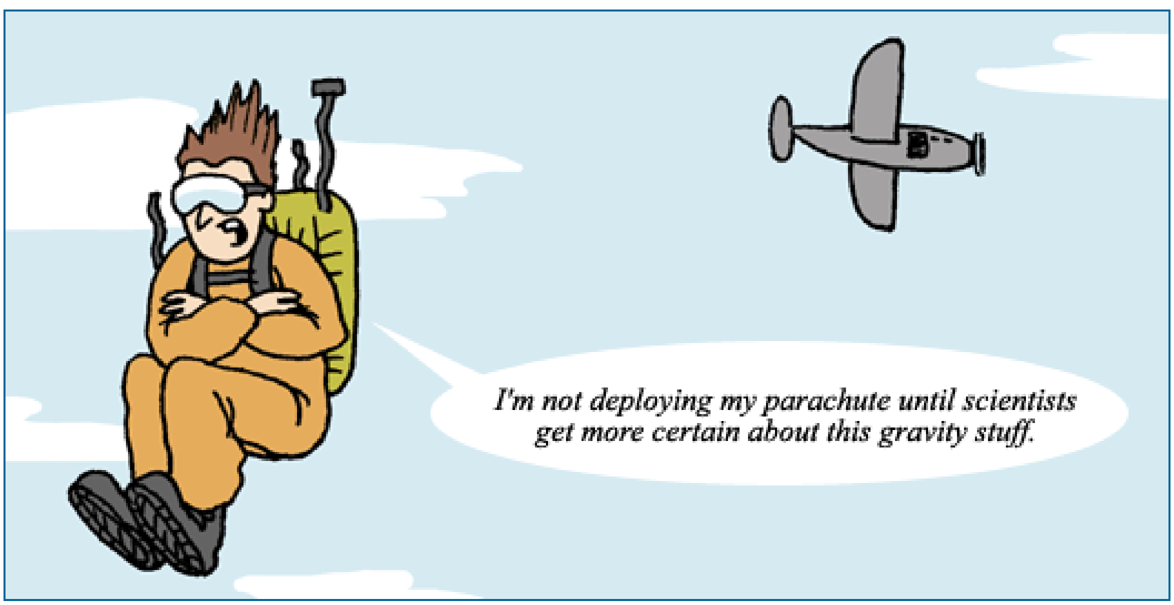
All scientific ideas—even the most widely-accepted and best-supported, like the germ theory of disease or basic atomic physics—are inherently provisional, meaning that science is always willing to revise these ideas if warranted by new evidence. However, that tentativeness doesn't mean that scientific ideas are untrustworthy … and this is where some media reports on science can mislead, mistaking provisionality for untrustworthiness. For example, in our sample article, the evidence for humanity's contribution to global warming is depicted as shaky ("*Some* scientists *believe* that human-produced carbon dioxide is causing Earth to warm dangerously. This view is supported by *some* ice core studies."), even though evidence supporting the idea is actually quite strong. Sure, science can't *prove* that human activities lead to global warming, but neither can it *prove* the existence of gravity; yet both ideas are trustworthy and strongly supported by evidence.



Some policies make the same misinterpretation of provisionality in science. For example, in 2002, the U.S. government called for more studies to resolve "numerous uncertainties [that] remain about global warming's cause and effect" before taking action. It is true that numerous uncertainties about global warming existed in 2002 and exist today. Uncertainty and tentativeness are inherent aspects of the nature of science. However, even in 2002, climatologists had a strong and well-supported understanding of key features of global warming.

HEED THE HYPE

On the opposite end of the scale, some media reports blow the implications of scientific findings out of proportion, failing to mention caveats and additional research yet to be done. For example, every few years, gene therapy makes a spotlighted appearance in the news—and for good reason. Gene therapy holds the promise of correcting genetic diseases at their source by replacing broken genes with working versions, but this is still largely just a promise. A 1993 newspaper article, for example, predicted that "Human DNA will be a major heart 'drug' of the near future with gene therapy a common treatment procedure," though such treatment was still unavailable as of 2007. Such sensationalized reports ignore the logistical difficulties of getting new genes to the cells that need them. So while the nightly news may herald widespread gene therapy as "just around the corner," a deeper investigation into the science behind the hype would paint a different picture. Almost 30 years after the first rumblings about the possibility of gene therapy, the technique is still in experimental stages.


THE TOWNSVILLE PAPER DECEMBER 14, 2

Miracles of gene therapy right around the corner

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What controversy: Is a controversy misrepresented or blown out of proportion?

Here's a headline unlikely to run in any paper: *Senate getting along: No fights or arguments for days!* That's because good news is generally no news. Clashes, on the other hand, are exciting and often important. So it's not surprising then that media reports on science often focus on controversy. However, when a scientific idea is portrayed as controversial in the popular media or in a policy, that conflict might be one of a few different types, which stem from different sources:

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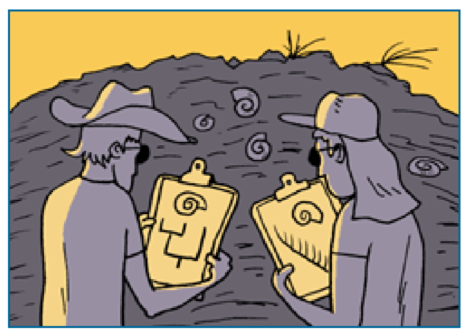
- **Fundamental scientific controversy**—scientists disagreeing about a central hypothesis or theory. If you imagine scientific knowledge as a web of interconnected ideas, theories and hypotheses are at the center of the web and are connected to many, many other ideas—so a controversy over one of these principal ideas has the potential to shake up the state of scientific knowledge. For example, physicists are currently in disagreement over the basic validity of string theory, the set of key ideas that have been billed as the next big leap forward in theoretical physics. This is a fundamental scientific controversy.



- **Secondary scientific controversy**—scientists disagreeing about a less central aspect of a scientific idea. For example, evolutionary biologists have different views on the importance of punctuated equilibrium (a pattern of evolutionary change, characterized by rapid evolution interrupted by many years of constancy). This controversy focuses on an important aspect of the mode and rate of evolutionary change, but a change in scientists' acceptance of punctuated equilibrium would not shake evolutionary biology to its core. Scientists on both sides of the punctuated equilibrium issue accept the same basic tenets of evolutionary theory.

- **Conflict over ethicality of methods**—disagreement within the scientific community or society at large over the appropriateness of a method used for scientific research. For example, many people have concerns over the ethicality of stem cell research that relies on human embryonic stem cells. These cells are gathered from fertilized eggs a few days old, which are donated by couples undergoing *in vitro* fertilization and who cannot use those eggs. Such concerns do not represent conflict

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over scientific knowledge, but over what constitutes ethical means for building that knowledge.

- **Conflict over applications**—conflict over the application of scientific knowledge. For example, activists sometimes clash over the issue of nuclear energy plants and whether or not they are a safe and environmentally sound means of producing energy. Although there are honest scientific controversies on issues relating to nuclear reactions, this is not one of them. This is not a conflict over a scientific idea, but over how such ideas should be applied.

- **Conflict between scientific idea and non-scientific viewpoint.** For example, scientific evidence supports the view that the Earth is about 4.5 billion years old; however, some groups reject this view in favor of a young Earth, created just a few thousand years ago. This *is* a conflict over scientific knowledge, but not one within the scientific community.

True scientific controversy (the first two sorts listed above) is healthy and involves disagreements over how data should be interpreted, over which ideas are best supported by the available evidence, and over which ideas are worth investigating further. This sort of catalyst sparks careful examination of the data and additional research and so can help science move forward. However, other sorts of controversy can impact science in different ways. Conflicts between scientific ideas and non-scientific viewpoints, for example, can hinder science if the controversy shuts down research in contested areas.

Furthermore, mistaking one form of controversy for another could easily lead one astray about the science at stake. For example, our sample article on global warming refers to "the so-called 'global warming' debate," but what is the nature of this debate? As reflected by the reports from the Intergovernmental Panel on Climate Change, the global scientific community is largely in agreement that global warming is occurring and that human activities are to blame—so this so-called debate is not a fundamental scientific controversy. However, there are many smaller details of climate change (how fast it is occurring, how best to model it, etc.) that are actively being researched and discussed—so the debate is an example of a secondary scientific controversy.

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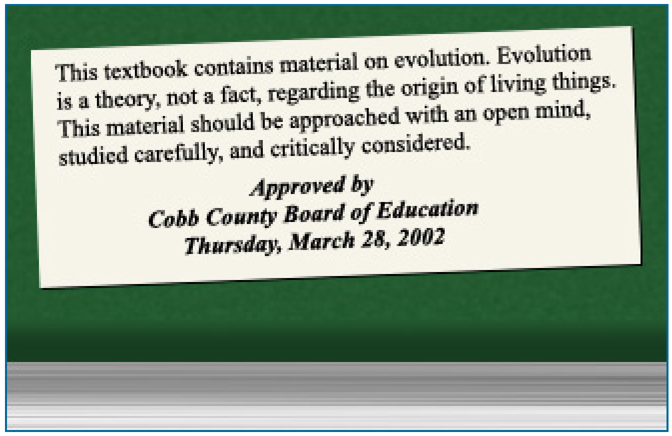
COUNTERFEITING CONTROVERSY



The social controversy about evolution has played out in many ways, like this textbook warning label, which was ruled unconstitutional.

Evolution provides an example of a conflict between a scientific idea and a non-scientific viewpoint. Biologists overwhelmingly agree that life has diversified through evolutionary processes over billions of years. Because of this scientific consensus, there is no fundamental scientific controversy over evolution. However, as with any area of scientific research, secondary scientific controversies (in this case, over the pace of evolutionary change, the frequency of different modes of speciation, etc.) continually arise as research progresses and scientists test new ideas against evidence. Unfortunately, groups against teaching evolution in schools sometimes take advantage of these secondary controversies, trumping them up as fundamental controversies and falsely presenting them as indicators of a "theory in crisis." Even more unfortunately, this misrepresentation has contributed to a social controversy over what ideas should be taught in our science classrooms, with the anti-evolutionists arguing for the inclusion of what they term *alternative* viewpoints. This social debate has long since departed from the science at stake. There is no scientifically viable alternative that can stand up to the overwhelming evidence supporting evolutionary theory.

The four tips we've seen so far have all dealt with misrepresentations or exaggerations of science. To check out tips for evaluating the science itself, read on …

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Getting to the source: Where can I get more information?

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Sometimes an article in your local newspaper just isn't enough. Maybe you've opened your morning paper to a report on herbal treatments for cold symptoms. With your stuffy nose and scratchy throat, the idea sounds appealing—but you need more information about side effects, drug interactions, and the supporting evidence. Or perhaps you've heard about policy changes that would encourage people to buy cars that can run on ethanol instead of regular gasoline, but before you jump on the bandwagon you want to know the scientific basis for this switch. A popular science article or an article in your local paper may not give you enough information to make a judgment and may even selectively discuss evidence, ignoring some lines entirely—but with a little extra research, you can do better than your local paper. Where should you go to learn more about the science underlying these issues? For topics of current research, the books available at your library may be out of date and many details are likely squirreled away in journal articles that could be difficult to access and interpret. In this situation, the internet is a great resource, but not all internet sites are created equal and not all of them offer unbiased explanations of the science at stake.

Here are a few considerations for finding additional sources of scientific information online:

- **Find sources with scientific expertise.** Try to find websites produced by a research institute, a governmental body, a respected educational institution, or a major scientific association (e.g., the American Psychological Association). These sorts of organizations are all key parts of the scientific community and have an interest in accurately explaining scientific issues. For example, the Centers for Disease Control, the American Association for the Advancement of Science, the U.S. Geological Survey, the U.S. Fish and Wildlife Service, or *Nature* magazine are all trustworthy choices. On the other hand, Badger Creek Elementary and Tipsfromtodd.com probably don't have access to up-to-date scientific information and may not feel any responsibility to provide fair and accurate information.

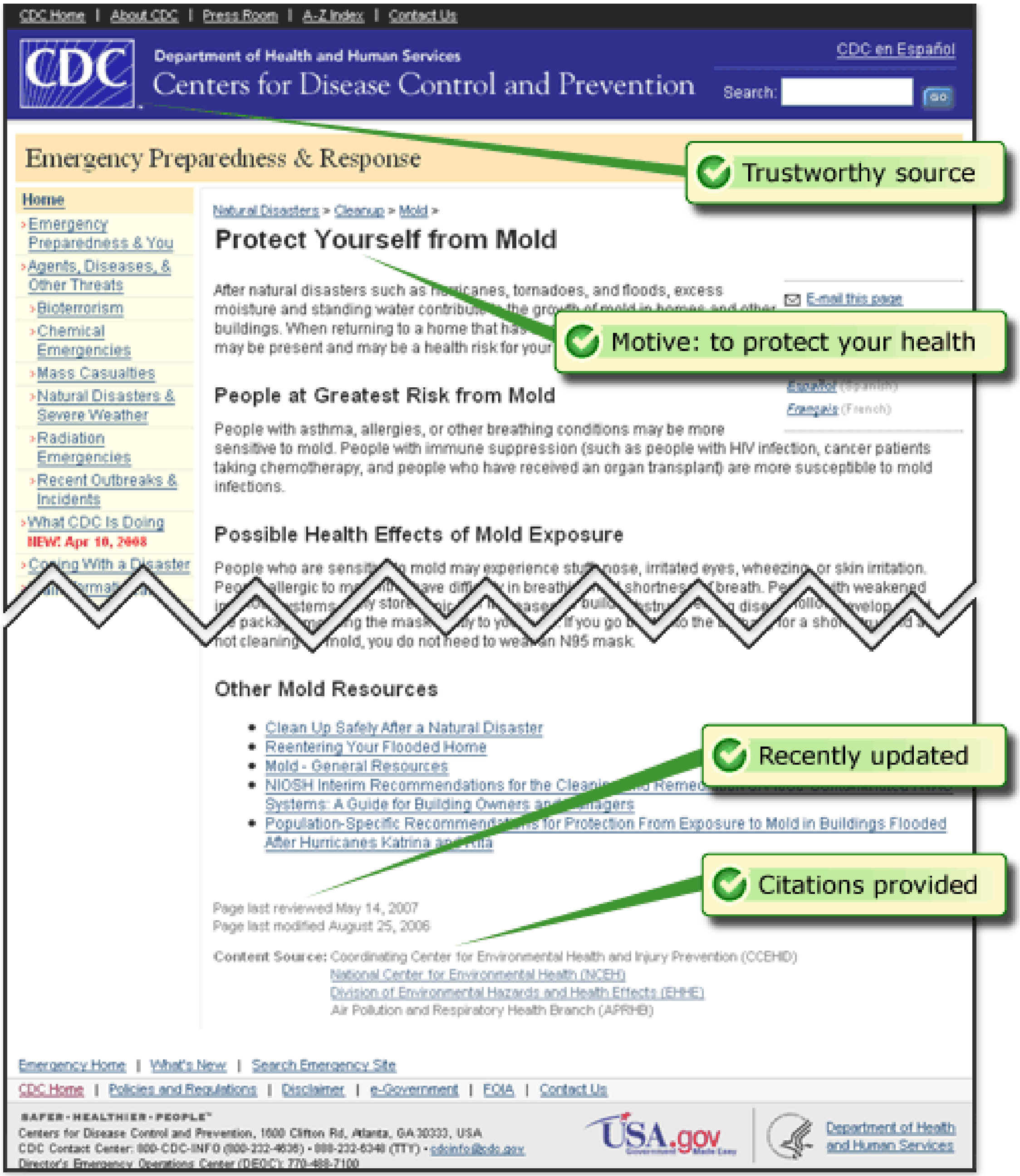
- **Avoid ulterior motives.** Try to avoid websites from groups that might stand to gain by biasing the information presented, like some lobbying or advocacy groups. It's particularly important (and easy) to avoid websites that are trying to sell something. For example, Buy-herbal.com is unlikely to give unbiased evidence of the effectiveness of the herb Echinacea. Instead you might try the National Institutes of Health website, since that organization has no stake in the issue other than helping people stay informed and healthy.

Can you spot the conflict of interest?

- **Keep it current.** Science is ongoing and is continually updating and expanding our knowledge of the universe. Scientists publish many hundreds of papers each year on areas of active scientific research. For example, in 2006 alone, more than 15,000 scientific articles on the topic of breast cancer were published. Because of the rapid pace at which our scientific knowledge advances, websites can easily become out-of-date if not actively maintained. So a website last updated in 2002 is unlikely to give you a useful understanding of the costs and benefits of using ethanol as fuel. Instead, look for a more current website.

- **Check for citations.** As described in *Scientific culture*, scientific publications generally give credit to related research by providing a list of citations—and that means that citations can help you gauge a website's scientific validity. A website that provides a comprehensive list of citations from scientific journal articles is more likely to provide an accurate portrayal of the science involved than one with suspicious, scanty, or nonexistent references. As an added bonus, by studying those references, you can double-check the website's information or dig even deeper into the issue.

A sample page from www.cdc.gov:



As an example of how one might get more information on a science-related issue, let's return to our sample article on global warming, which briefly describes scientist Lonnie Thompson's ice core studies. Where could one find more details on ice cores and how they can inform global warming research? First, you might check out an interview with the scientist from *National Geographic*. This 2004 article is written for the general public (and includes no citations) but is from a trustworthy source and offers the direct perspective of a scientist involved with the work. And if that's not enough, you might turn to NASA's in-depth tutorial on paleoclimatology, which meets all of our guidelines: it's from a trustworthy source without ulterior motives (NASA), was posted relatively recently (2005), and includes citations from the scientific literature.

Convince me: How strong is the evidence?

When evaluating a scientific idea, scientists carefully consider the relevant evidence …

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… and you can too. You've read an article in the newspaper, done a little more research, uncovered several lines of evidence, and now it's time to weigh those data for yourself. Here are some questions to ask as you consider the evidence:

- Does the evidence suggest correlation or causation? In other words, do the data suggest that two factors (e.g., high blood pressure and heart attack rates) are correlated with one another or that changes in one actually *cause* changes in the other?
- Is the evidence based on a large sample of observations (e.g., 10,000 patients with high blood pressure) or just a few isolated incidents?
- Does the evidence back up *all* the claims made in the article (e.g., about the cause of heart attacks, a new blood pressure drug, *and* preventative strategies) or just a few of them?
- Are the claims in the article supported by multiple lines of evidence (e.g., from clinical trials, epidemiological studies, and animal studies)?
- Does the scientific community find the evidence convincing?

For example, our sample article on global warming mentions one relevant line of evidence—ice cores—but provides few details. A little additional research reveals that ice cores contain bubbles of air captured from Earth's atmosphere many hundreds of thousands of years ago. Those air bubbles contain isotopes of oxygen that provide an indication of past temperatures. These samples suggest that, historically, global temperatures have risen and fallen in step with carbon dioxide levels. And further research into global warming uncovers other lines of evidence—for example: modern atmospheric records indicate that human activities have been increasing the concentrations of carbon dioxide and other greenhouse gases in the atmosphere, modern climate records indicate that the climate is currently warming, and models of the Earth's atmosphere provide a picture of why increased carbon dioxide levels might lead to higher temperatures. The scientific community finds this evidence convincing.

Understanding Science

FOLLOW THE MONEY

When examining the evidence behind a scientific issue, it's worth paying attention to the funding source for that research. Is it a group with no particular stake in the outcome (like the National Science Foundation), or is it a group with a more personal interest in the issue? Mars Incorporated, for example, funds research on the benefits of chocolate, and tobacco companies have funded research on the health effects of smoking. If research is funded by an interested party, it makes sense to examine that study carefully. Do its findings fit with those of other studies? Does the study seem to be fairly designed? Scientists strive to design fair tests and assess the evidence without bias, but because scientists are human too, biases sometimes sneak in and can take time to be corrected. For example, several studies have found that research funded by pharmaceutical companies is more likely to produce results favoring the company's product than is research with other funding sources.

Summing up the science toolkit

Here, we've seen that a little consideration can go a long way towards assessing the scientific messages that come your way everyday—whether it's the heart-healthy logo on your cereal box or a news report of a government decision on coastal conservation. You can get to the science beneath the spin by applying what you know about how science works: how scientific ideas are evaluated and publicized, the inherent provisionality of scientific ideas, the nature of scientific controversy, and how science is funded. Science itself is simply a way of learning about the natural world, but because that knowledge is powerful and affects many aspects of our lives, identifying misinterpretations and misrepresentations of science is a key part of a scientific outlook on life.

But that's not all that a scientific view of the world will buy you. Some aspects of the process of science can be put to use in your everyday life. For example, you can use scientific reasoning, evidence, and ideas to solve everyday problems—like figuring out what's wrong with your car by testing one hypothesis about the problem at a time, just as a scientist might set up an experiment. More generally, a scientific view of the world can help you retain and increase your curiosity about and appreciation of the natural world. A view of the Himalayas is certainly breathtaking, but it is even more powerful when viewed with an understanding of the natural processes that the mountain range represents—40 million years of colliding plates pushing up peaks and exposing them to the slow work of erosion. The night sky is pretty, but it is fascinating when one understands the distance of the stars and the ancient events that their light represents. And a hummingbird is beautiful, but it is awe-inspiring when one considers the lightning rate of the chemical reactions within its cells that power its fast-beating heart. Science asks the deepest of all questions about the natural world around us: how did the universe get to be the way it is today, and what will it be like tomorrow? This is an incredible mystery—but one which science gives us the tools to understand and appreciate.

A scientific view of the world has many practical benefits and can also help you to better appreciate the natural world.

Fire weather map provided by National Oceanic and Atmospheric Administration's National Weather Service; nutrition facts image provided by U.S. Department of Health and Human Services; medicine bottles provided by Courtesy Dewitt Stetten, Jr., Museum of Medical Research, National Institutes of Health; hummingbird photo provided by Dr. Lloyd Glenn Ingles © California Academy of Sciences; Himalayas photo provided by NASA; star photos provided by NASA/ ESA/Antonella Nota (STScI/ESA).