Science literacy and natural history museums

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It appears that developed countries, such as the US, the UK and Italy, are losing the race against irrationalism and arbitrary thinking in regard to nature and human interactions. The incidence of misguided beliefs and the detachment from and, in some cases, outright hostility toward science are on the rise. Paradoxically, this is probably the period in the history of advanced countries in which increasing public and personal efforts have been directed toward the dissemination of scientific knowledge to increase public understanding of science. This article vindicates the role of natural history museums in consolidating rational and critical scientific thinking while briefly examining scientific illiteracy in developed countries. It also discusses methods to improve the involvement of natural history museums in the promotion of rational thinking, the only appropriate avenue for objective knowledge.

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1. Introduction

To paraphrase the first sentence of *The Manifesto* of Marx and Engels, "a specter is haunting the developed countries – the specter of irrationalism". A proliferation of unfounded beliefs, incorrect thinking and confrontation with science has been on the rise despite the public and private investment in science and technology in recent decades. Powerful healing crystal, auras, biorhythms, creation science and several kinds of cryptozoological tales – of which the Loch Ness monster is the most familiar – are just a few of those concepts with some relation to natural history. These represent only the tip of the "fringe science" iceberg, and are present more in people's minds than the plethora of recent scientific achievements that have made our lives better and safer (for a full catalogue of pseudoscientific subjects, see the journal *Skeptical Inquirer*, *http://www.csicop.org/si/*). Paradoxically, the First World is the main producer of scientific knowledge. It is now clear that either the science does not reach the public or the form of its communication is flawed in some way. Transmission of pure facts, thought of by some as pure propaganda, does not allow the audience to judge or incorporate the news into their personal contexts of thought unless some of the processes involved in obtaining those facts are also understood. Complicating this matter is the public being bombarded often with "new scientific facts" by the media, which is quick to release them regardless of any sound scientific foundation. A good example is the war against cancer, where ever so often a new gene or molecule is found to be related to some kind or process of cancer. The press usually ends the news article with "we are closer to the end of the disease", whereas in truth, the rate of decline in cancer since the Second World War has only been 5% (Kolata 2009; Spector 2010; but *see* Byers 2010).

There is a growing concern regarding the transmission of scientific knowledge, and hence, to counter this state of affairs, a greater effort to involve scientists in the diffusion of scientific knowledge is being made by governmental agencies and the scientific community itself (e.g. House of Lords 2000; Mori 2001). Further, some authors (Williams 2008) target school science teachers to reinforce the principles and procedures of scientific research in order to transmit the message of science.

How to include this subject of critical thinking in scientific curricula is a concomitant problem that has been discussed recently (Uriarte *et al.* 2007). In this sense,

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institutions devoted to the dissemination of science, such as natural history and science museums, may, in general, be losing the battle because of the incomplete or deficient transmission of the critical attitude that is the basis of all scientific knowledge. There has been some recent debate and literature on the renewal of the approach of natural history museums to some of these challenging problems and the public's understanding of these problems (Krishtalka and Humphrey 2000; Winker 2004; Newmark and Rickart 2007). However, the main focus has been on evolution and biodiversity, and, more recently, on global warming and its effect on biodiversity. Accepting these as major themes, other important and polemic issues that are related to the area of influence of natural history museums, such as stem cell research (*see*, for instance, DEFCON, *www.defconamerica.org*), should not be left out. We believe that all subjects that are in some way directly (or indirectly) related to nature may be approached and form the subject matter of exhibitions in natural history museums. All these should include a solid foundation for rational thought, which is critical if museums are to play any role other than the broadcast of science news. This implies that museum public activity should be focused slightly differently, with a clear demonstration of how to incorporate scientific ideas and facts into a general thought in order to promote an active defence of rationalism and science as the only admissible attitude towards objective knowledge.

This article offers the following: (i) a short presentation of cases of attack on science in several developed countries. We assume that these are only instances of a more general problem, indirectly supported by science literacy surveys; (ii) a synopsis of the role of natural history museums in consolidating and bringing to the forefront objective knowledge and rational thinking in geology, biology and other natural sciences. This function has been weakened because of the emphasis on facts rather than the process of obtaining them; (iii) a summary of the predominance of irrationalism in different aspects of American life, where a continuous increase has culminated in an irrational opposition to scientific knowledge of nature; and (iv) a call for a new role for natural history museums, and science museums in general, which simply requires them to retrieve their initial goals and methods of promoting rational thinking and objective knowledge.

2. How widespread is irrational thought in our modern society?

An idea of how widespread irrational thought is can be obtained from the number of publications, magazines and books on numerous unsupported subjects such as crystal healing, aura and homeopathies. A clearer idea of how serious the problem is can be seen in countries such as Romania, where the theory of evolution has been eliminated from school curricula (Bird 2007). In Poland several politicians, including the minister of education, were involved in a major controversy over creationism in 2006, when they organized the workshop "Teaching evolution theory in Europe: is your child being indoctrinated in school?" (Graebsch and Schiermeier 2006).

The problem became so serious that, in 2007, the Council of Europe Parliamentary Assembly urged its members to "firmly oppose" the teaching of creationism as a scientific discipline in schools, as can be seen in this report (*http://assembly.coe.int/main.asp?Link=/documents/workingdocs/doc07/edoc11297.htm*). Evolution is still taught in Polish schools (*http://en.wikipedia.org/wiki/Creation_and_evolution_in_public_education#Poland*). An additional example is the Serbian minister of education saying in 2004 that the idea of evolution was no more legitimate than the idea that God had created all creatures (*http://news.bbc.co.uk/2/hi/europe/3663196.stm*); in Italy, the teaching of evolution was removed from middle-school curricula (Castellacci 2006). Even more problematic are individuals involved in the creation of scientific knowledge who manifest unsupported opinion close to unscientific or irrational thinking. In 2009 the Italian Consiglio Nazionale delle Richherche, a major scientific public entity, funded with 9000 Euros the publication of the antievolutionism book *Evoluzionismo. Il Tramonto de Una Ipotesi* (Evolution. Sunset of a hypothesis) (De Mattei 2009). The editor, an expert in the history of the Catholic Church, is the vice president of this institution, and among the contributors are antievolutionists such as Maciej Giertych, member of the European parliament and the father of the Polish minister of education.

The real measure of the impact of irrational thinking can be estimated in general surveys. In 2006 the BBC counted more creationists than evolutionists in a public poll in the UK (*http://news.bbc.co.uk/2/hi/science/nature/4648598.stm*). It would be interesting to know if this ratio has diminished after the 2009 commemoration of Darwin's *Origin of Species* and birthday. Our guess is that the situation has not changed substantially.

In some countries the interests of citizens towards science and technology have been on the decline in recent decades. In Spain, the importance of science and technology among the Spanish population is surveyed by the Spanish Foundation for Science and Technology (Fundación Española para la Ciencia y la Tecnología, FECYT) every two years since 2002. The results obtained in 2008 show that only 9.6% of the Spanish population was interested in receiving information about science and technology. This figure is much lower than that of other subjects, such as medicine (28%) or sports (26.1%). This figure has remained unchanged in the last (2006, 2008) polls. The main reason cited by the 33.6% citizens polled is that they "do not understand" what science and technology can achieve or the implications of these to their lives (FECYT 2009).

3. On museums

Natural history collections and museums have their origins in the need to empirically support and document the descriptions of organisms, plants and animals that were not easily available or were from other distant parts of the world. It was coincident with the revival of natural history culture in the Renaissance and the creation of a community of learned scholars (Ogilvie 2006). Thus, it is important to mention that the appearance of such collections implied the following methodological requirement: scientific knowledge should have robust empirical support. However, at some point in history, these collections widened their function beyond research material and became objects of enjoyment and diffusion of scientific knowledge, giving rise to the appearance of the first public collections and natural history museums. As an example, the Ashmolean Museum, housed in the University of Oxford, "celebrated the new scientific outlook of the Renaissance". Following the Baconian model, the museum was seen as a "place for all to visit and so enter the drama of seeking the truth through science and share the harvesting of its benefits" (Hackman 1992). Since then, the collection, preservation and exhibition of objects in research and education have been the three main functions of museums. The availability of natural specimens, the application of rational thought and careful observation allowed the full development of disciplines such as geology, paleontology, and all natural sciences, as well as the rejection of the magical and fantastic that had pervaded natural history for centuries.

4. On illiteracy, partial illiteracy and biased scientific literacy

In a strict sense, the illiterate are those who cannot read or write (Cowie 1989). More recently, the term literacy has been refined to include not only the ability to read and write but also to mean "reading for learning, specially the capacity to identify, understand, interpret create and communicate knowledge" (Schleicher 2010). In its broad usage, illiteracy can be defined as being ignorant of a certain subject. In this sense, everyone can be considered as "partially illiterate". In other words, nobody can know everything. Generally the weight given to this word is context dependent, and we may talk about literacy or its lack thereof in art, literature and, in the current article, science. We propose, however, that there is a special kind of illiteracy that could be called "biased scientific literacy". It may be defined as the building of unfounded narratives from empirical facts or even "pseudo-facts". In this case, the person is not illiterate and may be familiar with a certain branch of science but reaches incorrect conclusions because of selective use of empirical data or faulty reasoning. This form of illiteracy can be easily remedied except when it is deliberately imposed, such as when those disseminating that knowledge carry a hidden agenda.

Knowledge is a continuous process that may be represented by a three-step process. There is a general level traditionally called wisdom, which may be imprecise and incorrect in some cases but could be correct at critical times. A good example of wisdom is given by J Diamond (2001), who reported that the inhabitants of Papua New Guinea, when confronted with a rare cataclysm that devastated their usual food resources, had to rely on the knowledge of the elders, who could recall their experience in finding alternative sources of food not used in times of prosperity. See Baltes and Kunzmann (2004) and Ardelt (2004) for more detailed discussions on wisdom.

Rational knowledge uses proper reasoning and available evidence to reach sound conclusions. Two characteristics of rational thought are "critical thinking" and "scepticism". Marshalling our experiences and deliberating on them could help us take satisfactory decisions on important issues. Simple techniques such as a double-entry table (Gilovich 1993) are useful to decide if a "New Age" alternative medicine has been effective for the treatment of a certain illness. Another example is those thousands of couples convinced that adopting a baby could lower their presumed stress, making it easier to become pregnant. A careful analysis of the available evidence shows that there is more wishful thinking than rigour in this notion (Lamb 1979). Given a second thought, there is no reason why rearing a child – adopted or not – should lower anyone's stress! A good example of how selective sampling of facts could lead to one's own desired conclusions has been pointed out by Hengeveld (2004). In his review of S Conway Morris's *Life's Solution. Inevitable Humans in a Lonely Universe*. In his book, Conway Morris argues in favour of "inevitable" convergences. However, Hengeveld disputes the representativeness of his sampling: "What proportions of all fish species, for example, has this torpedo shape and what proportion does not due to divergence process? Which category dominates? Does convergence occur perhaps so infrequently that it represents the statistical error range?" On the other hand, genuine knowledge could be developed with good observations and rational thinking and be very useful to society, as Florence Nightingale demonstrated. She revolutionized the care of soldiers in the 19th century, saving hundreds of lives (Stone 2001).

Finally, scientific knowledge uses systematic observations and experiments to reach rigourous and verifiable conclusions. The breadth of application of the three kinds of approximation to knowledge decreases as we move down from wisdom to rational thinking to scientific knowledge, but the rigour and control of the conditions applied to obtain robust empirical data increase. Obviously, the use of one of these approximations depends, in part, on the information available. Biased literacy refers to a partial partisan use of the data or the information. In many cases, however, there is simply a lack of knowledge of relevant facts. In this sense, as already said, everyone is partially illiterate, as no one can be properly informed about everything that scientific research has produced.

5. Biased literacy versus illiteracy

There is a big difference between being illiterate and being irrational. In the example provided earlier, the tribes in Papua New Guinea were illiterate in the strict sense of the word but were far from being irrational. To be the latter could have had drastic consequences for their survival. On the other hand, many in our societies, not strictly illiterate, are able to write and read, but are clearly irrational when using flawed logic in their personal and public decision-making. Obtaining a proper estimate of a society's level of scientific illiteracy is a complex enterprise (Bauer *et al.* 2007). We may have glimpses of its relevance when using important reference items such as answers to questions about the moon landing, the atomic theory of matter or the theory of evolution. Accepting or rejecting those items provides clear information on gross personal scientific literacy. But to obtain a more refined image is a difficult task. A rough estimate of the rampant irrationalism in our modern society may be obtained by estimating the number of fortune tellers, astrologers, healers and the like. For example, a Gallup poll showed that more than 55% of American teenagers believed in astrology (Paulos 2001). On the other hand, some religious sects frequently cross the line between faith and impostures. An extreme example of the latter is the miracle crusade that took the evangelist Benny Hinn to Nigeria in 2005. Unable to produce the prodigy for a massive audience, Hinn departed from Nigeria a few days after his arrival, leaving for a better opportunity the production of other "minor miracles" such as different kinds of instantaneous healings (Igwe 2005).

On the political side, when presidential candidates such as Senator Sam Brownback, Governor Mike Huckabee and Representative Tom Tancredo raised their hands to the question "who doesn't believe in evolution?", then, as Jerry A Coyne explains, we are really in trouble (Coyne 2007). But to believe in astrology, instant healing and rejection of evolution are different faces of the same problem: a lack of proficiency to think correctly.

J D Miller has been studying the understanding of science, what he calls "the civic scientific literacy", for more than 30 years (Gross 2006). In his sense, "civic scientific literacy" is the capacity to make sense of opposing arguments in a scientific debate. Miller *et al.* (2006) found that the number of US adults accepting the idea of evolution has decreased from 45% to 40% during the last 20 years. From our point of view, Miller's concept should take into account the problem of scale. General theories, such as the theory of evolution or the atomic nature of matter, if rejected, produce a lack of understanding of present-day knowledge, and hence are easy indicators of the "civic scientific literacy". Rejection can only come from a partisan irrationalism. On a finer scale, more complex situations can be presented as in cases in which similar sets of facts are differently interpreted under different theories or when different sets of data are being assembled by competing theories and researchers. A typical example is the discussion regarding the different contributions of nature and nurture in shaping human behaviour and their implications for legal incrimination. Different points of view and different theories try to give an explanation for human behaviour (Laland and Brown 2002). Biased literates, in this case, could be those who are familiar with the subject and points of one interpretation but ignore the critics and alternative explanations of competing theories. Intelligent design is a compelling example of empirical facts under a flawed logic leading to erroneous conclusions. The continued support of the disproved theory when the biased arguments are exposed can justly be called irrationalism. In this particular case, it may be of interest to point out that a scientist like Francis S Collins – who has declared himself a believer – the co-director of the Human Genome Project, criticized the supposed scientific tenets of the proponents of intelligent design on scientific grounds (Collins 2006).

6. The role of natural history museums in a knowledgeable society

To be literate in science could be considered a process that pursues the familiarity with factual content and the application or generalization of rational thinking to life's affairs. Or, as the American Association for the Advancement of Science has defined it, to be aware of scientific facts and concepts and to use "scientific knowledge and scientific ways of thinking for individual and social purposes" (Liem 2005). But this implies, as Jonathan Osborne (2010) has remind us recently, that "one of the hallmarks of the scientist is critical, rational skepticism...". Science and natural history museums may play an important role in a rational literate society by going beyond the simple content of facts and theories while expanding their exhibitions to represent the processes used to obtain that knowledge; particularly, evaluating evidence, exercising critical thinking and dealing with uncertainty. Rational thought should be the link between exhibitions and knowledge. It might have a privileged place and should be expressed clearly in a variety of ways. New, imaginative and provocative exhibitions should attract the public and confront them not only with knowledge that has made our lives easier but also with the ways of thinking that help us to have a rational view of personal and public affairs. The following points are offered as tentative proposals to test new approaches to broaden the role of natural history museums in the promotion of scientific literacy among the general public:

1. There are two main kinds of public in relation to natural history museums: (i) those interested in natural history, and school/university students whose visits to these museums are included in their curricula. We may call them the "captive" NH population; and (ii) those who will not usually go to natural history museums because they think that what can be found there is not relevant to their interests. (The senior author still remembers the reply of an employee of a well-known photographic shop in New York when he heard about where the customer was working – American Museum of Natural History: "I never go to those places".) This last one belongs to the group that is to be attracted by bridging natural history with other aspects of culture such as painting and photography, literature and music. A few examples follow: Olivier Messiaen's enthralling "Catalogue d'oiseaux" could be the motto for a temporary exhibition on a particular kind of birds and their musical and natural qualities. Fátima Miranda's impressive combination of vocal creations close to the sounds of different animals, like the whales, is another possible choice for a similar exhibition (*http://www.fatima-miranda.com/finalok/home_eng.html*). Bestiary, either medieval or simply fantastic, as well as science fiction books, has sometimes been used as an argument for natural history exhibitions. However, books such as *Ocaso de Sirenas, Esplendor de Manaties* (Mermaids' Sunset, Manatee Sunrise) by the Peruvian author J Durand, which records the number of times since the discovery of America by Christopher Columbus that manatees were mistaken for classical mermaids illustrate the tendency to improperly interpret incomplete, imprecise observations. The number of possible paintings as subject matter for natural history exhibitions is unlimited. Some other suggestions can be found in Valdecasas *et al.* (2006). Additionally, natural history museums must be the focus of what cannot be found elsewhere in the media. In our experience, exhibiting real organisms in natural contexts, paraphrasing Kant's concept of "the-thing-in-itself", is what the majority of the public demand. And we have recently argued, because of the "kinesthesia of knowledge", that natural objects or their reproduction communicate knowledge or information better than the media (Valdecasas *et al.* 2009). Combining it with story-telling in the best Stevensonian tradition can have an even greater impact. Story-telling has an unending attraction for people, and natural history tradition is full of extraordinary stories with which to cover the core of an exhibition. Using other sources such as literature, art or music can add interest to such exhibitions. Knowledge transmission does not need to be a boring subject and, even less, an isolated field in the context of general culture. Knowledge and aesthetics should go together.
2. Invoke wonder and admiration by proposing new ways to look at old issues. Thought-provoking issues are essential for attracting attention before proceeding with a more conventional way of communicating knowledge. Despite some controversies, von Hagen's "Body Worlds" (*http://en.wikipedia.org/wiki/Body_Worlds*) is one of the best examples in recent times of how an old natural history subject – human anatomy – can be presented in a way that invokes awe and is at the same time highly informative. Another interesting avenue is to produce an exhibition on the different historical ways of representing natural bodies, such as the wax models of the Italian school (Poggesi 1999), the crystal model of the Blaschka brothers (Sigwart 2008) or the papier maché models of Dr Auzoux (Valdecasas *et al.* 2009). Museums, like other public displays, may benefit from a kind of "spectacular" beginning and a surprising ending. A close parallel is offered by the rule used by magicians in their performances: open with a great trick, follow with the selected performance and end with something to be remembered. The beginning and ending will be what most people will remember. The Natural History Museum in London, for instance, receives the visitors using a great dinosaur in a splendorous hall, something that many visitors never forget. Wonder and admiration are the keys to a deeper engagement with the pursuit of knowledge.
3. Include reasoning that would lead to conclusions, and if there are controversies, present them. Take the opportunity to point to erroneous ways of thinking about some phenomenon or subject so that the public can appreciate the difficulty of reaching a correct opinion. Important basic concepts like "variability", so fundamental for an adequate understanding of the world we live in, are not normally stressed as they should be. To be cautious in life, as in research, is a quality that should be continuously exercised. A good source of caution is the display of ways in which nature (or "human nature") can deceive us. There

are hundreds of examples in the sceptic literature (e.g. *Skeptical Inquirer*) of ways in which we could be mystified. On the other hand, it is remarkable that many of the results of evolutive psychology are based on a limited representation of the human population (Henrich *et al*. 2010). Detailed analyses of theories, scepticism and an open mind for alternative explanations are imperative. Reproduce polemics when possible. Polemics enlighten and provide models of thought for the future. Science is full of good stories of polemics between different points of view and characters. Retelling them with certain detail can help us understand the way present-day discussions takes place and, to a certain degree, puts a question mark on much that we read in newspapers. Do not avoid comparison of different views and different sources of data and make clear to the public that disagreement – if well founded – is the motor of knowledge.

4. Provide information on the sources of knowledge, even if it is specialized. No one knows where the curiosity of the public could lead them. Providing general and specialized literature is essential. There is an incorrect notion that specialized literature is useless for the public. There is no need to understand 100% of a scientific paper if part of the general context, the methods and conclusions can be grasped. The same happens to scientists: when R Lewontin asked the evolutionist Dobszhansky how he could explain so well in *Genetics and the Origin of the Species* a theory whose mathematical details he had neither read nor understood, Dobszhansky answered that he accepted as good the mathematical part "… and to read the conclusions he arrives at, and hope to goodness that … [the mathematics] is correct" (Provine 1989). For young attendees this could be a stimulus to learn more and be able to understand fully "cryptic" information. This is, for example, the approach taken by Körner in his very successful book *The Pleasures of Counting*, wherein he presents the following for his readers as an encouragement: "professional mathematicians consider a mathematics book worthwhile if they understand something new after reading it and excellent if they understand a fair amount that is new to them; anything more would lead them to suspect that the material was too easy to be worthwhile" (Körner 1998).
5. Display hierarchical learning, from more general theories to more particular, even if conflictive. Do not mix theories of differing levels of generality. There are general theories on which several millennia of human work and research have been based. There are particular theories that may be more polemic or conflictive, or are in competition with substantial alternative theories. Explain them. And, if necessary, say, "we do not know for sure". There is no danger in admitting uncertainty or ignorance, but there is a real danger in saying that something is true when six months later it is found to be not true after all. The important thing is not the transitory truth of the data or theory but the way we attempt to get that information. As Nature does not give up her secrets easily, we try to build knowledge on a clear intersubjective basis.
6. Give special emphasis to presenting how principles and theories can be used. The implications of general principles and laws should be shown. Principles or laws that have been gained by experience and research should be applied coherently. For instance, evolution, unity of life, has important consequences for our approach to research and solutions to disease and healing (Hillis 2005 and references therein). Paulos (2001) gives a good example with gravity and astrology, a pseudoscience that may have influenced the decisions of a former American president. In quantitative terms, the gravitational effect produced by someone going underground close to you is greater than that of some remote star or constellation. Those who postulate any stronger effect should identify the causal force or energy to which it is ascribed, and detail the way it can affect something as complex as future events. Unless this is explained, who would, in her or his sane judgment, conduct his or her life according to some unknown dictum? Besides this, it can be added that the best empirical studies (Gauquelin 1985) have not resisted detailed scrutiny (Benski *et al.* 1996; *see* also a short review by E Taner at *http://www2.truman.edu/~edis/writings/articles/mars-effect.html*). Some principles come simply from our life experience. One of these could be called "the specificity principle". In simple terms, it states that if you would like, for instance, to improve the power of your arms, it does not make much sense to exercise your legs! New Age proponents affirm that everything is connected. While this may be true, some connections are stronger than others, and many are so weak that they do not deserve consideration. If concerned with some empirical fact, why consider just any possible cause, even those so remote as to be almost "lacking influence"? It would be more interesting and productive to analyse those that could be closer to the effect. In others words, and to use the same case as before, who with a serious symptom would think about "all possible causes" in the entire "interconnected universe" to decide on a course of action? Would it be wise to think about the strange motion of an unknown planet in a distant galaxy to decide what to do about a particular disease? Examples of such thinking are manifold.

7. Challenge conflicting and fringe subjects in an exhibition, if they have a link to the natural history subject. Provide information and academic analysis of fringe subjects. Academic perspective and rigour are the keys to an adequate treatment of a given subject. The way to challenge some irrational beliefs is to expose them and argue and transmit a scientific evaluation that is understandable and convincing. One example could be an exhibition of rocks and precious stones, their physical properties and processes of formation. Compare their scientific, systematic organization with a classification of their supposed healing or magical powers and their proclaimed manner of working.
8. Above all, give a privileged place to critical reasoning and scepticism over legitimacy by authority. This, an extended phenomenon, even plays an important role in the internal affairs of scientific metabolism. Personalities in science with a media presence can help to attract the public but, at the same time, present the danger of replacing digested knowledge with appropriation of the more authorized opinion of others. This will confuse the lay person when he or she is confronted with another authorized voice that contradicts the former.

We live in a society overloaded with scientific facts and news. Our responsibility as researchers should not be to transmit those alone. Institutions involved in science dissemination and public scientific literacy should provide more "enlightenment" about how those facts are obtained and the essentials of critical rational thinking and the arguments that make them possible. How to apply this way of thinking to more mundane affairs should close the gap. Not doing so will lead to a dismal future.

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References

Ardelt M 2004 Where can wisdom can be found? *Hum. Dev.* **47** 304–307

Baltes P B and Kunzmann U 2004 The two faces of wisdom: wisdom as a general theory of knowledge and judgment about excellence in mind and virtues vs. wisdom as everyday realization in people and products; *Hum. Dev.* **47** 290–299

Bauer M W, Allum N and Miller S 2007 What can we learn from 25 years of PUS research? Liberating and expanding the agenda; *Public Underst. Sci.* **15** 1–17

Benski C, Caudron D, Galifret Y, Krivine J P, Pecker J C, Rouze M and Schatzman E 1996 *The 'Mars effect': A french test of over 1000 sports champions* (Amherst: Prometheus)

Bird M 2007 Romania removes theory of evolution from school curriculum; *The diplomat* (available at: *http://www.thediplomat.ro/reports_1207.php*; last seen on 16 August 2010)

Byers T 2010 Two decades of declining cancer mortality: Progress with disparity; *Annu. Rev. Pub. Health* **31** 121–132

Castellacci C 2006 The disease and the treatment: Some remarks on the Darwin-Moratti issue; *J. Sci. Commun.* **5** 1–3 (*http://jcom.sissa.it/archive/05/02/Jcom0502-%28-2006%29C01/Jcom0502%282006% 29C05/Jcom0502%282006%29C05.pdf*)

Collins F S 2006 *The language of God* (New York: Free Press)

Conway Morris S 2003 *Life's solution. Inevitable humans in a lonely universe* (Cambridge: Cambridge University Press)

Coyne J 2007 *Don't know much biology* (*http://www.edge.org/3rd_culture/coyne07/coyne07_index.html*)

Cowie A P 1989 *Oxford advanced learner's dictionary*, *fourth edition* (Oxford: Oxford University Press)

De Mattei R 2009 *Evoluzionismo. Il tramonto de una ipotesi* (Siena: Cantagalli Edizioni)

Diamond J 2001 Unwritten knowledge; *Nature (London)* **410** 521

FECYT 2009 *Percepción Social de la Ciencia y la Tecnología* (Madrid: Fundación Española para la Ciencia y la Tecnología)

Gauquelin M 1985 *Cosmic influences on human behaviour* (Santa Fe: Aurora Press)

Gilovich T 1993 *How we know what isn't so* (New York: Free Press)

Graebsch A and Schiermeier Q 2006 Anti-evolutionists raise their profile in Europe; *Nature (London)* **444** 406–407

Gross L 2006 Scientific literacy and the partisan takeover of biology; *PLOS Biol.* **4** 680–683

Hackman W 1992 "Wonders in one closet shut": The educational potential of history of science museums; in *Museums and the public understanding of sciences* (ed.) J Durant (London: Science Museum) pp 65–69

Hengeveld R 2004 Conway Morris' inevitable solution; *Acta Biotheor*. **52** 221–228

Henrich J, Heine S J and Norenzayan A 2010 The weirdest people in the world?; *Behav. Brain Sci.* **33** 61–135

House of Lords 2000 Science and technology; Third report (available at: *http://www.publications.parliament.uk/pa/ld1999-00/ldselect/ldsctech/38/3801.htm*

Hillis D M 2005 Health applications of the tree of life; in *Evolutionary science and society: educating a new generation* (eds) J Cracraft, R. Bybee and N M Washington (BSCS) pp 139–144

Igwe L 2005 Faith-healing no substitute for medicine in Africa; *The Skeptic* **Spring** 46–47

Kolata G 2009 In long drive to cure cancer, advances have been elusive; *The New York Times* **April 24**, p 1

Körner T W 1998 *The pleasures of counting* (Cambridge: Cambridge University Press)

Krishtalka L and Humphrey P S 2000 Can natural history museums capture the future? *Bioscience* **50** 611–617

Laland K and Brown G 2002 *Sense and nonsense: Evolutionary perspectives on human behaviour* (Oxford: Oxford University Press)

Lamb E J 1979 Does adoption affect subsequent fertility? *Am. J. Obstet. Ginecol*. **134** 138–144

Miller J D, Scott E C and Okamoto S 2006 Public acceptance of evolution; *Science* **313** 765–766

MORI 2001 *The role of scientists in public debate* (London: The Wellcome Trust)

Newmark W D and Rickart E A 2007 Are natural history museums telling the right story?; *Bioscience* **57** 390

Liem A 2005 Promoting science literacy by engaging the public; *PLOS Biol.* **3** 2075–2076

Ogilvie B W 2006 *The science of describing* (Chicago: The University of Chicago Press)

Osborne J 2010 Arguing to learn in science: The role of collaborative, critical discourse; *Science* **328** 463–466

Paulos J A 2001. *Innumeracy: Mathematical illiteracy and its consequences* (New York: Hill and Wang)

Provine W B 1989 *Sewall Wright and evolutionary biology* (Chicago: University of Chicago Press)

Schleicher A 2010 Assessing literacy across a changing world; *Science* **328** 433–434

Sigwart J D 2008 Crystal creatures: context for the Dublin Blaschka Congress; *Hist. Biol.* **20** 1–10

Spector R 2010 The war on cancer. A progress report for skeptics; *Skeptical Inquirer* **January/February** 25–31

Stone M 2001 Florence Nightingale. in *Statisticians of the Centuries* (eds) C C Hayde and E Seneta (New York: Springer) pp 171–175

Uriarte M, Ewing H A, Eviner V T and Weathers K C 2007 Constructing a broader and more inclusive value system in Science; *Bioscience* **57** 71–78

Valdecasas A G, Correia V and Correas A M 2006 Museums at the crossroad: Contributing to dialogue, curiosity and Wonder in natural history museums; *Museum Management and Curatorship* **21** 32–43

Valdecasas A G, Correas A M, Guerrero C R and Juez J 2009 Understanding complex systems: lessons from Auzoux's and von Hagen's anatomical models; *J. Biosci.* **34** 835–843

Winker K 2004 Natural history museums in a postbiodiversity era; *Bioscience* **54** 455–459

Williams J D 2008 Creationist teaching in school science: A UK perspective; *Evo. Edu. Outreach* **1** 87–95

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