(美) THOMAS A. EASTON 编

TAKING SIDES 立场

辩证思维训练

科技与社会篇

10TH EDITION 第10版

CLASHING VIEWS IN

SCIENCE, TECHNOLOGY, AND SOCIETY

外语教学与研究出版社

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TAKING SIDES: Clashing Views in Science, Technology, and Society

Tenth Edition

EDITORS

Thomas A. Easton
Thomas College

ACADEMIC ADVISORY BOARD MEMBERS

英语思辨，攻错他山

朱绩崧

学界奉为圭臬的《牛津英语大词典》（*The Oxford English Dictionary*）在side (n.)[1]条目的18.a.义项里，把18.b.所收词组“to take a (or one's) side, take sides. Also to hold side (with one)”里的side解释为[t]he position or interests of one person, party, etc., in contrast to that of an opposing one，个人立场相反、党派利益对立之意，了然无疑。

惜我愚钝，近年才明白，take sides不仅仅是英语词典里的一个词组，甚至可说是英国议会制度的根本；而议会制度，实在是英国对人类文明进步最大的贡献之一：通过take sides，把思辨，而非独断专行，尊奉为国事决策那不可撼动的核心机制。我们不会忘记，电影《铁娘子》（*The Iron Lady*）里梅里尔·斯特里普（Meryl Streep）新学一口英国腔就来西敏寺宫滔滔激辩的场景，那不是骂街，虽然嘘声迭起，那是两股思想在龙争虎斗，最终推进历史。

谈到西方好争论、善思辨的传统，古希腊已臻化境，垂范千古。但这并不意味着我国真如某些评论家所言，为定于一尊的儒学所戕害，使得读书人唯服从传承是务，从不挑战权威。

《古文观止》读到最后几卷，便会看到编注者吴楚材、吴调侯叔侄鼓励读者对古时定论大胆质疑的用心。如建文忠臣方孝孺的名篇《豫让论》，标新立异，一反古说，直指春秋时代为主雪仇的刺客豫让“不能扶危于未乱，而捐躯于既败者”，不配“国士”之誉。

甚至，在我们历史课本一向蔑之为“埋头故纸”、“皓首穷经”的乾嘉学派里，多数学者的考据也都具有很高的思辨性。从王念孙的《读书杂志》、刘宝楠的《论语正义》，到戴震“由字义以明经义”的治学方法和段玉裁《东原先生年谱》所载的戴氏札记——“仆生平著述最大者为《孟子字义疏证》一书，此正人心之要。今人无论正邪，尽以意见误名之曰理，而祸斯民，故《疏证》不得不作”——从文本到现实，立场鲜明，无不指向对真理的上下求索。

读书为求真。这句话，是儿时由老师灌输给我的，我不曾怀疑过。可也正是老师告诉我“乾嘉学派在历史上的作用是反动的”、“高考答题时，如遇到岳飞，不能勾选为民族英雄，他打的仗是人民内部矛盾”等等当年不容我怀疑辩驳的“事实”。

往事固不可追，令我大失所望的却是“寓教于乐”、“反对应试教育”了不知凡几年，中小学生竟在变本加厉地背记历史、语文的“标准答案”，到了易只字则为错的地步。有人甚至把中小学生语文水平的普遍降低归咎于英语课太多，视母语、外语修习为零和博弈，全然不去审视、拷问、批判当下严重阻碍思辨与创造的文科教育体制本身。试问这样的教育，又如何能培养出活泼泼的人来？如何能引导他们求真？

求真，真真何其不易也。有时，权威发声，莫敢深究。有时，缺乏条件，无从寻觅。信息爆炸、思路开阔的今天，更多情况下是众说纷纭，莫衷一是，乃至有时在“是”与“非”这两者之间，都不知何从矣。

而相对综合型、重意合（parataxis）的汉语，英语是分析型语言，重形合（hypotaxis），语法规则更明确，对指代、性数格一致等形式要求更高，且有强烈的时态观。不能不说，这在很大程度上避免了汉语常见的因文害意：把一些站不住脚的歪理，用华丽辞藻一包装，就算是“美文佳构”了。（这方面，韩愈的个别名作，如为名教张目的《原道》，可算反面教材，远逊柳宗元的《驳复仇议》。后者的论理，简朴而流畅，本质上与今天英美法院经典判词如出一辙，堪称我国古代taking sides的典范。）加之英美学者好辩的传统在当代通过课堂教育、学术论文等形式得以强化，思辨的局面委实优于我国。

我素为古罗马倾倒，曾读国人编著的几种罗马史，又看了英国剑桥大学克里斯托弗·凯利（Christopher Kelly）教授写的《罗马帝国简史》（*The Roman Empire: A Very Short Introduction*），后者末章呈现的学者思辨生动别致，过目难忘，非我国传统重介绍“史实”的史书可比：20世纪初，英国历史学家、律师、自由党政治家詹姆斯·布赖斯（James Bryce）认为罗马帝国与大英帝国非常相似，都能维持高水平的内部和平与秩序，民人深谙工程技术，勇猛活跃，不畏困苦；牛津古代史教授弗朗西斯·哈弗菲尔德（Francis Haverfield）进一步说明，罗马帝国的成功，在于把行省居民同化为一个秩序井然、富有凝聚力的文明；曾奉职印度的英国古典学会会长埃弗林·巴林（Evelyn Baring）持不同看法，在“同化”问题上，大英帝国与罗马帝国有不可弥合的区别，单论印度语言、宗教、种族的多样性，就和罗马人征服的任何地区不同；哈弗菲尔德不同意巴林，认为英国之所以有印度问题，是因为征服印度时，印度已经发展成发达社会，文明形态稳固；牛津的古代史专家、考古学家D. G. 霍加斯（D. G. Hogarth）也反对巴林，认为罗马帝国有三个阶段，即“尚未同化”、“有意同化”、“积极同化”，大英帝国对印度犹处“尚未同化”的第一阶段。

把学者taking sides过程中的各种观点陈列出来，供读者思辨，是我国各阶段教材的短板。同时，也应注意，为提高我国学生的思辨水平以及英语能力，taking sides的内容不宜学科专业化程度过高（上述关于罗马帝国与大英帝国的争辩即有此虞），还是具有一定社会影响力、为民众熟知的话题更宜为组织教材的出发点。

美国著名的*Taking Sides*丛书，其宗旨正在于满足成长中的思考者兼英语学习者的需要。这套书系，诞生于20世纪80年代，迄今出版52种专题分册，多数一版再版，其中传媒凡12版，经济、环境达15版，社会、教育更已有17版之多。畅销程度，不劳赘言。

从题材看，外研社首批择取的七册分别覆盖了社会、教育、经济、环境、科技、大众传媒与全球性问题，无一不是当下公众话题的焦点。但呈现的手法却很“单一”，即先提出问题，再摆出正反双方最典型、最具说服力的论证，最后引导读者作进一步的阅读与思考：

问：计算机对学生成长是否有副作用？

正：有。学校对电脑技术的迷信与滥用，导致学生心智发育与创造力受损。

反：无。如对电脑善加利用，能促进教学革新，从而使学生获益。

后记："学校"或许正在由"地点"转变为"概念"，随着计算机技术的进步，许多教育手段都不必在课堂实施，但随之而来有许多新问题，需要探讨。多媒体能让学生与更多的信息产生互动，但往往也减少了学生与学生、学生与所在环境之间的互动。相关研究请见……（扩展阅读涉及三十余处学术资源）

（《教育篇》第10话题）

目录并不冗长，但当读者学完全书，必会惊喜地发现，自己在这一领域的知识结构已搭建得初具规模。摆在面前的问题往往庞大空疏，报章常见，迄无公断。从这个角度思考，有这样的道理可知；从那个方面切入，有那样的结论可得。读者的任务，就是跟着两派的思路各走一遍，最终判定哪派有理。当然，结果也可能是两派皆不尽善，或者需要修正调和之后才能获得正解。但无论如何，这一过程本身，实在是智力上的一次奥德修斯式的旅行（an intellectual odyssey）。

之所以要用荷马史诗的隐喻，是因为读*Taking Sides*与看街边吵架或中学生议论文最根本的差别，就是需要调用的思想、学术资源极多。以《社会篇》第8话题为例，菲利普·迪瓦恩（Philip E. Devine）在得出"酷刑不可保留"的结论之前，将自由主义政治学、康德学说、功利主义、自然法等一一引出，要言不烦。对迪瓦恩这位哲学学者而言，这些理论或许早已熟烂于胸。但对一般读者而言，为了确证作者没有断章取义，至少得就上述内容再读通几本导论、简介之类的书。顺便一提，酷刑当否的问题，我在近年畅销的一部法律通俗读物《法治》（*The Rule of Law*）论恐怖主义的一章中，也曾读到评论。作者、已故英国前首席大法官汤姆·宾厄姆（Tom Bingham）反对向恐怖主义犯罪嫌疑人施以酷刑的理由本质上与孔子的"己所不欲，勿施于人"无异，认为这是对法治原则的破坏。与迪瓦恩相较，其说直指人心，唯于学理微缺然。

事实上，*Taking Sides*书系所选文章，无论篇幅修短，莫不观点鲜明，针锋相对，而每一方都有强大的理据支撑，乍看难以撼动。由此，我们也不得不感叹，人类文明在今天呈现出的多样性，自有其道理，无论是同一文明内还是不同文明间发生的碰撞冲突，其背后都有复杂的理性动因，绝非皂白可以分明，需要我们全面观察，深度分析，最终选定立场。

我出身英文系，工作后常应媒体之邀，写些时事评论。落笔之前，现已养成习惯，会去新浪微博、知乎、Quora等网站，浏览各方的理性评论，在争议极大的问题上，熟悉*Taking Sides*封面上印的那两个词：Clashing Views（对立观点）。这是我在"后大学"时期补上的一堂课。

回想本科求学时，这方面所受教育几乎为零。教育的重点是背同义词、反义词

与词形变化。文章，读通便好，却读不透，因为读通之后，总觉所言有理，不会想着去倾听“不同的声音”。这个弊端，到写毕业论文时曝露无疑：说明文还凑合，议论文就写不好了。名虽论文，连核心的论点都渺不可寻。这几年，本专业内，我还常常看到号称博士论文的研究综述，或者连文献回顾都没有的论文。

为了矫正这一通病，不少学校从编教材上下功夫，课文引入争议性话题，意在以此激发学生的critical thinking——“批判性思维”遂成高校英语教师培训班极为青睐的广告亮点。可惜，在我有限的学术视野内，能一变风气的作品，尚阙如焉。我看到过浅尝辄止者，其内一篇课文，取自美国某小报，讲一对夫妻人工受孕后离婚，胚胎留在医院冰箱里，不知如何处置，遂对簿公堂。最终，作者只是提出问题，没能向学生指出解决的途径。如果有至少两种具备一定思想深度与差异性的观点呈现在教材里，附上扩展研读的书目、提要，教育的效果定会面目一新，我们也会真正地开始在语言教育中培养思想者，而不只是机械的记忆者、复制者。这一任务，如前所示，*Taking Sides*完全胜任。

我乐于推荐该书系作精读教材的另一项理由在于语言质量。就量而言，目前的精读课（Intensive Reading），阅读量普遍过低，一两千词的文章，一读就是十天半月，课程设计者不明白唯有大数量与短时间的结合，方成就intensive之效。与此相比，以本书系一卷之量，读一学期，日均1500词左右，恰到好处。以质而论，本书系符合我的外语习得理念：中高阶学生，应以非虚构作品（non-fiction）为“主食”。例如，本书系中有大量美国国会证言（congressional testimony），思维严谨，语言地道，学习西方法律、外交以及高等翻译等专业的学生如能熟读成诵，其英语学习的眼界势必更上层楼。从实用的角度看，有理、有力、有节的明快文风才是日常工作、生活所需，是语言的“常态”；文学作品中因作者意图而创造出的丰富表达，只是语言的“变态”。由常入变，初地坚固，发展空间亦大。反是，恐事倍功半。

至于“泛读”，也有一个基于*Taking Sides*的策略可行：各个话题牵涉到的著作，一学期可读上三五本。如读《环境篇》，可辅读雷切尔·卡森（Rachel Carson）的《寂静的春天》（*Silent Spring*）；读《科技与社会篇》，可辅读阿道司·赫胥黎（Aldous Huxley）的《美丽新世界》（*Brave New World*）。此时，不妨多些文学作品，加深对“精读”义理的体悟思辨，可全“文以载道”之功。

此外，*Taking Sides*对如今各高校流行的英语辩论也有直接的指导作用，无论其辩题还是论据，都可在模拟阶段直接取用。我更相信，认真研读过本书系的学生，其论文一定不会沦为简介、综述，不会抄袭维基、百度，因为他们掌握了论文写作的核心技术：如何灵巧运用事实与逻辑来作严肃的学术之论，而非执着于印象、习惯、偏见的意气之争。

总之，希望*Taking Sides*书系的引进，能综合我国英语学生的语言习得与思维训练，既提升交流的效率，更开启求真的法门，在乱云飞渡的当今时代，帮助读者迅速达成思想之质与辞藻之文的兼美共谐。

Introduction

Analyzing Issues in Science and Technology

In his 2008 inaugural address, President Barack Obama said, "We will build the roads and bridges, the electric grids, and digital lines that feed our commerce and bind us together. We will restore science to its rightful place and wield technology's wonders to raise health care's quality and lower its costs." At the 2010 meeting of the American Association for the Advancement of Science, Eric Lander, co-chair of the President's Council of Advisors on Science and Technology, asked, "What is the rightful place of science?" and answered that it belongs "in the president's cabinet and policy-making, in the nation's classrooms; as an engine to propel the American economy; as a critical investment in the federal budget, even in times of austerity; as a tool for diplomacy and international understanding and as an organizing principle for space exploration." (See Eric S. Lander, "Obama Advisor Weighs 'The Rightful Place of Science'," *Science News* [June 5, 2010]; the question is also discussed in Daniel Sarewitz, "The Rightful Place of Science," *Issues in Science and Technology* [Summer 2009].) However, John Marburger, science advisor to President George W. Bush, notes in "Science's Uncertain Authority in Policy," *Issues in Science and Technology* (Summer 2010), that policymakers often ignore science in favor of preference, prejudice, and expedience.

The discussion of "the rightful place of science" is important for several reasons. One is simply that previous administrations have often made decisions based less on evidence than on politics and ideology. The other is that a great many of the issues that the United States and the world face today cannot be properly understood without a solid grounding in climatology, ecology, physics, and engineering (among other areas). This is not going to change. In the twenty-first century, we cannot escape science and technology. Their fruits—the clothes we wear, the foods we eat, the tools we use—surround us. They also fill us with both hope and dread for the future, for although new discoveries promise us cures for diseases and other problems, new insights into the wonders of nature, new gadgets, new industries, and new jobs (among other things), the past has taught us that technological developments can have unforeseen and terrible consequences.

Those consequences do *not* belong to science, for science is nothing more (or less) than a systematic approach to gaining knowledge about the world. Technology is the application of knowledge (including scientific knowledge) to accomplish things we otherwise could not. It is not just devices such as hammers and computers and jet aircraft, but also management systems and institutions and even political philosophies. And it is of course such *uses* of knowledge that affect our lives for good and ill.

We cannot say, "for good *or* ill." Technology is neither an unalloyed blessing nor an unmitigated curse. Every new technology offers both new benefits and new problems, and the two sorts of consequences cannot be separated from each other. Automobiles provide rapid, convenient personal transportation, but precisely because of that benefit, they also create suburbs, urban sprawl, crowded highways, and air pollution, and even contribute to global climate change.

Optimists Vs. Pessimists

The inescapable pairing of good and bad consequences helps to account for why so many issues of science and technology stir debate in our society. Optimists focus on the benefits of technology and are confident that we will be able to cope with any problems that arise. Pessimists fear the problems and are sure their costs will outweigh any possible benefits.

Sometimes the costs of new technologies are immediate and tangible. When new devices—steamship boilers or space shuttles—fail or new drugs prove to have unforeseen side effects, people die. Sometimes the costs are less obvious.

The proponents of technology answer that if a machine fails, it needs to be fixed, not banned. If a drug has side effects, it may need to be refined or its permitted recipients may have to be better defined (the banned tranquilizer thalidomide is famous for causing birth defects when taken early in pregnancy; it is apparently quite safe for men and nonpregnant women).

Certainty Vs. Uncertainty

Another root for the debates over science and technology is uncertainty. Science is by its very nature uncertain. Its truths are provisional, open to revision.

Unfortunately, most people are told by politicians, religious leaders, and newspaper columnists that truth is certain. They therefore believe that if someone admits uncertainty, their position is weak and they need not be heeded. This is, of course, an open invitation for demagogues to prey upon fears of disaster or side effects or upon the wish to be told that the omens of greenhouse warming and ozone holes (etc.) are mere figments of the scientific imagination. Businesses may try to emphasize uncertainty to forestall government regulations; see David Michaels, *Doubt Is Their Product: How Industry's Assault on Science Threatens Your Health* (Oxford University Press, 2008).

Is Science Just Another Religion?

Science and technology have come to play a huge role in human culture, largely because they have led to vast improvements in nutrition, health care, comfort, communication, transportation, and humanity's ability to affect the world. However, science has also enhanced understanding of human behavior and of how the universe works, and in this it frequently contradicts what people have long thought they knew. Furthermore, it actively rejects any role of God in scientific explanation.

Many people therefore reject what science tells us. They see science as just another way of explaining how the world and humanity came to be; in this view, science is no truer than religious accounts. Indeed, some say science is just another religion, with less claim on followers' allegiance than other religions that have been divinely sanctioned and hallowed by longer traditions. Certainly, they see little significant difference between the scientist's faith in reason, evidence, and skepticism as the best way to achieve truth about the world and the religious believer's faith in revelation and scripture. This becomes very explicit in connection with the debates between creationists and evolutionists. Even religious people who do not favor creationism may reject science because they see it as denying both the existence of God and the importance of "human values" (meaning behaviors that are affirmed by traditional religion). This leads to a basic antipathy between science and religion, especially conservative religion, and especially in areas—such as human origins—where science and scripture seem to be talking about the same things but are contradicting each other. This point can be illustrated by mentioning the Italian physicist Galileo Galilei (1564–1642), who in 1616 was attacked by the Roman Catholic Church for teaching Copernican astronomy and thus contradicting the teachings of the Church. Another example arose when evolutionary theorist Charles Darwin first published *On the Origin of Species by Means of Natural Selection* in 1859. Mano Singham notes in "The Science and Religion Wars," *Phi Delta Kappan* (February 2000), that "In the triangle formed by science, mainstream religion, and fringe beliefs, it is the conflict between science and fringe beliefs that is usually the source of the most heated, acrimonious, and public debate." Michael Ruse takes a more measured tone when he asks "Is Evolution a Secular Religion?" *Science* (March 7, 2003); his answer is that "[t]oday's professional evolutionism is no more a secular religion than is industrial chemistry" but there is also a "popular evolutionism" that treads on religious ground and must be carefully distinguished. In recent years, efforts to counter "evolutionism" by mandating the teaching of creationism or "intelligent design" (ID) in public schools have made frequent appearances in the news, but so have the defeats of those efforts. One of the most recent defeats was in Dover, Pennsylvania, where the judge declared that "ID is not science." See Jeffrey Mervis, "Judge Jones Defines Science—And Why Intelligent Design Isn't," *Science* (January 6, 2006), and Sid Perkins, "Evolution in Action," *Science News* (February 25, 2006).

Even if religion does not enter the debate, some people reject new developments in science and technology (and in other areas) because they seem "unnatural." For most people, "natural" seems to mean any device or procedure to which they have become accustomed. Very few realize how "unnatural" are such ordinary things as circumcision and horseshoes and baseball.

Yet new ideas are inevitable. The search for and the application of knowledge is perhaps the human species' single most defining characteristic. Other creatures also use tools, communicate, love, play, and reason. Only humans have embraced change. We are forever creating variations on our religions, languages, politics, and tools. Innovation is as natural to us as building dams is to a beaver.

Efforts to encourage innovation are a perennial topic in discussions of how nations can deal with problems and stimulate their economies (see David H. Guston, "Innovation Policy: Not Just a Jumbo Shrimp," *Nature* [August 21, 2008]). India has a National Innovation Foundation, and a similar government agency has been suggested for the United States (see Robert Atkinson and Howard Wial, "Creating a National Innovation Foundation," *Issues in Science and Technology* [Fall 2008]; see also Robert Atkinson and Howard Wial, *Boosting Productivity, Innovation, and Growth through a National Innovation Foundation* [Washington, DC: Brookings Institution and Information Technology and Innovation Foundation, 2008], available online at http://www.brookings.edu/~/media/Files/rc/reports/2008/04_federal_role_atkinson_wial/NIF%20Report.pdf or http://www.itif.org/files/NIF.pdf). The closest we have come so far is the Defense Advanced Research Projects Agency (DARPA; http://www.darpa.mil/), famous for its initiation of Internet technology, and ARPA-Energy (http://arpa-e.energy.gov/), launched in 2007 with hopes for equally impressive results in the field of energy.

Voodoo Science

Public confusion over science and technology is increased by several factors. One is the failure of public education. In 2002, the Committee on Technological Literacy of the National Academy of Engineering and the

National Research Council published a report (*Technically Speaking: Why All Americans Need to Know More About Technology*) that said that although the United States is defined by and dependent on science and technology, "its citizens are not equipped to make well-considered decisions or to think critically about technology. As a society, we are not even fully aware of or conversant with the technologies we use every day."

A second factor is the willingness of some to mislead. Alarmists stress awful possible consequences of new technology without paying attention to actual evidence, they demand certainty when it is impossible, and they reject the new because it is untraditional or even "unthinkable." And then there are the marketers, hypesters, fraudsters, activists, and even legitimate scientists and critics who oversell their claims. Robert L. Park, author of *Voodoo Science: The Road from Foolishness to Fraud* (Oxford University Press, 2002), lists seven warning signs "that a scientific claim lies well outside the bounds of rational scientific discourse" and should be viewed warily:

- The discoverer pitches his claim directly to the media, without permitting peer review.
- The discoverer says that a powerful establishment is trying to suppress his or her work.
- The scientific effect involved is always at the very limit of detection.
- Evidence for a discovery is only anecdotal.
- The discoverer says a belief is credible because it has endured for centuries.
- The discoverer has worked in isolation.
- The discoverer must propose new laws of nature to explain an observation.

The Soul of Science

The standard picture of science—a world of observations and hypotheses, experiments and theories, a world of sterile white coats and laboratories and cold, unfeeling logic—is a myth of our times. It has more to do with the way science is presented by both scientists and the media than with the way scientists actually do their work. In practice, scientists are often less orderly, less logical, and more prone to very human conflicts of personality than most people suspect.

The myth remains because it helps to organize science. It provides labels and a framework for what a scientist does; it may thus be especially valuable to student scientists who are still learning the ropes. In addition, it embodies certain important ideals of scientific thought. It is these ideals that make the scientific approach the most powerful and reliable guide to truth about the world that human beings have yet devised.

The Ideals of Science: Skepticism, Communication, and Reproducibility

The soul of science is a very simple idea: *Check it out.* Scholars used to think that all they had to do to do their duty by the truth was to say "According to" some ancient authority such as Aristotle or the Bible. If someone with a suitably illustrious reputation had once said something was so, it was so. Arguing with authority or holy writ could get you charged with heresy and imprisoned or burned at the stake.

This attitude is the opposite of everything that modern science stands for. As Carl Sagan says in *The Demon-Haunted World: Science as a Candle in the Dark* (Random House, 1995, p. 28), "One of the great commandments of science is, 'Mistrust arguments from authority'." Scientific knowledge is based not on authority but on reality itself. Scientists take nothing on faith. They are *skeptical.* When they want to know something, they do not look it up in the library or take others' word for it. They go into the laboratory, the forest, the desert—wherever they can find the phenomena they wish to know about—and they ask those phenomena directly. They look for answers in the book of nature. And if they think they know the answer already, it is not of books that they ask, "Are we right?" but of nature. This is the point of "scientific experiments"—they are how scientists ask nature whether their ideas check out.

This "check it out" ideal is, however, an ideal. No one can possibly check everything out for himself or herself. Even scientists, in practice, look things up in books. They too rely on authorities. But the authorities they rely on are other scientists who have studied nature and reported what they learned. In principle, everything those authorities report can be checked. Observations in the lab or in the field can be repeated. New theoretical or computer models can be designed. What is in the books can be confirmed.

In fact, a good part of the official "scientific method" is designed to make it possible for any scientist's findings or conclusions to be confirmed. Scientists do not say, "Vitamin D is essential for strong bones. Believe me. I know." They say, "I know that vitamin D is essential for proper bone formation because I raised rats without vitamin D in their diet, and their bones turned out soft and crooked. When I gave them vitamin D, their bones hardened and straightened. Here is the kind of rat I used, the kind of food I fed them, the amount of vitamin D I gave them. Go thou and do likewise, and you will see what I saw."

Communication is therefore an essential part of modern science. That is, in order to function as a scientist, you must not keep secrets. You must tell others not just what you have learned by studying nature, but how you learned it. You must spell out your methods in enough detail to let others repeat your work.

Scientific knowledge is thus *reproducible* knowledge. Strictly speaking, if a person says "I can see it, but you can't," that person is not a scientist. Scientific knowledge exists for everyone. Anyone who takes the time to learn the proper techniques can confirm it. They don't have to believe in it first.

As an exercise, devise a way to convince a red-green colorblind person, who sees no difference between red and green, that such a difference really exists. That is, show that a knowledge of colors is reproducible, and therefore scientific, knowledge, rather than something more like belief in ghosts or telepathy.

Here's a hint: Photographic light meters respond to light hitting a sensor. Photographic filters permit light of only a single color to pass through.

The Standard Model of the Scientific Method

As it is usually presented, the scientific method has five major components. They include *observation, generalization* (identifying a pattern), stating a *hypothesis* (a tentative extension of the pattern or explanation for why the pattern exists), and *experimentation* (testing that explanation). The results of the tests are then *communicated* to other members of the scientific community, usually by publishing the findings. How each of these components contributes to the scientific method is discussed briefly below.

Observation

The basic units of science—and the only real facts the scientist knows—are the individual *observations*. Using them, we look for patterns, suggest explanations, and devise tests for our ideas. Our observations can be casual, as when we notice a black van parked in front of the fire hydrant on our block. They may also be more deliberate, as what a police detective notices when he or she sets out to find clues to who has been burglarizing apartments in our neighborhood.

Generalization

After we have made many observations, we try to discern a pattern among them. A statement of such a pattern is a *generalization*. We might form a generalization if we realized that every time there was a burglary on the block, that black van was parked by the hydrant.

Cautious experimenters do not jump to conclusions. When they think they see a pattern, they often make a few more observations just to be sure the pattern holds up. This practice of strengthening or confirming findings by *replicating* them is a very important part of the scientific process. In our example, the police would wait for the van to show up again and for another burglary to happen. Only then might they descend on the alleged villains. Is there loot in the van? Burglary tools?

The Hypothesis

A tentative explanation suggesting why a particular pattern exists is called a *hypothesis*. In our example, the hypothesis that comes to mind is obvious: The burglars drive to work in that black van.

The mark of a good hypothesis is that it is *testable*. The best hypotheses are *predictive*. Can you devise a predictive test for the "burglars use the black van" hypothesis?

Unfortunately, tests can fail even when the hypothesis is perfectly correct. How might that happen with our example?

Many philosophers of science insist on *falsification* as a crucial aspect of the scientific method. That is, when a test of a hypothesis shows the hypothesis to be false, the hypothesis must be rejected and replaced with another.

The Experiment

The *experiment* is the most formal part of the scientific process. The concept, however, is very simple: An experiment is nothing more than a test of a hypothesis. It is what a scientist—or a detective—does to check an idea out.

If the experiment does not falsify the hypothesis, that does not mean the hypothesis is true. It simply means that the scientist has not yet come up with the test that falsifies it. The more times and the more different ways that falsification fails, the more probable it is that the hypothesis is true. Unfortunately, because it is impossible to do all the possible tests of a hypothesis, the scientist can never *prove* it is true.

Consider the hypothesis that all cats are black. If you see a black cat, you don't really know anything at all about all cats. If you see a white cat, though, you certainly know that not all cats are black. You would have to look at every cat on Earth to prove the hypothesis. It takes just one to disprove it.

This is why philosophers of science say that *science is the art of disproving,* not proving. If a hypothesis withstands many attempts to disprove it, then it may be a good explanation of what is going on. If it fails just one test, it is clearly wrong and must be replaced with a new hypothesis.

However, researchers who study what scientists actually do point out that the truth is a little different. Almost all scientists, when they come up with what strikes them as a good explanation of a phenomenon or pattern, do *not* try to disprove their hypothesis. Instead, they design experiments to *confirm* it. If an experiment fails to confirm the hypothesis, the researcher tries another experiment, not another hypothesis.

Police detectives may do the same thing. Think of the one who found no evidence of wrongdoing in the black van but arrested the suspects anyway. Armed with a search warrant, he later searched their apartments. He was saying, in effect, "I *know* they're guilty. I just have to find the evidence to prove it."

The logical weakness in this approach is obvious, but that does not keep researchers (or detectives) from falling in love with their ideas and holding onto them as long as possible. Sometimes they hold on so long, even without confirmation of their hypothesis, that they wind up looking ridiculous. Sometimes the confirmations add up over the years and whatever attempts are made to disprove the hypothesis fail to do so. The hypothesis may then be elevated to the rank of a *theory, principle,* or *law.* Theories are explanations of how things work (the theory of evolution *by means of* natural selection). Principles and laws tend to be statements of things that happen, such as the law of gravity (masses attract each other, or what goes up comes down) or the gas law (if you increase the pressure on an enclosed gas, the volume will decrease and the temperature will increase).

Communication

Each scientist is obligated to share her or his hypotheses, methods, and findings with the rest of the scientific community. This sharing serves two purposes. First, it supports the basic ideal of skepticism by making it possible for others to say, "Oh, yeah? Let me check that." It tells those others where to see what the scientist saw, what techniques to use, and what tools to use.

Second, it gets the word out so that others can use what has been discovered. This is essential because science is a cooperative endeavor. People who work thousands of miles apart build with and upon each other's discoveries, and some of the most exciting discoveries have involved bringing