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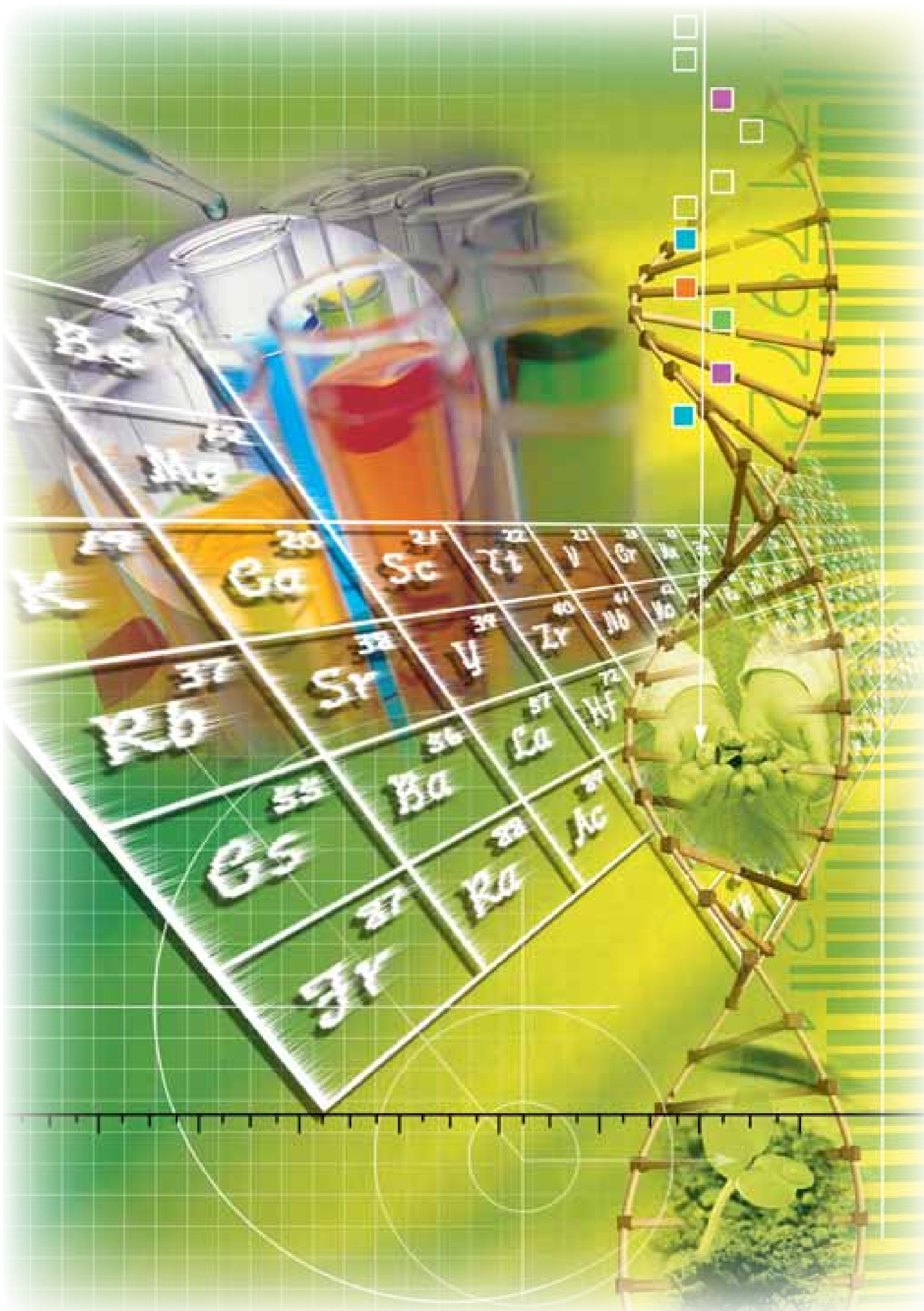

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Contents

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ASEJ publishes scholarly work and strictly follows the blind review procedures and many other editorial policies described in the *Publication Manual of the American Psychological Association*, 5th edition (Washington, DC: American Psychological Association, 2001). Thus *ASEJ* is a refereed journal similar to most other scholarly periodicals published in Canada and the United States.

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From the Editor

Wytze Brouwer

Tracy Onuczko and Susan Barker, of the Department of Secondary Education, University of Alberta, in "Integrating Aboriginal Perspectives: Issues and Challenges Faced by Non-Aboriginal Biology Teachers," discuss the many challenges faced by Alberta biology teachers in integrating Aboriginal perspectives in their biology classes. The authors note that Alberta biology teachers are very committed to the goal of integrating Aboriginal perspectives, but need much more help and resources to do so effectively.

Dougal Macdonald, of the Department of Elementary Education, University of Alberta, in "Why Argument Matters in Science Teaching and Learning," presents a case for emphasizing evidence-based reasoning more explicitly in science classes. Macdonald uses Stephen Toulmin's classification for evidence-based reasoning as an example of proper scientific argumentation.

Dr Anton Z Capri, Professor Emeritus, University of Alberta, in "The Higgs: What Is It, What Is Its Function and Why Don't I Believe It Exists?" argues that, despite the very tentative discovery of a particle at a seemingly appropriate mass, he does not believe the Higgs particle will be found, principally because it is based on a theory that was introduced primarily to make the physics theories fit present ways of calculating, rather than on fundamental principles.

Dr Capri has also submitted a paper entitled "Birth of a New Science, or The Dollar—A Universal Scientific Unit." In an amusing way, Dr Capri traces the way that quantification and measurement have left the domain of science and threaten to take over our everyday lives. Read on if you want to know how a price can be put on love, beauty and honour, for example.

Michael Kohlman, of the Department of Secondary Education, University of Alberta, in "Project Plowshare—Education for the Peaceful Uses of Nuclear Explosions," reviews the history and eventual demise of early Cold War efforts to promote the use of nuclear explosions for peaceful purposes such as giant construction and geological-engineering projects, including excavating canals, blasting harbours or artificial reservoirs, liquefying the Athabasca tar sands, and so forth.

Kohlman also looks into the history of the North American eugenics movement in "The Anthropology of Eugenics in America." In his article, Kohlman not only summarizes the history of the movement in a fascinating way, but also traces elements of eugenic thinking in modern humane genome research.

Arthur Stinner, Juergen Teichmann, Barbara McMillan and Ian Winchester, in "Famous Surprises in the History of Science That Illustrate the Methods of Science," discuss the shortcomings of the traditional methods of science and illustrate, in a number of case studies, how the emergence of surprise discoveries in science requires higher-grade mental activities to take scientific traditions into new directions. Many of these case studies are relevant to the high school science curriculum.

Integrating Aboriginal Perspectives: Issues and Challenges Faced by Non-Aboriginal Biology Teachers

Tracy Onuczko and Susan Barker

The K–12 science curriculum in Alberta presents a predominantly Eurocentric and western view of the world, yet science curriculum reform worldwide has emphasized "science for all" (Aikenhead and Jegede 1999). There are many scientists and educators who believe that science is culturally neutral, inherently universal and global in perspective (Morey and Kitano 1997) and thus there is no need to have broader or more multicultural perspectives. However, students bring the legacy of their cultural backgrounds to their studies and there can be substantial discontinuity between what young people experience in science classrooms and the rest of their lives (Teaching and Learning Research Programme 2006). Reiss (2000) has suggested that school science education can be successful only when students believe that the science they are studying is of personal worth to themselves. Unless school science explicitly engages with the enthusiasms and concerns of today's students, it could lose their interest; therefore, as science teachers we need to respond positively to these opportunities. Science teaching needs to better address women, those who hold strong religious views, those who have little cultural capital and those whose current or recent roots lie outside Western societies (Teaching and Learning Research Programme 2006). In Canada—including the province of Alberta—in the spirit of reconciliation, ministries of education now recognize indigenous ways of knowing as fundamental content in school science (Aikenhead and Michell 2011) in what has been termed *infusion of Aboriginal perspectives*. Aikenhead and Michell (2011) point out the range of terms used to describe indigenous ways of knowing nature, including indigenous knowledge, Aboriginal knowledge, Aboriginal science, indigenous science, traditional knowledge, traditional ecological knowledge, Native science and so on. Worldwide, the term *indigenous* encompasses the original inhabitants of a place and their descendants who have suffered colonization; in Canada, the term includes Canada's Aboriginal peoples, to whom the Canadian constitution refers collectively as First Nations, Inuit and Métis peoples of Canada (Aikenhead and Michell 2011). These are three distinct peoples with unique histories, languages, cultural practices and spiritual beliefs. Given that the cultural context of Alberta is rapidly changing through immigration accompanied by a rapidly increasing Aboriginal population, there is increasing need to address traditional knowledge, the philosophy of native science and multicultural science education in our classrooms. The need to ensure that science taught in schools is culturally relevant, and thus is truly for all, is one of the main reasons for the implementation of Aboriginal perspectives throughout the Alberta science curriculum. It is also a way for all students to develop an appreciation of the contributions that Aboriginal peoples have made to science and technology, demonstrate humankind's interconnectedness to the environment, integrate learning from different scientific disciplines, and improve the success of all learners in the classroom (Alberta Education 2007). Implementation in other programs of studies in Alberta (for example, social studies) and curricula in other jurisdictions has been successful, particularly with Aboriginal students. However, teachers (mostly those who are not Aboriginal) have expressed difficulties with this implementation (Aikenhead 1997; Aikenhead and Huntley 1999; Coalition for the Advancement of Aboriginal Studies 2002; den Heyer 2009; Kanu 2005; Taylor 1995). A recent study in Alberta by one of the authors of this paper (Tracy

Onuzcko; see Blood 2010) explored how biology teachers conceived of incorporating Aboriginal perspectives into their delivery of the Alberta biology curriculum. She too found that teachers not only found this infusion to be difficult but that they also questioned the value of incorporating Aboriginal perspectives into their science teaching. Moreover, the teachers had access to only limited resources for incorporating Aboriginal perspectives into the curriculum. To build cultural bridges between indigenous and scientific ways of knowing nature, teachers need a contemporary and general understanding of the two knowledge systems; currently, there is a paucity of resources, but new publications such as the book *Bridging Cultures*, by Aikenhead and Michell (2011), will help to fill this gap. In this paper we present some of the findings of the research and highlight its significance for science teachers in Alberta.

Teachers are pivotal to the success of any curriculum implementation (Fishman and Krajcik 2003; Fullan 1993; Fullan 2007; O'Sullivan 2002; Pinto 2005; Snyder Bolin and Zumwalt 1992); therefore, when any innovation is introduced, working with teachers at the outset (or even prior to implementation) is important. Pinto (2005) suggests that, either consciously or unconsciously, teachers take new curriculum proposals, interpret, categorize and select which of them they will take on and which they will not. Pinto (2005) also found that "even a real willingness to implement a curriculum innovation doesn't necessarily lead to its faithful implementation" (p 8). In Alberta, the infusion of Aboriginal perspectives into the science curriculum has had mixed response from teachers. While we do not have access to any hard data, our own interactions with Alberta science teachers through workshops on this topic suggest that many teachers give only marginal attention at best to the infusion. The Coalition for the Advancement of Aboriginal Studies (CAAS) (2002) suggests that teachers have difficulty incorporating Aboriginal perspectives into the curriculum because they are not adequately prepared; that the purchase of resources in schools with a limited Aboriginal student population may not appear be justified; and, in some cases, the incorporation of the Aboriginal perspectives may not be mandated or required. In Alberta, although teachers are mandated to deliver the Alberta programs of studies (see http://education.alberta.ca/teachers/program.aspx), in which Aboriginal perspectives have been infused, there is little evidence of assessment of these perspectives in provincial examinations, which maybe one reason that it is apparently less of a priority for teachers. In a study of how teachers perceived integrating Aboriginal culture into the Manitoba English and social studies curriculum, Kanu (2005) concluded that teachers felt that integration of Aboriginal perspectives was crucial, but he found that they understood and approached integration differently. He also found that teachers themselves identified "teachers' own lack of knowledge about Aboriginal cultures; the lack of Aboriginal classroom resources; the racist attitudes of non-Aboriginal staff and students; school administrators' lukewarm support for integration; and incompatibility between school structures and some Aboriginal cultural values" (p 57) as barriers or challenges to integration.

Much of Canadian literature addressing teacher viewpoints concerning integration of Aboriginal perspectives has come from Manitoba and Saskatchewan (Aikenhead and Huntley 1999; Goulet 2001; Kanu 2005; Witt 2006; Wotherspoon 2007) rather than Alberta, so it is difficult to make generalizations, although it is likely that similar sorts of challenges will exist. Statistics Canada (2006) reports that 5.8 per cent of Alberta's total population identify themselves as Aboriginal (First Nation, Métis, or Inuit). The Government of Alberta (www.aboriginal.alberta.ca, accessed December 2011) provides the following facts about Aboriginal people in Alberta:

- Alberta's Aboriginal ancestry population is close to 250,000, an increase of 23 per cent in five years (2001–06).
- Alberta has Canada's third-largest Aboriginal identity population, the majority of whom live in urban areas (63 per cent).
- Alberta has one of the youngest Aboriginal populations in the country. Almost a third (31 per cent) of the province's Aboriginal population is under 14 years of age, compared to 19 per cent for the non-Aboriginal population.
- Alberta's First Nation population is 108,318 (registered under the federal *Indian Act*); 37 per cent live off reserve.
- There are 48 First Nations and 134 reserves in Alberta, comprising 787,336 hectares (1.95 million acres) and covering three treaty areas: Treaty 6 (central), Treaty 7 (south) and Treaty 8 (north).
- Alberta's Métis population is 85,500, the largest Métis population in Canada. Most (88 per cent) live in major urban centres.

- There are eight Métis settlements in Alberta, comprising 512,121 hectares (1.25 million acres). This is the only recognized Métis land base in Canada.
- Approximately 8,000 people are members of Metis settlements in Alberta.
- Alberta is home to 1,610 people who have identified themselves as Inuit.

This information highlights that there are many areas located in Alberta that have extremely small Aboriginal populations, yet this is often traditionally where opportunities lie for involving indigenous knowledge. In urban areas where there are large numbers of Aboriginal students, it has been shown that indigenous students feel particularly isolated from their rural roots (Environics Institute 2010). The Environics survey also demonstrated that urban indigenous peoples maintain great reverence for their heritage and express strong indigenous pride (Environics Institute 2010). If teachers are an instrumental factor in curriculum implementation, as multiple researchers have suggested (Fishman and Krajcik 2003; Fullan 1993; Fullan 2007; O'Sullivan 2002; Pinto 2005; Snyder, Bolin and Zumwalt 1992), then the success or failure of the incorporation of Aboriginal perspectives rests on teachers' views regarding this incorporation.

Given the lack of literature focusing on an Alberta context, Blood (2010) investigated how teachers conceive of incorporating Aboriginal perspectives into their delivery of the Alberta biology curriculum. The participants in the study were all non-Aboriginal Alberta biology teachers who taught in schools with predominantly non-Aboriginal students. She conducted semistructured interviews with each teacher participant and explored issues and challenges that the teachers face in infusing Aboriginal contexts into their teaching. Questions for the interviews were derived from a framework developed by Rogan and Grayson (2003) for investigating curriculum implementation. The framework included the following three constructs:

- Capacity to innovate
- Outside influences
- Profile of implementation

Capacity to innovate describes the "factors that are able to support, or hinder, the implementation of new ideas and practices" (Rogan and Grayson 2003, 1186). *Outside influences* describes the support from outside agencies such as a department of education. *Profile of implementation* describes the degree to which a particular curriculum innovation has been or is being put into place (Rogan and Grayson 2003). As this study did not evaluate how successfully the teachers had incorporated Aboriginal perspectives and was more concerned with how teachers conceived of their own practice, this study focused on the construct *capacity to innovate*, particularly those ideas surrounding teacher factors.

The majority of the teachers saw value in incorporating Aboriginal perspectives into the curriculum but highlighted some concerns, specifically

- unclear definitions of *Aboriginal* and *Aboriginal perspectives*,
- an inadequate knowledge base and
- lack of material resources and professional development opportunities.

These findings concur with a vignette provided by Aikenhead and Michell (2011), in which a Grade 8 science teacher attempting to incorporate indigenous perspectives by teaching a lesson on snowshoes felt inadequate because of not knowing more about the following points:

- What kind of knowledge is this new content?
- What does it have in common with knowledge currently taught in science classes?
- What are some important differences a teacher should know about?
- How can a teacher better prepare to implement this culturally responsive teaching? (Aikenhead and Michell 2011, 4)

Some teachers highlighted the relevance of incorporating Aboriginal perspectives in biology due to the content matter but had concerns about other sciences, where the perception was that it was less relevant and more challenging. For example, Jessica valued Aboriginal perspectives because she thought that a more holistic viewpoint was tied with the idea of Earth being an ecosystem. Silvia thought that Aboriginal perspectives were

> "related to biology in the sense that *Aboriginal perspectives* is a fairly natural and probably effective way to describe nature of science as opposed to other knowledge systems and it's related to biology because the content matter is usually biological"(Silvia).

Hank valued an Aboriginal perspective because he believes that "there's a space in biology to say, 'Let's look at other perspectives.' Like, let's look at a traditional Aboriginal way of thinking." Hank also believes that

> Biology has a really good place for bringing perspective, alternate perspectives in. And I think biology always has because it's been based on stories and seeing things happen rather than making theoretical predictions and then working toward solving problems. But we're at the point now where we're creating problems, biological problems. And do we have to start taking in different perspectives. And so maybe thinking of other people's theories about how things work would be useful." (Hank)

Rebecca saw incorporating Aboriginal perspectives in all curricula as a great way to combat stereotypes and misunderstanding associated with Aboriginal people, while two other teachers (Amanda and Brad) both thought it would expose students to more than one way of knowing in science.

Although most teachers saw value in incorporating Aboriginal perspectives, only two (Hank and Rebecca) had made serious attempts to incorporate Aboriginal *perspectives*, as opposed to Aboriginal *content*. This included lessons that asked students to engage in storytelling and fusing concepts in Biology 30 with Aboriginal knowledge. However, both experienced a variety of difficulties, including inability to access elders, negative student reaction, lack of material resources and an inadequate knowledge base. One of these two participants (Rebecca) described the reaction from her students as being "absolutely indignant." The students felt as though they should be able to choose the perspective they looked at these Biology issues from and should not be forced to choose an Aboriginal perspective. Such student hostility raises serious issues for teachers with regard to student's motivation and understanding of the science.

From the conceptual framework, factors such as teachers' unclear or varying definitions of *Aboriginal* and *Aboriginal perspectives*, a lack of education and workplace training, and a lack of confidence in teaching an Aboriginal perspective were identified as teacher factors that may hinder the implementation of Aboriginal perspectives. All of the participants with the exception of three (Steve, Hank and Roger) expressed uneasiness with integrating Aboriginal perspectives. Steve, for example, taught a split Biology 20/30 class in summer school and did not feel he had enough time to do anything beyond the knowledge objectives in the curriculum. He felt that incorporating Aboriginal perspectives was valuable but not a high priority for his teaching situation. Hank and Roger both expressed a desire to learn with and from the students regarding Aboriginal perspectives. Even though neither of them were Aboriginal, they did not think this made them unqualified to teach/learn about Aboriginal perspectives.

The teachers in this study indicated a willingness to try to incorporate an Aboriginal perspective; however, they did not think that they were very successful. Such feelings are similar to findings of Aikenhead and Huntley (1999), who describe teachers expressing "openness to include Aboriginal knowledge in the science program … but in practice little or moderate headway is being made except for in a few unique instances" (p 167). Aikenhead and Huntley investigated Aboriginal and non-Aboriginal teachers' views on Aboriginal students learning science. Of particular interest is that the non-Aboriginal teachers all taught in schools with low Aboriginal student populations and they still indicated openness to teaching Aboriginal perspectives in biology. Several participants suggested that this was because the content matter they associated with Aboriginal perspectives was biological or ecological and thus was relevant to their specialist background and teaching experience.

The lack of resources in Alberta is acute, and the resources that are available were not widely used by the participants. The most identified resource that participants indicated having access to was the Internet, including websites such as the Government of Alberta, Alberta Education, LearnAlberta, Google and Wikipedia. Other resources specified were elders, divisional consultants, course material from graduate courses and the high school class textbook. The lack of appropriate informational support was exacerbated by lack of appropriate professional development opportunities; the professional development sessions that were attended were reported as being not very informative and disappointing.

Most of the teachers, however, were able to describe what they would find particularly useful, including sessions at teachers' conferences, sessions at the Alberta Teachers Association Science Council conference, more extended workshops (for example, three-day workshops) and graduate courses. Of significance was a need for clarification on what exactly the Biology 20–30 program of studies (Alberta Education 2007) actually means by *Aboriginal perspectives*. Many teachers reported that the description provided in the document was ambiguous and unhelpful. The Alberta Education (2005) document *Our Words, Our Ways: Teaching First Nations, Métis and Inuit Learners* does define *Aboriginal* and *Aboriginal perspectives*, but this resource is neither a required or recommended resource for biology teachers, and none of the teachers in the study had used it or even heard of it. Many participants indicated that they would like professional development that helped to clarify what teachers should do when attempting to incorporate Aboriginal perspectives; professional development needs to be tied to the curriculum—that is, targeted to biology. The teachers in this study also suggested that it would be helpful to have a wider variety of resources such as elder contacts, Internet resources, worksheets, lesson plans and proper support.

Therefore, we need to address some common issues significant to Alberta's non-Aboriginal teachers and their students if we are to improve the effectiveness of infusion of Aboriginal perspectives into the science curriculum. What is needed is

- greater clarity on the definition of *Aboriginal* and *Aboriginal perspectives* as they relate to the science programs of study;
- professional development opportunities and resources that are rooted in subject-specific contexts;
- contacts in Aboriginal communities that could help provide guest speakers—for example, elders; and
- a more extensive rationale on why Aboriginal perspectives have been included in Alberta programs of study and what this means for students.

In addition, we suggest that

- non-Aboriginal biology teachers and school administrators need to actively pursue professional development opportunities and encourage sessions related to Aboriginal perspectives in biology at teachers' conventions and Alberta Teachers' Association Science Council conferences;
- teachers and students should engage collaboratively in the exploration of Aboriginal perspectives—teachers do not need to be the expert all the time;
- to assist in developing foundational knowledge, science teachers are advised to read *Our Words, Our Ways: Teaching First Nations, Métis and Inuit Learners* (Alberta Education 2005). This resource provides information pertaining to general Aboriginal perspectives, as well a list of treaties and Métis settlements in Alberta; and
- we need a consistent and shared school vision regarding Aboriginal perspectives integration.

Ultimately, the most significant recommendation is that we need to have a better understanding of the constraints and opportunities faced by teachers. Therefore, we suggest that more research in the area of non-Aboriginal teachers incorporating Aboriginal perspectives in Alberta curriculum be undertaken. There is clearly a commitment to ensuring we have "science for all," but the enactment in the classroom is somewhat limited.

Acknowledgements

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Why Argument Matters in Science Teaching and Learning

Dougal Macdonald

> Improvement at argumentation is possible if it is explicitly addressed and taught.
> —Osborne, Erduran and Simon 2004, 1015

Introduction

Social constructivist learning theory places great importance on learning through language and social interaction. In classrooms, this is manifested in the use of collaborative or group work as an integral part of a lesson. Students in science classrooms are given opportunities to work in small groups with their peers to carry out scientific inquiry, do technological problem-solving, and come to decisions about science–technology–society (STS) issues.

A collaborative approach to learning requires students to argue out their ideas with each other in a constructive way in order to reach valid conclusions. An *argument* in science can be usefully defined as a discussion in which reasons and evidence are advanced for and against some claim . Argument is an important aspect of science teaching and learning because it is a way that scientific claims are clarified, analyzed and validated.

Teaching students how to frame and analyze arguments at a level appropriate to their abilities can help them gain an understanding of concepts in science (for example, like magnetic poles repel) and concepts about science (for example, science predicts and explains). As well, it encourages students to base their beliefs more on evidence and reasoning than on an authority such as a scientist, teacher or textbook. As physicist Richard Feynman once famously remarked, "Science is the belief in the ignorance of experts."

Toulmin Argument Pattern

A useful theoretical framework for an argument that has stood the test of time suggests that an argument has four main parts (Toulmin 1958):

- Evidence
- Warrant
- Backing
- Claim

Evidence

Evidence is the first requirement of any argument because it is the explicit grounds on which the argument rests. Evidence consists of one or more items of knowledge (or belief) that are accepted as true. The most basic evidence is empirical evidence—the evidence of the senses such as the eyes and ears—gathered, for example, from observing and/or measuring what happens during an experiment. Often, empirical evidence is accessible to all or at least to many. Evidence can be gathered by the claimant by observation or experiment, or by others. Common types of evidence are facts, reports of states of affairs, statistics and exhibits (Toulmin 1958; Ehninger 1974).

Examples of Evidence

- (E1) A huge quartzite boulder sits isolated on the prairie near Okotoks, Alberta.
- (E2) A dolphin has a backbone and mammary glands.
- (E3) A structure strengthened by triangles holds more weight than equivalent structures without triangles.
- (E4) Unsafe levels of PCBs have been measured at the Swan Hills Waste Treatment Centre.

Warrant

The warrant is the *since* that connects the evidence with the claim and provides the implicit reason for accepting the claim. It answers the question "*Why* does that evidence mean that your claim is valid?" Warrants are general and certify all arguments of the appropriate type, not just the specific argument or case that they are applied to (Toulmin 1958; Ehninger 1974).

Examples of Warrants

- (W1) Since the boulder deviates from the size and type of rock native to that area
- (W2) Since a vertebrate with mammary glands is a mammal
- (W3) Since the shape of a structure and its parts determines the structure's strength
- (W4) Since an unsafe level of PCBs is dangerous to human health

Backing

Backing is what the warrant ultimately rests on. Backing can be difficult to discern because it is often implicit rather than openly stated. Backing needs to be explicitly introduced when the warrant itself is not convincing enough. Examples of backing include theories, laws, systems of classification and standards. Backing promises that the warrant constitutes a valid justification for the claim and is the assurance that the warrant possesses legitimacy. Backing is field dependent; for example, backing for a claim in the field of geology will differ from backing for a claim in the field of engineering (Toulmin 1958; Ehninger 1974).

Examples of Backing

- (B1) On account of glacial theory
- (B2) On account of the Linnaean system of taxonomical classification
- (B3) On account of engineering design theory and practice
- (B4) On account of Health Canada standards

Claim

A claim is a statement or assertion about the world that we think is true. A claim consists of, at minimum, a subject, a verb and an object (or possibly a predicate adjective or noun). Claims may be unqualified, which implies no exceptions to the claim, but may also be qualified (for example, *probably*, *typically*, *usually*, *except in the case of*) (Toulmin 1958; Ehninger 1974).

Two types of claims are common: analytic claims and normative claims. *Analytic* claims are those claims whose truth seems knowable by knowing the meanings of the constituent words alone, rather than by also knowing something about the world. Roughly speaking, analytic claims are true by definition. In contrast, *normative* claims state how things *should* be, implying that one attitude, situation or course of action is better than another. Normative claims affirm which things are good or bad, right or wrong.

The two common types of analytic claims are declarative and classificatory.

- *Declarative* claims are declarations that a certain state of affairs exists or existed, for example: (C1) So the Okotoks boulder is a glacial erratic.
- *Classificatory* claims are declarations as to how something that is recognized to be the case should be classified (Ehninger 1974). For example: (C2) So the dolphin is a mammal.

The two common types of normative claims are evaluative and actuative.

- *Evaluative* claims are the attitude we should take toward a given action or state of affairs, for example: (C3) So the best way to strengthen a structure is to use triangles in its construction.
- *Actuative* claims are the course of action we should take to bring new states of affairs into existence (Ehninger 1974), for example: (C4) So the Swan Hills Waste Treatment Centre should be closed.

Examples of Complete Arguments

Here is an example of an argument for a declarative claim in scientific inquiry:

- (E1) A huge quartzite boulder sits isolated on the prairie near Okotoks, Alberta.
- (W1) Since the rock deviates from the size and type of rock native to the area in which it rests,
- (B1) On account of geological/glacial theory
- (C1) So the boulder is a glacial erratic.

This is an example of an argument for a classificatory claim in scientific inquiry:

- (E2) A dolphin has a backbone and mammary glands.

- (W2) Since a vertebrate with mammary glands is a mammal,
- (B2) On account of the Linnaean system of taxonomical classification,
- (C2) So a dolphin is a mammal.

Here is an example of an argument for an evaluative claim in technological problem-solving:

- (E3) A structure strengthened by triangles holds more weight than equivalent structures without triangles.
- (W3) Since the shape of a structure and its parts determines the structure's strength,
- (B3) On account of engineering design theory
- (C3) So the best way to strengthen a structure is to use triangles in its construction.

Following is an example of an argument for an actuative claim (STS decision-making):

- (E4) Unsafe levels of polychlorinated biphenyls (PCBs) have been measured at Alberta's Swan Hills Waste Treatment Centre.
- (W4) Since an unsafe level of PCBs is dangerous to human health
- (B4) On account of Health Canada standards,
- (C4) So the Swan Hills Waste Treatment Centre should be closed.

Of course, an actual argument in science will not be stated as formulaically as in the examples just given. In fact, it is more likely that the evidence, warrant, backing and claim will need to be embedded in or extracted from a somewhat longer account. At the same time, the Toulmin argument pattern is very useful both for building and analyzing arguments because it does suggest what kinds of statements must be included, at minimum, to satisfy the requirements for the completeness and validity of a scientific argument.

Conclusion

Argument matters in science teaching and learning because claims in science are not self-evident, nor should they be treated as such. The co-construction of knowledge in science classrooms by teachers and students needs to be based on reasons and evidence. In fact, the rationality of science and the very existence of science depend on its commitment to evidence and reasoning, just as does the rationality of those who teach and learn science. Knowledge claims about the natural world that are not based on reasons and evidence are not just bad science—they are not science at all.

Teachers and students must become aware not only of what is claimed to be true in science but also of *why* it is considered to be true. If so, they will be more likely to hold their beliefs about the natural world in an evidential manner. This means that it will be more likely that (a) the belief will be held with regard to evidence relevant to its rational assessment, (b) the holder of the belief will be able to critically inquire into the worthiness of the belief and (c) the belief will yield to negative or contrary evidence (Green 1971).

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The Higgs: What Is It, What Is Its Function and Why Don't I Believe It Exists?

Anton Z Capri

With conflicting reports coming from physicists at the Large Hadron Collider (LHC) at CERN [European Organization for Nuclear Research], excitement about the discovery of the Higgs particle is mounting. Unfortunately, as more data accumulate, the significance of data originally thought to signal a Higgs particle at the now decommissioned Tevatron at Batavia, Illinois, is fading away. Admittedly, the search for the Higgs is extremely difficult because it has so many decay channels—that is, it can decay into so many different particles. One starts by smashing protons into antiprotons to create the Higgs and then looks at the decay products. The three main decay channels for identifying the Higgs are two W particles, two Tau particles, or a bottom quark and a bottom antiquark. Although at the Tevatron there appeared at first (last December) a hint of the Higgs, as last reported from the ATLAS experiment at CERN, these decay channels are empty of the excess one expects if a Higgs exists. The definitive results are expected from the ATLAS and CMS detectors by the end of 2012. This might be a good time to review what the Higgs is and what it is supposed to do.

Let me begin by stating that I have a rather heretical view of the Higgs particle: I don't think it exists in the form proposed by the current theory of subatomic particles and their interactions, the so-called Standard Model. As long as fifteen years ago I told my graduate students that the Higgs may not exist. By the way, I am not alone in my opinion. All this talk of "the God particle" or that the Higgs provides an explanation for the origin of mass is hyperbole of epic proportions. Let me explain my position by starting with mass.

The origin of mass as it is supposedly explained by the existence of the Higgs is nothing other than a different parametrization of mass. Let me elaborate. In the standard way of introducing mass, one includes a parameter with the dimension of mass directly into the field equations for the particle studied. In the case of the mass as introduced by the Higgs, one introduces this parameter in the equation for the Higgs field. In this case it is given the exotic name: the *vacuum expectation value,* or VEV, of the Higgs field. The details, as far as mass is concerned, are unimportant. The important point is that the vacuum expectation value of the Higgs field is just another way of introducing a parameter with the dimension of mass. To reiterate, this is just a different way of introducing a mass parameter.

Now why was the Higgs field introduced in the first place? The answer is that it was a brilliant idea by Peter W Higgs: how to make a theory that mimics the most successful theory—quantum electrodynamics, or QED—as closely as possible but, unlike electromagnetism, acts over a short distance.

Why mimic electrodynamics? Because it is the most successful field theory ever devised and has been tested to incredible accuracy; prior to Higgs, it was the only theory with which physicists knew how to calculate. The measurement of the electron's spin g-factor agrees with its theoretical prediction to better than one part in a trillion. It would indeed be wonderful if strong interactions could approach this kind of precision.

What makes electrodynamics so successful? There are two reasons:

1. The fine structure constant α, which controls the strength of the electromagnetic force, is small. $\alpha = 1/137.034$. This suggests that a perturbative approach of successively smaller corrections (involving successively higher powers of α) will work.
2. In calculating with QED, the corrections to the important physical parameters of the theory—the charge and mass of the electron— that were originally introduced in the (bare) equation for the electron can be isolated and replaced by the

measured physical parameters. This is called *renormalization*. No theory exists in which these two parameters (mass and charge) can be computed from first principles.

So far, physicists know how to calculate only with theories in which such a perturbative approach including renormalization is possible. These are called *renormalizable theories*. Before Higgs, the theory of strong interactions—the standard model—was not renormalizable. The reason for this was that the gluon field, the field that acts in analogy to the photon field in QED, had to be short range. Back in the 1930s, Hideki Yukawa had already shown that the range of a field is inversely proportional to its mass. This means that gluons, which act over a short range, should be massive. Problem: gluons are spin 1! Massive fields with spin 1, so-called vector fields, are *not* renormalizable.

Enter Peter Higgs. If you start with a massless vector field, as in QED, so that the theory is renormalizable and then somehow manage to give the field a mass without destroying the fact that the theory is renormalizable, you can calculate as in QED. That is precisely what the Higgs field was designed to do. As rewritten by Peter Higgs, the standard model becomes renormalizable. The remarkable thing is that this approach was successful and that the standard model with a Higgs field has made highly accurate, tested predictions.

So why don't I believe that the Higgs needs to exist? Because if one is honest, one sees that the Higgs serves only one essential function: it renders the standard model renormalizable. It does not explain the mass of elementary particles. Making a theory renormalizable is, in my opinion, not a physical but rather a mathematical requirement. Physicists want a theory to be renormalizable only because so far we don't know of any other way to calculate. In my opinion, introducing the Higgs field is a Procrustean solution to make the theory fit our way of calculating.

To sum up, I don't expect the Higgs to be found. This is why the experiments now being performed are so important. If the Higgs is found, it will be the most exciting event in particle physics in the last half a century and justify the effort that was expended in the search. It will force physicists to look at strong interactions in a new way and keep physics fresh. If I am wrong and the Higgs is found, high-energy physics will enter a period of relatively dull computations as physicists pursue the next decimal place. It will be as Res Jost said about QED once Feynman had rendered that theory accessible to all.[1] "In the late forties and early fifties under the demoralizing influence of perturbation theory the mathematical sophistication of a physicist was reduced to a rudimentary knowledge of the Greek and Latin alphabets."

Recently another result that casts doubt on the standard model has come to my attention. Precision measurements of the muon's spin g-factor disagree by an enormous amount with the corrections that come from the standard model. This suggests that there is much more interesting stuff to be discovered in regions beyond the standard model. We may be on the verge of another huge puzzle in physics that may take years or even decades to solve—and physicists love puzzles.

[1]Res Jost (1918–1990) was a Swiss theoretical physicist and Richard Feynman (1918–1988) an American theoretical physicist.

Birth of a New Science, or The Dollar— A Universal Scientific Unit

Anton Z Capri

Maybe it was the beer. Anyhow, whatever it was that set Frank off, it was most wonderful because as soon as he got home he started to formulate his new theory. All through graduate school, working on his PhD in physics, he had prided himself that he was producing real knowledge. Hadn't Lord Kelvin, the great 19th-century physicist, made it abundantly clear that all other studies were but the beginning of knowledge when he stated, "When you can measure what you are speaking about and summarize it in numbers, you know something about it. And when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind. It may be the beginning of knowledge, but you have scarcely in your thought advanced to the stage of science." Now Frank had found the ultimate theory, a theory that quantified and unified everything. With this idea he was going to turn all studies into science and thus into real knowledge.

At first it was only a vague idea. It had started with his annual evaluation. The quality of his research was crucial for promotion to associate professor. But how had his work been evaluated? The dean told him plainly that his research grant was too small. That was why he had not been promoted and had sought solace in beer, but instead found inspiration. Now, he realized that he had gained an important insight: the quality of his research had been quantified and expressed in numbers, namely the number of dollars in his grant. Thus, the judging of his research was done scientifically. Once he started thinking along these lines he soon—after his fifth beer—realized that everything could be quantified. But, even more important, there was a universal unit, the dollar. Everything could be measured in dollars. Just as Einstein had managed to unify space and time so that ever after distance and time could both be measured either in kilometres or seconds, now he, Frank Salviati, was about to achieve an even greater unification and show that everything could be measured in dollars.

As a first step it was necessary to find a conversion factor for the typical physical quantities—for example, length. Although the use of dollars for measuring distance might not catch on—after all, even though in Einstein's relativity theory distance was measured in seconds, how many people measured the length of a piece of wood in seconds rather than inches or centimetres—still, it was important to know how to do so for the theory to work. Einstein had only shown that length was relative to an observer, but Frank, with his new insight, realized that Einstein had not gone far enough. Even as a child he had realized that distances depended not only on how fast you were going, but also on where you were going. The trips to the dentist had seemed ever such a short distance, whereas when looking at a queue to a rock concert he was sure that the length of the queue was incredibly long. That also made it easier to understand the relativity of time—why the same length of time as measured by a Timex was sometimes very long and at other times much shorter. These were facts that Einstein had failed to incorporate into his theory, but using dollars as a unit would rectify this. The answer had been there in front of everyone all the time. Time really is money!

Time could be measured in dollars. This now also gave a unit of length in dollars: the distance light would travel in that time. Not only that, but it also accounted for the relativity involved in the state of mind of the observer. The more Frank thought about it, the more he was convinced that the dollar was a truly fundamental unit of length.

He realized that all of this was just a first approximation. As the science of dollar metrology (the name he invented for his new approach) advanced, more refined techniques with greater scope for precision would have to be developed; a bureau of international standards would have to be established.

He considered the next simplest case: energy. Rather than measure energy in Joules, calories or kilowatt hours, energy could be measured in dollars. This was nothing new. Utility companies already measured energy in dollars when they mailed out their bills for electricity or natural gas. The same thing was true at gas stations. The advantage of measuring energy exclusively in dollars was that all energy was treated as equal, something that everyone, especially physicists, should appreciate.

Now for the more interesting cases: the so-called unquantifiable things. Could honour be measured? How about beauty, or love? These quantities used to be beyond the pale when it came to quantifying them. Not so any longer. This was where Frank had his most brilliant insight—he realized that the universal unit by which all of these could be measured was the dollar. Modern economics, not physics, was the queen of all sciences. Although they may not have realized it, economists had slowly developed the most universal science and now he, Frank Salviati, was ready to reveal this to the world.

He began with love, maybe because that was where he had most recently suffered a loss. Interesting how the word loss applied equally to what had happened to him with Dolores and what had happened to him with the stock market. Yes, economics was the answer. Of course not all love was the same. His love for Dolores had been easily quantified. They had signed a prenuptial agreement specifying in precise dollar terms what they were willing to invest in their relationship—how much they were willing to spend on their love. At the time they signed the agreement, they had not thought of it in those terms, but Frank now realized that this was precisely what they had done. They had measured their love in dollars. That the love of a man and a woman could be measured in monetary terms had already been known in earlier times and then forgotten. After all, until not too long ago—and even today, in many parts of the world—brides had to be purchased. What could possibly have been a more precise way of specifying love than the bride price?

What about parental love? Here, too, Frank had kept up with developments, especially as shown on television. The various programs for children abounded with commercials that made it abundantly clear that the love of parents could be measured by how much they were willing to spend on their children. Every child could measure its parents' love by the money spent on toys. Love definitely had a dollar tag.

He next considered honour, definitely an abstract quantity. To determine the quantity of an individual's honour one simply needed to measure how many dollars it would take for the individual to part with his or her honour. What could be simpler? Of course every individual's honour would have a different measure, but then so did every individual's height and weight.

When it came to beauty, he stopped and thought. He recalled visiting a campground just outside Abbotsford, British Columbia. Huge cedars, at least two metres in diameter, sheltered each picnic table. He had stood in awe, gazing at these giants and wondering about all that they might have seen. These trees had survived for centuries while all around their kindred had been cut down for lumber or else just cleared to make room for housing and agriculture.

A man from the adjacent campsite wandered over and saw him gazing with wonder and admiration at these trees. "They're something else, aren't they?" the neighbour began the conversation.

"Yes, they are. They're beautiful." Frank responded.

His neighbour regarded him with appreciation and continued, "They sure are. Each of these beauties is worth at least four thousand bucks. Yeah, they're beautiful."

That was what Frank failed to realize back then, but understood now: beauty did indeed have a price.

In fact, beauty presented no problem at all. After all, the art market provided a perfectly valid dollar measure of the beauty of a painting, sculpture or other work of visual art. The beauty of literature, poetry or music could also clearly be measured in the same way. Some might argue that the dollar value of an object is not constant. This was never a problem in physics, the so-called purest of sciences. Many physical quantities varied with time. In fact, Frank was sure that this aspect of his theory needed little elaboration, except for a dynamical theory of how things evolved in time.

Even justice had a dollar value. How expensive a lawyer did it take to get a satisfactory legal verdict? The judiciary already recognized that the legal system had nothing to do with justice, but was only concerned with legality. So why not quantify this? With the universal unit, the dollar, everything could be measured and analyzed scientifically allowing definite social progress.

What about democracy? This was really easy. During an election every candidate spent dollars to get elected. The election was totally fair because all dollars were equal. Bill Gates's dollars were equal to those of a welfare recipient. So there was a true measure of democracy—the democracy of the dollar. Quickly he jotted down this last idea and then, with the satisfaction of having achieved greatness, stumbled off to bed.

In the morning he awoke with a vague memory of having been brilliant the night before. There, in not too neat but still legible script, he found his thesis of the previous night. Although his head felt far bigger than normal and he had the sensation that the walls of his room were squeezing his noggin, he tried to read the manuscript. His eyes blurred and he was forced to stop. He took two aspirins and his head cleared after a while. He returned to his writings and found his ideas brilliant. This was to be his seminal achievement, his greatest work, but the introduction had to catch the attention of the reader. Slowly, laboriously, he began to write.

Almost from the beginning of natural philosophy, physicists have been under the delusion that theirs is the only truly fundamental science, when all along economics, especially the free-enterprise style of economics, has evolved into the most fundamental and catholic science. It seems that what Einstein did for physics by showing that space and time can both be measured in either metres or seconds, depending on one's choice, was only a small step. There is an even more fundamental unification and, as we shall demonstrate, everything *can be measured in the same unit: the dollar. Clearly, we are at the dawn of a new scientific age.*

Project Plowshare and Education for the Peaceful Uses of Nuclear Explosions

Michael Kohlman

"So you want to beat your old atomic bombs into plowshares?"

—I I Rabi, on hearing Harold Brown's idea to use peaceful atomic explosives to "give people a more rational viewpoint" on nuclear weapons. (O'Neill 2007, 27)

Introduction

This article explores the aborted Cold War-era Project Plowshare program for its rather forgotten role in military–industrial-based big science and technology and for the associated efforts to promote the cause through education. *Plowshare* was the American term for Project Plowshare, and "Education for the Peaceful Uses of Nuclear Explosions" part of the international scheme to use peaceful nuclear explosions (PNEs) for giant construction and geological-engineering projects. It evolved from President Eisenhower's 1953 Atoms for Peace initiative, which was revealed to the world in a speech at the United Nations.[1] The euphemism was taken from the Old Testament passage (Isaiah 2:4) "they shall beat their swords into plowshares, and their spears into pruning hooks: nation shall not lift up sword against nation, neither shall they learn war any more" (O'Neill 2007, 27). Excavating canals, blasting harbours or artificial reservoirs, liquefying the Athabasca tar sands, and generating abundant energy and useful radioisotopes were just a few of the novel schemes to use thermonuclear weapons (rather than fission reactors) to benefit all mankind.[2] Plowshare was to usher in a new age of plentiful energy and agricultural, civil engineering or transportation miracles through the peaceful use of what was previously only the scourge of Total War.[3]

In a sense, Plowshare was an attempted revival—following in the atomic halo of America's victory in World War II and the postwar economic boom (and baby boom)—of the sort of Progressive-era values that gave us eugenics, electrification and other giant engineering projects that inspired Americans who came of age in the last decades of the 19th century and first decades of the 20th century.[4] The Soviet analogue was Lysenkoism or Michurinism, a few decades later.[5]

When I mention Plowshare to today's undergraduates or my young graduate student colleagues, who came of age during the late 20th century—the age of environmentalism and social activism, the reaction is

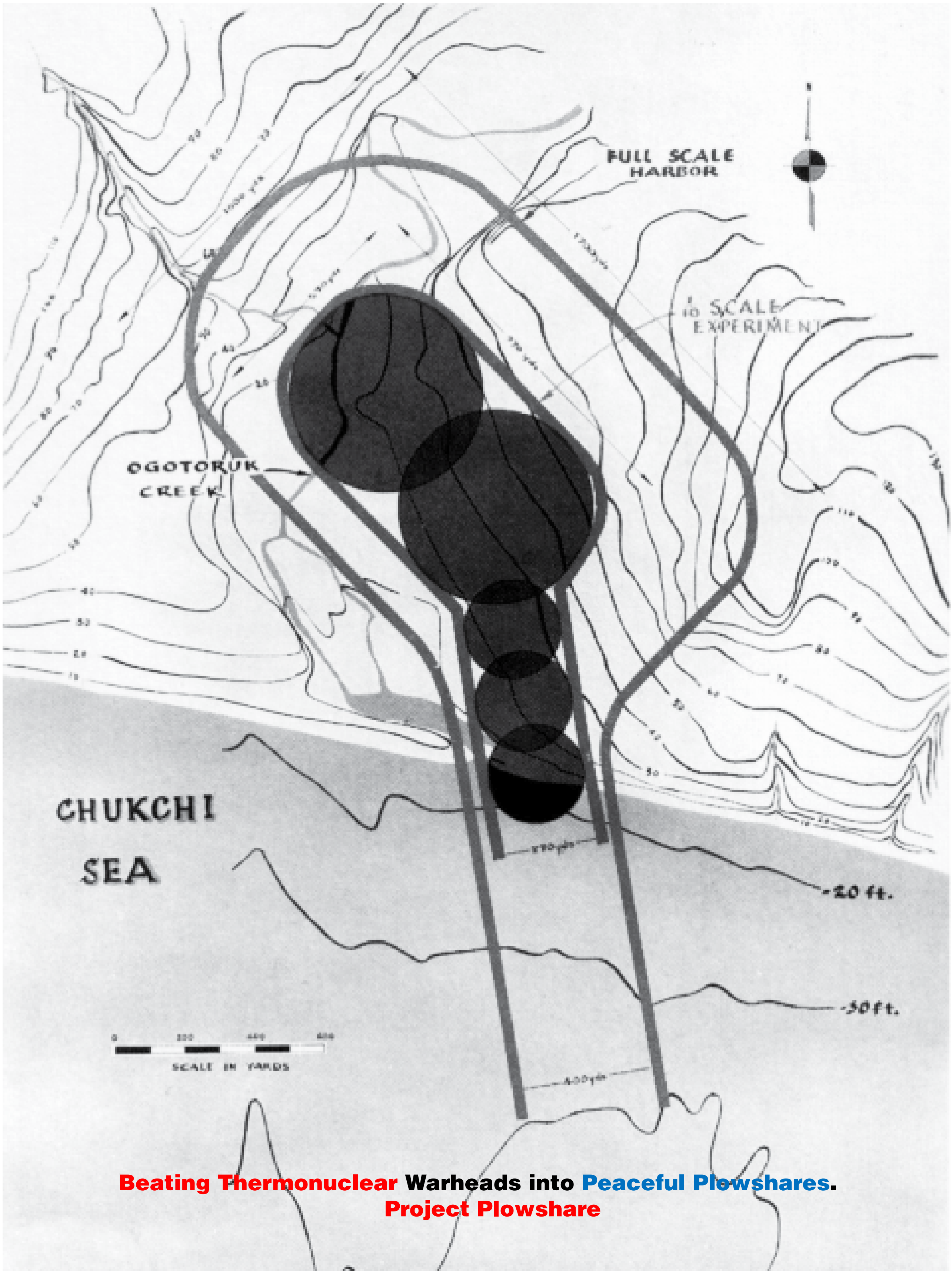
[1] Eisenhower was not the first to suggest the idea. It was a Russian idea in 1949, after the successful test of the A-bomb, as set out by Findlay (1986, 1–3). For an evolutionary saltation in the opinion of an American atomic physicist to the idea of PNEs pre- and post-Plowshare, see the articles, letters (and exchanges with Lewis Mumford) by Frederick Reines in the *Bulletin of Atomic Scientists*. Over a period of 9 years (1950, 1954, 1958) he undergoes a marked conversion from skeptic to agnostic to believer. Just part of being a team player at Los Alamos and the Atomic Energy Commission? I defer to the reader's judgment.

[2] For a popular glimpse of these schemes (before *tar sands* morphed into *oil sands*), see Teller 1960. This fascinating article, published in *Popular Mechanics*, was written to be easily understood and includes the schematic diagram of the Chariot harbour excavation on page 19; note, though, that Teller does not mention that the original plan was for a combined 4.6 MT rather than the 460 kT (that is, 10 times larger) or the growing opposition to the project.

[3] A prominent historical and psycho-social-cultural analysis of the awe, fear and loathing inspired by atomic weapons and technologies is found in Weart 1988.

[4] For the progressive promise of eugenics, see Galton 1904, 1–25. For a uniquely American expression of Galton's vision at the virtual height of the movement, see Huntington 1926.

[5] As a primer to Lysenko's enduring appeal in Soviet science and society, see Roll-Hansen 2008, 166–88.



Beating Thermonuclear Warheads into Peaceful Plowshares.
Project Plowshare

incredulity. For people of my age or older who are not versed in its peculiar history, the reaction is muted indignation or a knowing "what were they thinking" shaking of their postmodern heads. And yet, Plowshare is not unlike the fascination with any powerful technology when it is novel, spectacular, terrifying—particularly if it is associated with nationalistic pride and accomplishment.[6] Even more compelling, in a time of imminent or smouldering war—as with the first Red Scare following the Bolshevik Revolutions of 1918–20—the potential advantage of any new science or technology, however dangerous or unpleasant, is a powerful incentive to its development and acceptance.[7]

Plowshare was in very good company, historically speaking. Previous precedents for using fearsome military weapons for peaceful purposes (gunpowder and high-explosives for blasting, chemical weapons for insecticides and fumigants, radioactive isotopes for atomic reactors) had been successful on many fronts.[8] The scientists and military–industrial leaders who brought these "most damnable inventions" (Bown 2005) to fruition sought to recruit public acceptance and support for weapons of mass destruction following the cataclysmic wars in which they were pioneered or premiered. From Dynamit-Nobel to the Nobel Prizes; from poison gas to Standard Oil's Flit guns and roach-bombs for exterminating insect enemies; and nuclear power's promise for producing energy too cheap to meter—there is nothing like the practical peacetime benefits of wartime science and technology to soothe public fears and anxieties over a new wonder-weapon.[9] (Is this an alternate example of converting technological terror into Nye's *Technological Sublime*? [Nye 1994]) The scientists, engineers, and institutions involved in Plowshare and its Soviet analogues (under the umbrella of "Nuclear Explosions for the National Economy")[10] sought to mobilize support in many diverse constituencies and generated many studies, proposed projects, popular and formal education efforts, and a voluminous paper trail that begs further study and reflection.[11]

Project Plowshare's timing, like that of the late-Cold-War–era's aborted Superconducting Super Collider,[12] was not fortuitous. It followed on the heels of early radiation scares that sparked a spate of science fiction stories and films all over the world, perhaps best exemplified by the enduring *Godzilla* movie franchise of cult status. It also preceded the Cuban Missile Crisis, America's involvement in Vietnam, and the counterculture and environmental movements of the 1960s and 1970s. By the time Saigon fell, Plowshare was moribund, although it was not officially terminated until the post-Vietnam Carter administration finally put a stake in its thermonuclear heart in 1977. Plowshare has been largely forgotten in light of new threats and crises; but the program was well-documented, like its analogous historical antecedents.

This paper will be limited to considering the American genesis of Plowshare, along with Project Chariot, the thermonuclear excavation of a harbour on the frozen coast of Alaska, at Cape Thompson. Chariot was the linchpin of Plowshare, the first major proof of concept. It would have opened the door to even more elaborate projects, the Holy Grail of which would have been the excavation of a *fully* sea-level canal across Central America to replace the narrow and aging Panama Canal, with its cumbersome system of locks and limited traffic (O'Neill 2007, 26, 27, 42, 43; Teller 1960, 100). I will argue that Chariot, like Plowshare in general, was designed to soothe public fears about nuclear weapons, forestall or pre-empt nuclear testing moratoriums, and provide useful data and test results for the effects of new nuclear weapons in a bipolar world in which their actual use in war would result in mutually assured destruction. I suggest that Plowshare was

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6 See Josephson 1990 or Nye 1994.

7 See Missner (1985) for an interesting examination of the influence of the first Red Scare upon Einstein's American fame, and of relativity as a potential counter-measure (a theoretical *Technological Sublime*) to this threat in a pre-Sputnik "Age of Anxiety." Also see Russell (2001), especially chapters 3 and 5.

8 For the story of the peaceful uses of blasting powder, nitroglycerin and dynamite, see Bown (2005). For the equally fascinating account of the campaign to promote the peaceful uses of chemical weapons, see Russell (2001), chapter 4.

9 For a dose of the Soviet strain of Cold-War "big tech" fever, see Josephson (1990).

10 For a detailed and illuminating description of the Soviet PNE program for comparison to Plowshare, see Nordyke (1998).

11 I wonder if the volume of Plowshare documentation and analysis qualifies as a record for a stillborn program.

12 *Editor's note*: The Superconducting Super Collider was a particle accelerator complex under construction in the vicinity of Waxahachie, Texas, that was set to be world's largest and most energetic, surpassing even the current record held by the Large Hadron Collider. Its planned ring circumference was 87.1 kilometres (54.1 miles), with an energy of 20 TeV per proton. The project was cancelled in 1993 due to budget problems. More information is available through http://en.wikipedia.org/wiki/Superconducting_Super_Collider.

also to have been Dr Edward Teller's great personal legacy to the future, to overshadow his reputation as "Father of the Hydrogen Bomb" and the scientist who brought down J Robert Oppenheimer.[13] Ironically, the *real* legacy of Chariot and Plowshare was their profound role as catalysts of the environmental movement, the antinuclear movement, and Aboriginal land claims and rights movements, and as a template for the sorts of environmental impact assessments that are now commonplace, if not as universally applied or stringent as many of these groups might wish (O'Neill 2007, 292–310).

American Genesis and Evolution of Plowshare

In the early 1950s (November 1952 in America and August 1953 in the Soviet Union) (Findlay 1986, 2, 6), fusion-based thermonuclear weapons supplanted fission-based atomic bombs. These fusion-based weapons, also known as H-bombs, had an almost unlimited destructive potential, but they still needed a fission weapon to initiate the fusion reactions. This reliance on a conventional fission core meant that the new bomb would still produce deadly radioactive isotopes and fallout. The trials at Eniwetok atoll proved this, to the detriment of various witnesses and innocent victims caught in the wake of the blasts' fallout plume (Carlson 2006, 75–77). These trials prompted a second wave of radiation- or fallout-scare.

Undeterred by bad press, the physicists and publicists on both sides put a super-sized spin on the new invention. Once again, the Russians took an early lead, first in a 1954 Soviet science journal (later to be used against them in a 1958 Geneva conference on halting weapons testing):

> Progressive science claims that it is possible to utilize the noble force of the explosion for peaceful purposes … With the help of directional explosions one can straighten out the beds of large rivers to construct gigantic dams, to cut canals literally in a few minutes whose construction by ordinary machines would be prolonged for years … Indeed unlimited are the possibilities disclosed due to the new atomic energy. (Findlay 1986, 6)

In America, after prolonged campaigning by Teller, a new national laboratory to compete with Los Alamos[14]—the University of California Radiation Laboratory at Livermore—was formed in July 1952, to be operated under Atomic Energy Commission (AEC) and university oversight.

The Livermore Radiation Laboratory (LRL) is considered to have been founded by Ernest O Lawrence, a Nobel laureate in physics, and Edward Teller. The lab was renamed the Lawrence Radiation Laboratory in Lawrence's honour upon his death, in 1958, and is currently known as the Lawrence Livermore National Laboratory (LLNL). Future AEC chair and presidential science advisor Glenn T Seaborg, also a Nobel laureate in physics, enthusiastically described the new "idea factory" at Livermore:

> The late Ernest Lawrence and Edward Teller assembled a corporal's guard of amazingly young men, most of whom had only recently received their PhDs … Their job was to help improve and diversify the nuclear weapons that are so important to American security and to explore some proposals for applying nuclear energy for peaceful purposes. They were infected with the 'gung-ho' spirit of Ernest Lawrence, a spirit that has prevailed at Livermore ever since. (Findlay 1986, 4)

The 1956 Suez Crisis provided the stimulus for the idea of using hydrogen bombs as a sort of nuclear dynamite to excavate a 300-mile bypass of the Suez Canal through Israel, from Gaza through to the Gulf of Aqaba. A group headed by Harold Brown met in November 1956, to discuss the idea to end the blockade as an academic exercise (Teller 1968, vi). Brown, Teller and Gerald Johnson wrote to the AEC with a number of imaginative proposals, which were "to feed the high hopes held for PNEs and which largely relied on the experiences of those who had spent their lives designing nuclear weapons rather than solving the problems which would arise in carrying out nuclear explosions in inhabited locales" (Findlay 1986, 7–9). They held a closed conference in February 1957 (the first Plowshare Symposium) to "sift fact from fancy in the new field," and proposed several projects.

[13] For a relative judgment of Teller vs Oppenheimer, and of Galton and Davenport vs Laughlin, see Carlson (2006), chapters 6 and 2 respectively.
[14] *Editor's note*: Los Alamos, New Mexico, was the location of the weapons research and design laboratory of the Manhattan Project, which produced the first atomic bombs.

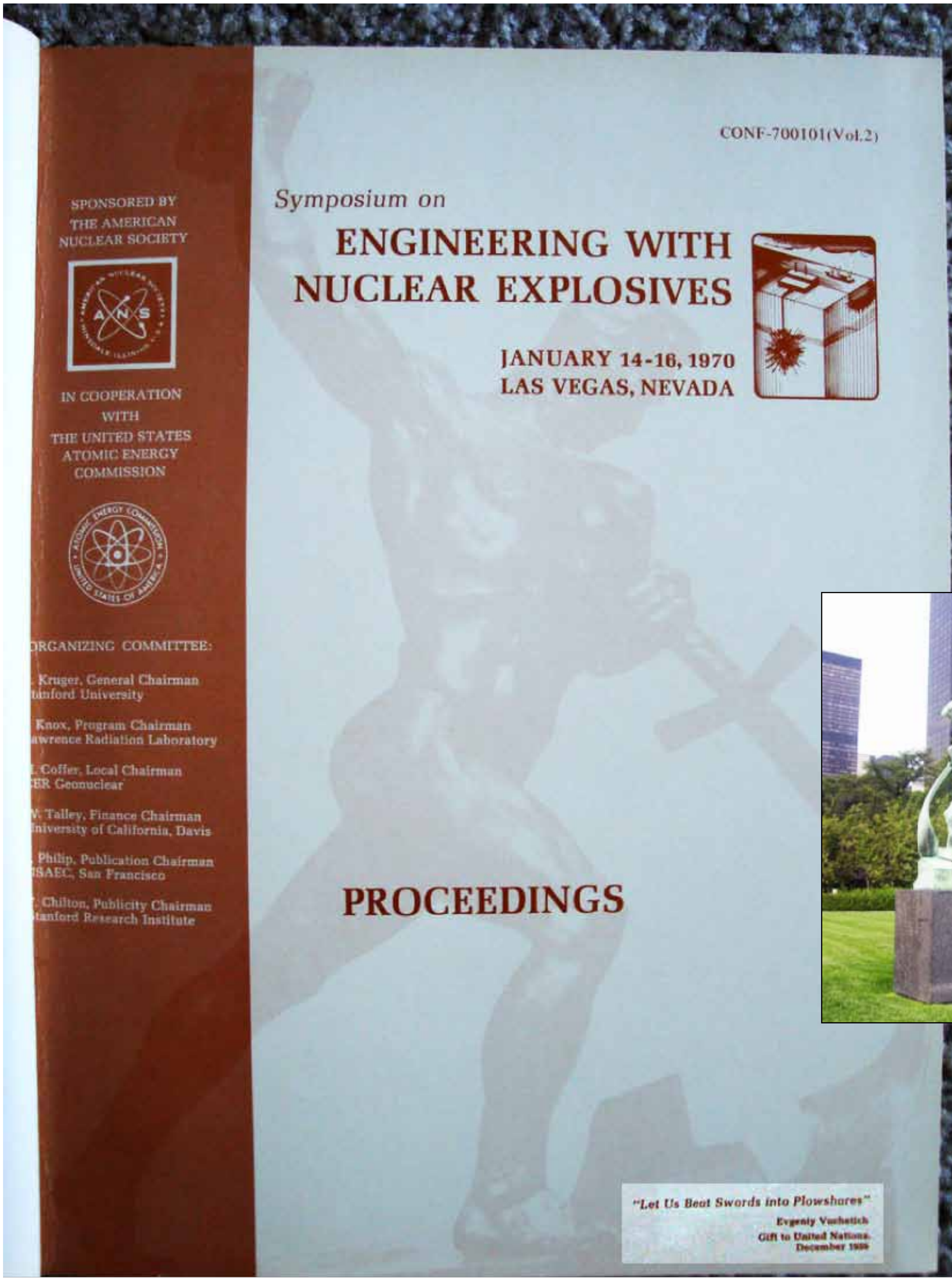


Figure 1: Title page from a 1970 Plowshare symposium. Note the Soviet statue (a 1959 gift to the United Nations—see inset photo—an optimistic "new Soviet Man" for the nuclear age?) and the caption from sculptor Evgeniy Vuchetich. Was this homage the US atomic engineers' attempt at détente?

One of the critical tasks for the idea factory was to create and promote "clean bombs" (a foreshadowing of the neutron bomb of the 1980s) that would enable planetary engineering on a grand scale. One early exposition of this effort was Teller's own "How to Be an Optimist in the Nuclear Age," a chapter from *The Legacy of Hiroshima*, written with Allen Brown (Teller and Brown 1962).[15] Teller enthuses about the unlimited potential of fusion explosions for geographical engineering and outlines plans for giant construction, mining, and oil and gas stimulation projects, including an early outline of Project Chariot. He dismisses as unwarranted pessimism the "overblown fears" of radiation effects and fallout damage (he states that this pessimism is the reason he no longer reads science fiction). Teller also insinuates a "Plowshare gap" vis-à-vis the Soviets, and vehemently argues against the proposed nuclear testing moratorium (Teller and Brown 1962, 83–93). Teller predicted that clean bombs could soon be realized; he had communicated his enthusiasm to Eisenhower in a June 1957 meeting, along with Ernest O Lawrence, Lewis Strauss and Mark Mills. Eisenhower was greatly interested in the idea. Teller's later recollection includes this excerpt:

> One point raised in the discussion which was and is of great importance. We can perfect 'clean' nuclear explosives. These can be used in war to destroy an intended target without releasing radioactivity to be carried by the winds to do damage indiscriminately … These 'clean' explosives can also be used in peace as powerful workhorses in mammoth construction jobs. (Findlay 1986, 11)

Eisenhower announced at a press conference the next day that a moratorium on nuclear tests "might impede progress on the production of a fall-out-free nuclear bomb and the development of nuclear energy for peaceful purposes" (Pringle and Spigelman 1981, 252). A month before Sputnik changed everything, Operation Rainier, the first fully underground bomb test in Nevada, provided a graphic example of possibilities for Plowshare, confirming Teller's optimistic speculations (Findlay 1986, 12). What was needed now was a large-scale test of one of those practical possibilities to get everyone on board.

Teller and LRL had just the project in mind. In the turbulent wake of Sputnik (which is beyond the scope of this paper), no idea was too optimistic or bold, so long as it promised to restore America's technological supremacy. The Plowshare program was promoted as one avenue to recapturing America's crown, even so far as declassifying part of the first Plowshare Symposium, proposing an international conference for the next year in Geneva and publishing a fanfare expose of the "Non-Military Uses of Nuclear Explosives" in *Scientific American* (Findlay 1986, 14–17).[16] There was to be only a short window of opportunity before other events intervened. Teller and his "corporal's guard" made plans for a full-scale test that would not only make future projects and applications possible, but would convince America and the world that nuclear dynamite could be cost effective, efficacious and safe. They needed a remote location in need of a major project that only PNEs could provide. They chose Cape Thompson, Alaska, and called it Chariot. Like Apollo's golden chariot, they would bring the power of the sun to the Land of the Midnight Sun.

Teller Greases Chariot's Wheels

The story of Project Chariot contains all the promise of Plowshare, as well as the seeds of its long, languishing demise. Any detailed description is beyond the scope of this paper, but it has been well documented and analyzed from myriad perspectives.[17] The long story might be analogized as a sort of best-laid plans of mice and men, where the lab mice are taken out of their element and thrust into a world they did not know or understand. Teller and his colleagues took their plans on a whirlwind tour of Alaska in the summer of 1958, to a newly opened frontier territory on the cusp of great-state status, but which had suffered something of a downturn in fortunes since the great burst of Federal spending during World War II and its aftermath. They found an enthusiastic and eager response from the business community, media, local politicians and community leaders. Teller was magnanimous in his praise for the people of Alaska and their pioneer can-do spirit.

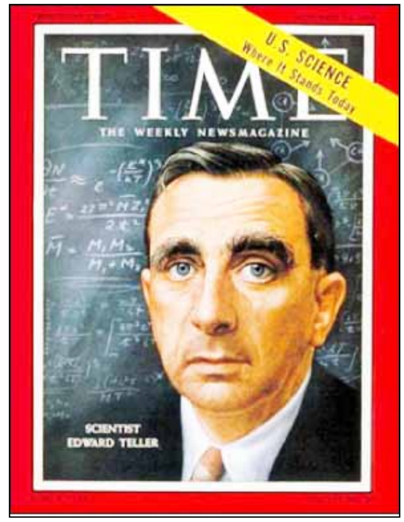
[15] Perhaps the original inspiration for Stanley Kubrick's tongue-in-cheek subtitle for *Dr. Strangelove*?

[16] One problem voiced by the Soviets in Geneva was the fact that Plowshare was assigned to the AEC's Division of Military Applications. This was corrected in August 1961, with the establishment of a new Division of PNEs.

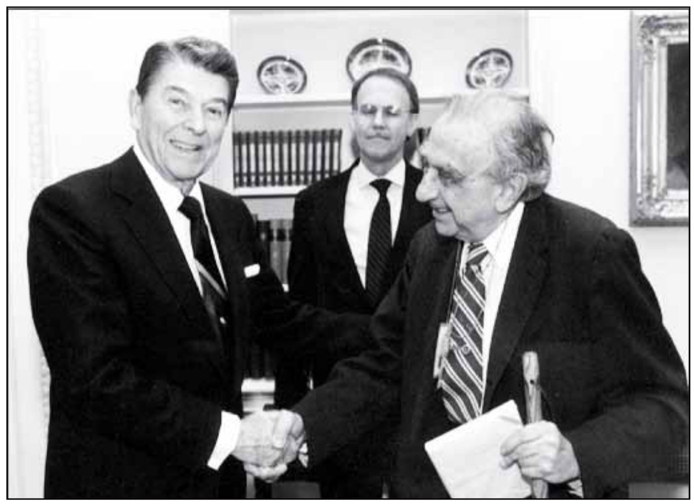
[17] The authoritative, full story is provided by O'Neill (2007, 1989 and 1994). Another excellent source is Kirsch and Mitchell (1998).

A Collage of Edward Teller Images

Teller making headlines at the Fairbanks Airport, 1958



Teller at his LRL desk (same photo as 1960 *Popular Mechanics* article)



Reagan congratulating Teller for his work and support of the SDI initiative, 1983

Teller passionately testifying in opposition to the Limited Test Ban Treaty, circa 1962

Figure 2: A quintet of Teller images from the Web. Sir Francis Galton once used the number of lines in obituaries to judge the eminence of men. On that score Teller would surely be a man of distinct genius, Galton's highest category. Is rarity of genius the problem Galton would have us believe?

The visitors were welcomed with a curious mix of awe and puzzlement:

> Selling the plan to Alaskans, Teller mixed flattery with frontier bravado. He said that Alaska had "the most reasonable people," and that the atomic scientists had "looked at the whole world" for the right place to host the visionary technology. Teller said a number of proposals were under consideration, but that the harbor at Cape Thompson seemed most likely. Planning for the shot had progressed to a stage where it could be fired the following summer, provided the harbor was economically justifiable and that Alaskans were ready to step in and develop it. (O'Neill 1989, 29)

The groups they addressed were warm to the general idea of grand projects, and raised nary an eyebrow to nuclear dynamite's potential for altering grand geographic features even more ambitious than Teller's modest plan. In fact, they could not understand why he wanted to dig a harbour where he did, and peppered the distinguished visitors with suggestions for a bewildering variety of other schemes that they thought made better economic and geographic sense:

> As alternatives to the Cape Thompson project, they suggested shortening the shipping lane to Bristol Bay, the world's richest fishing grounds, by blasting a canal across the Alaska Peninsula; or a harbor in Norton Sound near Nome; or on the Arctic coast to serve Umiat, where oil was known to exist. "I'm delighted," said Teller. "This is just the type of suggestion and objection we are looking for … We came here to be partners with you, and because we want suggestions." By the time Teller's group reached Fairbanks, Project Chariot appeared wide open: the Yukon, Susitna, or Copper Rivers might be dammed with nuclear explosives, harbors or canals might be excavated at a half dozen locations. (O'Neill 1989, 30)

In fact, Teller and the AEC had already made up their minds. They had already submitted a classified application to the Department of the Interior, and their compatriots were already on the ground at the Arctic outlet of Ogotoruk Creek, planning where to set their thermonuclear charges. Teller relayed the results in a classified letter to General Starbird, director of military applications at the AEC, citing the lack of general acceptance for a "commercial harbor" at Cape Thompson (O'Neill 1989, 31).

Shortly after the Livermore group returned from Alaska, the underground Neptune test in Nevada produced unexpected results and an accidental escape of considerable radioactive steam and dust.[18] When test officials returned to the site (after a prompt evacuation of the blast site), they were shocked to see a crater, considering the depth of burial and low yield of the device. Neptune revealed that crater size increased with depth of burial (to a limit), while the release of radiation decreased. Thus, optimum depth of burial could theoretically be calculated for a particular yield; excavation could be accomplished with lower yields and radiation release could be minimized. This was great news for Plowshare promoters, but before the atomic scientists' new theoretical models could be applied in large-scale explosions near populated areas, they would need to be tested in a suitably remote location (O'Neill 1989, 31, 33).

Thus Chariot planners now switched to the idea of an experiment "using two to three 20 kT explosions plus two at about 200 kT" in a scaled-down test or proof-of-concept that could be applied elsewhere, where more obvious economic or military advantages might dictate general acceptance of the validity of Plowshare (O'Neill 1989, 33). For the next decade, even after other global events intervened, Teller continued to tout the theoretical economic benefits of the Cape Thompson scheme, despite the mitigating geographical, logistic and environmental realities of the scheme. Like the true optimist he claimed to be, Edward Teller rarely allowed economic or geopolitical realities to dampen his faith or enthusiasm in the march of progress and science (see, for instance, Kirsch and Mitchell 1998, 105–108).

> "When you come to the end of all the light you know, and it's time to step into the darkness of the unknown, faith is knowing that one of two things shall happen: Either you will be given something solid to stand on, or you will be taught to fly."
> —Edward Teller, quoted in O'Neill 1989, 33.

[18] Teller's prior and later denials of any significant radiation hazard at Cape Thompson are belied by the facts and dangers detailed in Teller and Latter (1958).

"The Crystal Reveals" the Prophet/Scientist at the Altar

Figure 3: One of the photo-plates from A Cressy Morrison's 1937 iconographic book, sponsored by the American Chemical Society (Ede 2004)

Chariot Encounters Obstacles and Grinds to a Halt (But Quietly)

Even before the inception of Plowshare, opposition to nuclear weapons development and testing had a luminous and storied history. Early mavericks like Linus Pauling, geneticist H J Muller and philosopher Bertrand Russell had begun to chip away at the pervasive enthusiasm and authority of the atomic physicists and their chorus of mimics and sycophants. The images of Hiroshima and Nagasaki, despite best efforts to generate a positive spin and downplay the dangers, had shaken many scientists and lay people. One response was the establishment of the *Bulletin of the Atomic Scientists*, perhaps best known for its Doomsday Clock.[19]

Even before Eisenhower's Atoms for Peace initiative was announced at the United Nations, Lewis Mumford had delivered a speech to the American Philosophical Society, in November 1953, which was published in the *Bulletin* in February 1954 (Mumford 1954).[20] Mumford criticized the social detachment of atomic scientists, and the inherent irrationality of their research program:

> [T]he advance in scientific knowledge, in which we are now committed to processes whose tempo we do not dare to retard, whose direction we do not govern, and whose ultimate results we do not stop to evaluate. Under such conditions every permission becomes a compulsion. As long as our present knowledge continues to expand the sphere of the irrational and the pathologically automatic, the survival of man, to say nothing of his development, is plainly threatened. The dangers of our present situation would not be so great had our responses to it been alert and timely. Even now, we should probably be able to mobilize enough political wisdom to provide a minimal basis for the necessary cooperation and safeguards, if only we could throw off the sleepwalker's insulation from reality that characterizes our collective conduct. (Mumford 1954, 34)

Mumford proposed a "World Assize" of scientific knowledge on the effects of atomic bombs, and pleaded for a reorientation of scientific paradigms away from a "passive acceptance of the catastrophes their old tradition of social irresponsibility helped to create" (Mumford 1954, 36).

That Plowshare (and the larger Atoms for Peace program) was designed and conducted (in part) as a strategy to combat Mumford's perception of atomic science and its practitioners is one consideration. The continuance of the practices that he decried is an indictment that Big Science and Technology continues to combat with similar tactics and strategies, but enhanced sophistication.

In 1958, the year that Teller and his crew planned Chariot and visited Alaska for the first time, Linus Pauling and Edward Teller engaged in a furious exchange—in the media, in debate and in a series of publications—over the dangers posed by radiation and nuclear fallout. In January, Pauling presented to the United Nations a petition to stop nuclear testing, coauthored by Barry Commoner of the Centre for Nuclear Information with veteran physicist Leo Szilard, signed by some 9,000 scientists, including H J Muller, a Nobel laureate for his work on the effects of ionizing radiation on DNA (Kirsch 2005, 32–36).

In Alaska, Teller's young associates also ran into trouble in the form of the biology faculty (though not the administration) at the University of Alaska, Fairbanks. These faculty members were to form a vital local front of the opposition to Chariot. In a fission-style cascade reaction, the biologists' actions and efforts expanded into a huge network of activists, academics, Aboriginal groups and mass media, finally reaching high-level bureaucrats and politicians in both the state and federal governments. Whereas now we hear about grass-roots activism or environmentalism, this was a "lichen-roots" prototype and still one of the great eco-activism successes that has rarely been replicated. But it was a creeping, quiet victory, one that was not obvious for some time.

> The opponents of Project Chariot—the Eskimos, biologists, and conservationists—were denied a clear-cut acknowledgment of their success. But their victory is as stunning as it is historic. They took on Edward Teller's dream to use nuclear explosions in the "great art of geographic engineering,"

[19] See Commoner, Friedlander and Reiss (1961) for a sample of the back-and-forth between the AEC/Los Alamos/LRL "hawks" and the many prominent scientists who took them on.

[20] This article was followed by a spate of letters and replies, including one from Frederick Reines (of Los Alamos) (Reines 1954), in May, the same month as the notorious Bravo Test at Bikini Atoll. The fiasco that resulted glaringly called into question the expert appraisals and reassurances of the minimal danger of radiation and fallout in weapons tests.

and they turned it into a stimulus to the incipient environmental movement. And something larger than Chariot was knocked off-course. Bogged-down also was Teller›s headlong rush to establish Plowshare as a highly visible affirmation of nuclear power. Indeed, the civilian application of nuclear energy, other than for electric generation, never regained its momentum. On the surface, Chariot is a tale of conflict and even scandal, involving passionate, radical, pioneering people. But it is more than that …The lesson Chariot offers is that a free society must be a skeptical one, and that rigorous questions and dissent protect, rather than subvert, our freedoms (O'Neill 1994, 34).

Of course, the efforts of these and many others were allied and aided by the announcement, in October 1958, of a voluntary bilateral moratorium on nuclear testing that lasted for almost three years. By then Chariot was in real jeopardy, both from the studies conducted by the Alaska scientists and others the AEC had contracted to study the botany, ecology, geology, hydrology, human geography and zoology of the Cape Thompson region, and from unfavourable public opinion (O'Neill 1994, 29–33). By the end of the moratorium, the AEC had put the brakes on, but they and the physicists at LRL did not want the opposition to declare a victory. Rather than calling off Chariot, it was announced that it was to be "postponed indefinitely."

Livermore officials concluded that Project Chariot should be canceled, but were concerned that the decision might create "serious political problems." LRL planners had always been sensitive to any change in the design that "looks like another retreat to mollify local demands." So when Livermore director John S Foster finally wrote to the AEC to recommend cancellation, he pointed out: "Such an action could have repercussions which would adversely affect the whole Plowshare program … since Chariot has been vigorously criticized from the standpoint of safety ... its cancellation will contribute to the skepticism on the safety of nuclear excavation." (O'Neill 1994, 34)

Attempted Plowshare Revivals and Last Rites

The end of Chariot was by no means the end of Plowshare. Indeed, like so many creations of American technocracy and the military-industrial-academic complex (so poignantly captured by Ike's swan-song speech in 1961), Plowshare had a momentum and inertia of its own that was to propel it for another decade before grinding to a halt.[21] Further tests, such as the scaled-down Gnome and Sedan shots in Nevada, followed the end of the voluntary moratorium in a flurry of nuclear activity reminiscent of that which preceded it.[22] The AEC and LLRL (both under new management) undertook further studies, hosted additional conferences and symposia, published numerous books, articles, and films to advocate for PNEs; and they campaigned to exempt their programs from any future moratoria.[23] Even after the Limited Test Ban Treaty (implemented in October 1963), funding for Plowshare work and studies continued, including $18 million for a five-year study of the Central American canal project, beginning in the fall of 1964 (Kirsch 2005, 1–5; Langer 1964). A set of promising latter-day schemes involved underground detonations for mining or fossil-fuel extraction, including a novel plan to liquefy the Athabasca tar sands.[24]

In the end, no Plowshare project was ever carried to fruition outside the Nevada test area, except for underground tests in Colorado and New Mexico. These were of low to modest yields to assess the possibility of gas or oil-well stimulation and shale-oil fracturing, ending with Rio Blanco in May, 1973.[25] Plowshare was terminated in 1977, in the wake of America's demeaning defeat in Vietnam and Southeast Asia, the Watergate fiasco, and the crunch of the first energy crisis.

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[21] Plowshare was subsumed in the US Department of Energy (DoE). US Department of Energy (1977) contains a compendium of projects, publications, tests, conferences, et al, until the absolute end of the project.

[22] For an enthusiastic account of Sedan, see Kelly (1962, 50–51).

[23] See, for example, Sanders (1962) and his response to a lukewarm review and impertinent letters to the editor (Sanders 1963). For an appeal to pure science and basic research, see Cowan (1961) on a Los Alamos initiative under the unfortunate acronym Project SANE, which provided an easy target for jibes from critics.

[24] Profiled by Teller in his popular articles (1960), books (Teller 1958, 1962, 1968) and Plowshare symposia (1959, 1964, 1970). See US Department of Energy (1977) for a complete listing of tests and projects and a comprehensive chronology of important events.

[25] US Department of Energy (1977, 7–10). The list of non-nuclear and cancelled test shots is longer.

After the creation, in 1969, and gradual strengthening of the Environmental Protection Agency and the cumulative effects of eco-activism on many fronts, even the great urge to achieve energy independence in a Fortress North America could not resurrect Plowshare to active duty for even limited underground tests for energy-related projects.[26] To close this chapter, let me quote from the Department of Energy executive summary of Plowshare termination:

> Plowshare was a program that started with great expectations and high hopes. Many projects did not progress beyond their planning phase and construction was not started. In general, planners were confident that the projects could be completed safely, at least within the guidelines at the times. There was less confidence that they could be completed cheaper than by conventional means and most importantly, there was insufficient public or Congressional support for the projects. Projects Chariot and Coach were two examples where environmental concerns and technical problems prompted further feasibility studies and, after several years of continuous field work and numerous delays, each project was eventually canceled. In addition, throughout the course of the Plowshare Program citizen groups voiced concerns and opposition to some of the tests.
>
> By 1974, approximately 82 million dollars had been invested in the nuclear gas stimulation technology program (ie, nuclear tests GASBUGGY, RULISON, and RIO BLANCO). It was estimated that even after 25 years of gas production of all the natural gas deemed recoverable, that only 15 to 40 percent of the investment could be recovered. At the same time, alternative, non-nuclear technologies were being developed, such as hydrofracturing. Consequently, under the pressure of economic and environmental concerns, the Plowshare Program was discontinued at the end of FY 1975. (US Department of Energy 1977, 6–7)

After an investment of some $770 million, Plowshare was terminated (Kirsch 2005, 6–7),[27] but certainly not forgotten—hopefully, not to be mourned, or resurrected in some future *Project Lazarus*.[28]

Education for Peaceful Uses of Nuclear Explosives

Before closing the book on Plowshare, one additional development is worth exploring briefly. As was the case of the eugenics movement, Plowshare was seen as a multigenerational endeavour that required extensive public and formal education efforts to recruit new supporters and cadres of bright young graduates in the associated science, technology and related administrative disciplines. In addition to previous symposia and conferences, both classified and open to the public, a late campaign for the hearts and minds of nuclear engineers, physicists and related educators was mounted in April 1969, in the form of a symposium entitled "Education for the Peaceful Uses of Nuclear Explosives," at the University of Arizona, Tucson. It resulted in an edited book, under the direction of Lynn E Weaver, associate dean of the College of Engineering, University of Oklahoma. It is dedicated to the late Dwight (Ike) Eisenhower "… a gallant warrior who also dreamed of converting the sword of nuclear energy into a plowshare for peace" (Weaver 1970).

The book includes featured presentations by Plowshare veterans at the Livermore Radiation Lab and the AEC, including Gerald Johnson, Wilson Talley, William Libby and the ever-optimistic Edward Teller, on all aspects of Plowshare, old and new. Even Chariot was resuscitated as an exemplar. The latter sections of the book deal with "Legal Problems and Educational Programs," "University Research and Manpower Needs" and "Educational Development." Teller himself contributed a keynote address on the "University Role in Nuclear Explosives Engineering Research," in which he again optimistically argued for continued R&D on clean

[26] Project Independence was launched in the waning years of the Nixon administration. It included huge schemes to rapidly exploit the Alberta tar sands and Colorado oil shales, the focus of much Plowshare study in the final years. For a brief introduction, see Weinberg (1974). It is all the more ironic for the same-page story "EPA Criticizes Atomic Assessment," in which the upstart EPA criticizes the venerable AEC for shoddy monitoring and management of its reactors and waste disposal facilities. I wonder if Mumford would be amused and/or vindicated.

[27] This figure is stated in 1996 dollars—not big by Cold War standards, but an expensive study.

[28] *Project Lazarus* is a *Doctor Who* audiobook, in which the villain tried to trick the Doctor into regenerating him. I wonder if that would be optimistic enough for Dr Teller's approval. Might Teller have been a passable "Doctor"?

thermonuclear devices (Weaver 1970, 293–98).[29] Representatives of many nuclear engineering or physics departments showcased their institution's inclusion of Plowshare-related courses or programs, optimistically forecasting future expansion with increased demand, contingent upon the development of new technologies. Willard F Libby, a Plowshare veteran then UCLA chair, gave the closing keynote, recapping the history of the project and its initiatives, and optimistically concludes

> It seems to me that the future is particularly bright. Of course, we Plowshare enthusiasts have always had this attitude, and it is natural that we find ourselves continuing to be hopeful." (Weaver 1970, 338)[30]

Conclusion

That Chariot (and ultimately Plowshare's other proposed mammoth projects) did not see the "light of a thousand suns"[31] is cause for retrospective celebration. But it was only the tireless efforts and courageous actions of dedicated activists and academics and the eventually enlightened decisions of those leaders and politicians that curbed Edward Teller and his coterie of atomic physicists and engineers, squelching their dreams of nuclear geographical engineering. However, as history has proved and current societies continue to witness, it was by no means the end of global nuclear fear or man-made environmental catastrophes. Nor was it the fall or even decline of large-scale industrial-engineering projects that—in their cumulative impacts and sheer ubiquity—have done much more collateral damage to the biosphere and humanity than Chariot or even its planned follow-on projects would have caused.[32]

"Progressive" American eugenics required the exposure of Nazi racial-hygiene programs and genocide to curb it (though some critics argue that eugenics still lives under new aliases) (see Kohlman 2012). Had Plowshare projects been allowed to proceed, it *might* have shocked the world into a more drastic rejection of the kind of technological hubris that is embodied in this sort of radical military–industrial Big Technology (O'Neill 2007, 29). It might also have slowed the pervasive onset of *technopoly*, as enunciated by Postman (1993). I am skeptical on both counts. In addition to examples like the debacles in Vietnam or Afghanistan (both Soviet and US), Bhopal, Chernobyl and Fukushima, there are many other cautionary tales that have been and continue to be played out that argue against the prospects of real success for the "World Assize" on irrational Big Science and Technology that Lewis Mumford advocated (Mumford 1954). The will to power is too strong. We are destined to progress ever onward and upward, on supreme faith, even stepping into the face of total darkness, just like Edward Teller. Will we always have something solid to stand on, or be taught how to fly? Or is this all "just another line in the [well-plowed and fertilized] field of time"?[33]

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[29] Teller even invokes Hamlet's dilemma, paraphrased as "To shoot or not to shoot," arguing that it is time for the Prince of Denmark to stop the off-stage soliloquies and make a triumphant entrance on the world stage.

[30] Libby even hopes to try making diamonds by "placing a large block of graphite near a device."

[31] Robert Oppenheimer is said to have recited these lines from the Bhagavad-Gita upon seeing the first nuclear detonation in 1945: "Brighter than the light of a thousand suns, now I am become death, the destroyer."

[32] This cautionary tale is made especially poignant by the current political debate and public relations campaigns that are being played out at this writing by the Keystone XL and Northern Gateway pipelines being contemplated to carry Alberta's oil sands bitumen to refineries and markets in America and China, respectively.

[33] Neil Young, "Thrasher" (*Rust Never Sleeps*, Track 2, Warner Records 1979).

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The Anthropology of Eugenics in America: Ethnographic, Race-Hygiene and Human Geography Solutions to the Great Crises of Progressive America

Michael Kohlman

Introduction

My doctoral research explores the educational programs for and the impacts of the eugenics movement in North America from its Progressive-era ascent through its purported rapid decline after World War II. Eugenics education was a top priority for the disciples of Sir Francis Galton, the celebrated founder of the science of race-betterment. In America, the seminal ideas of Galton and other pioneers combined with pre-existing Nativist or Nordic biases and prior strains of scientific racism, such as Samuel Morton and the American School of Anthropology.

In the first half of what was to be called the American Century, public eugenics education for the burgeoning middle classes and professional groups, and formal courses for future generations who would inherit the onus of racial civic duty were both seen as vital to the success of the movement.

Popular eugenics education progressively pervaded America, becoming prominent in fairs, museum exhibits, public lectures, and even eugenic church sermons (Rosen 2004). Formal education was also a crucial resource in the evangelization and politicization of this widespread social movement. During the interwar period, hundreds of colleges, universities and normal schools offered eugenics courses (Cravens 1978). High schools often embedded eugenics units within civic biology, home economics or social-hygiene courses. In Western Canada, American-style eugenics was also prevalent, once the immigration pattern switched away from primarily Nordic regions to Eastern and Southern Europe, shortly before World War I (Grant 1918).

After the Nuremburg Trials revealed the racial bias of American-style eugenics, organized eugenics went underground or was rebranded (as physical anthropology, social biology, family planning, genetic counselling and so on) to avoid the links with the mass euthanasia and sterilization campaigns of the Nazi race-hygiene programs that culminated in the Final Solution. However, the transmission of liberal or progressive neo-eugenics memes continued, with the historical associations to eugenics sanitized. Many of the leaders in the eugenics movement were influential social scientists as well as educators, administrators and public health professionals. From the natural sciences, such as evolutionary biology and genetics, to social sciences, such as anthropology and human geography, to curriculum and educational policy, eugenics was based on the melding of a broad range of fields, whose harmonious combination was foreseen as leading to scientifically based societal efficiency and progress, and the eventual rise of "the Overman" (Bobbitt 1909).

This paper will explore the directors, educators and popularizers of the anthropological and geographical basis of the American eugenics movement. Anthropology (particularly the inherent traits and characteristics of races), human geography (especially the fledgling disciplines of demography and population study), sociobiology (especially considerations of human fertility and social hygiene) and ethnology (pedigree studies and racial hygiene) were considered important roots of the tree of the applied science of eugenics (see Figure 1). I will concentrate on the primary anthropology and human geography theorists and popularizers of American eugenics: Madison Grant, Henry Fairfield

Osborn (and his nephew Frederick H Osborn), Earnest A Hooton and Ellsworth Huntington. I will explore their influence on the movement, including immigration, as well as related social policies or education efforts. This is a fascinating era of American history and applied social science before the excesses of Nordic Fascism branded eugenics with the label of racist pseudoscience.

Eugenics: A New Science—A New Religion

The abridged creation story of eugenics begins with the acknowledged founder of eugenics, Francis Galton (celebrated polymath and cousin of Charles Darwin), and his influential protegé, Karl Pearson (pioneering statistician of biometrics). Galton revealed the "definition, scope and aims" of eugenics to a distinguished audience of his British peers, at the first meeting of the Sociological Society at London University, in May 1904. It was duly noted that Professor Karl Pearson occupied the chair. Influential clergy, scientists, business magnates and ladies of high birth were in attendance. "Eugenics," Galton pronounced, "is the science which deals with all influences that improve the inborn qualities of a race, also with those that develop them to the utmost advantage" (Galton 1904, 2). Galton ended his address with an agenda for the future and an appeal to "make eugenics a familiar academic question, a subject for serious study," one that

> must be introduced into the national conscience, like a new religion. It has strong claims to become

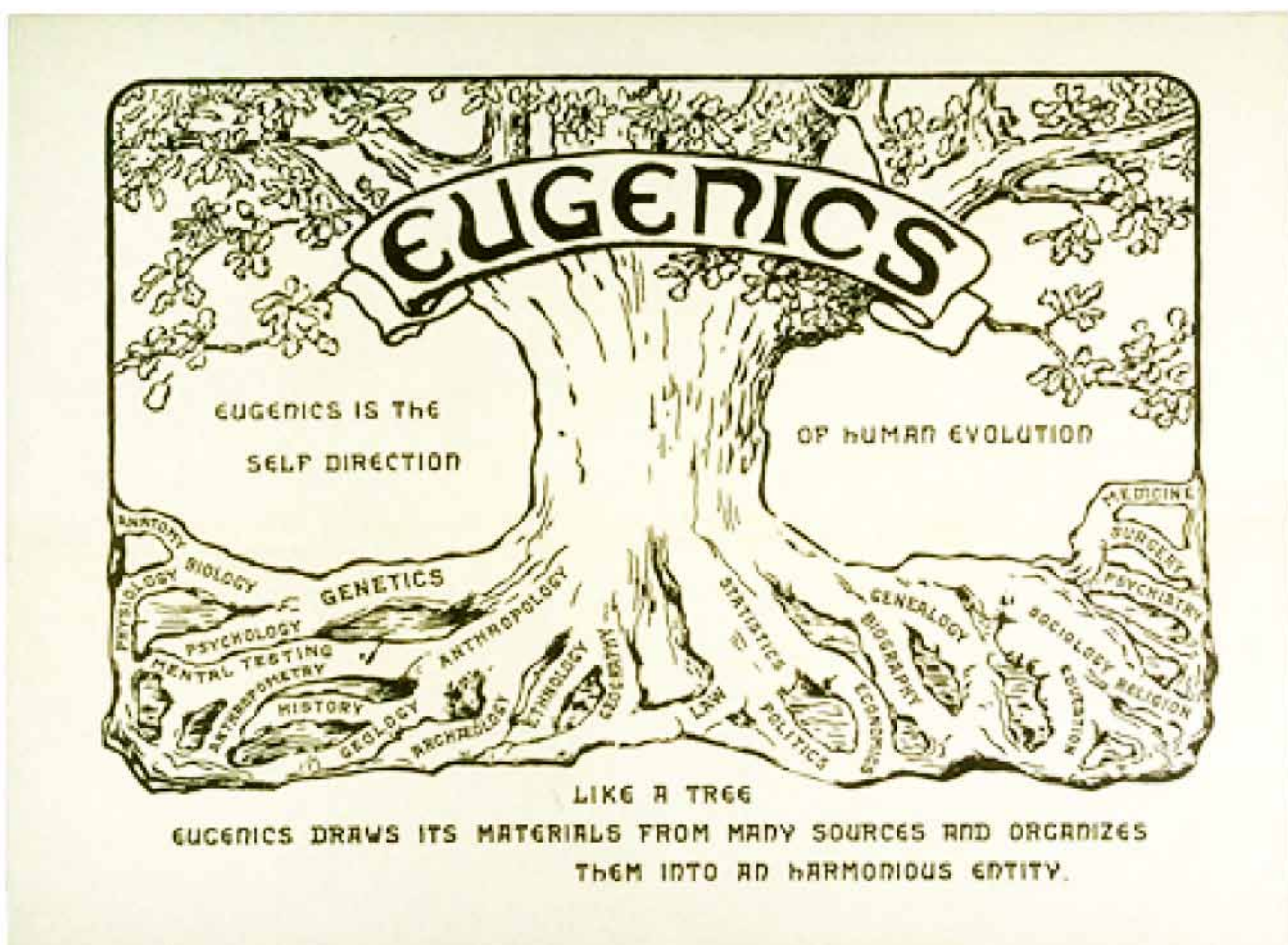


Figure 1: The Eugenics Tree, from a poster for the Second International Congress of Eugenics, held at the American Museum of Natural History in New York, September 22–28, 1921 (Engs 2005, 203)

an orthodox religious tenet of the future, for eugenics cooperate with the workings of nature by securing that humanity shall be represented by the fittest races. What nature does blindly, slowly, and ruthlessly, man may do providently, quickly, and kindly. (Galton 1904, 24)

Galton and his protegés created the new science of biometry as their divining rod, and were the leaders of the British eugenics movement for decades (Bowler 2003, 259). The Galton School initially engaged in a feud of sorts with Mendel's acolytes, at least until the experimental evidence for Mendel's laws operating in human heredity became too great to ignore (Ludmerer 1972, 45). The biometricians primarily studied continuous traits, such as intelligence, and preferred quantitative statistical analysis of large populations over the qualitative experimental study of discontinuous traits in individuals, which was favoured by the Mendelians.

Galton and Pearson founded a journal, *Biometrika*, in 1902. Galton lived to see eugenics and Galton societies form throughout the Empire, in America and around the world. He was knighted in 1909. Upon his death, in 1911, University College at London founded a Galton Eugenics Professorship and the Galton Biometric Laboratory, with Karl Pearson as its head (Kevles 1995, 35–38). Although they have largely expunged the references to eugenics (replaced by *genetics*) in their titles and publications, if not their agenda, the institutions they created survive to this day (Kevles 1995, 251–52). But nowhere else (with the eventual exception of Nazi Germany) would Galton's orthodox religion bear such prodigious fruits as in that scion of Puritanism that colonized the new shores of British North America. This transplantation across the Atlantic occurred quickly and with great vigour.

Unlike the class-based eugenics of Galton and his British cohorts, in America the seminal ideas took on a more race-based tone, synergistically combining with pre-existing Nativist (and "Nordic") sentiments, a proud history of scientific racism and racial segregation in the South,[1] and powerful social-efficiency and social-hygiene movements in a country on the cusp of Great Power status. Although only a generation or two removed from an essentially rural society based on agriculture, America became the world's greatest industrial power just before World War I, and reaped a rich harvest in new academic, scientific, social and technical fields (Bland 1977).

Scientific Authority for American Eugenics

Some of the most influential leaders of American eugenics were professional biologists and science educators who lent their considerable reputations and credentials to the movement and to related educational initiatives. American disciples of Galton's biometrics and Mendel's genetics joined with devotees of anthropology, evolutionary biology, psychology and sociology. Collectively, these academics lent scientific authority to the proto-eugenical seedlings from the "Clean-Living Movement" that followed on the heels of the brutality and social dislocation of the American Civil War (Engs 2005, 32). These reputedly precise and empirical sciences validated and legitimized eugenics as a rational, progressive social movement, just as Darwin's scientific theories validated the pre-existing social Darwinism of Thomas Malthus and Herbert Spencer.

Capturing the imaginations of a first wave of doctoral students from rechristened research universities—like Columbia, Harvard, and Yale—genetics, anthropometrics and demographics seemed to offer the same sort of mathematical certainty and predictive power to transform social science and American society in the Progressive era as Newton and his clockwork universe had done for physics and philosophy in European society during the Enlightenment. For this new generation of American academics and professionals,

[1] The infamous case of Samuel G Morton (1799–1851), a prominent Philadelphia physician, collector of skulls and amateur anthropologist, is now considered one of the most socially embarrassing episodes in the history of American science. Morton amassed a personal collection of almost 1,000 human skulls, from various races and parts of the world. His empirical measurement of the cranial capacity of those skulls, and the attempted correlation with racial intelligence, primarily by his supporters, brought Morton and this area of research to international fame. They are remembered most for their assertion that the various human races are different species, with separate origins (polygeny). Morton was the most respected of the group of amateur scientists and academics who became known as the American School of Anthropology. Although the science and logical arguments they held as irrefutable truths have been discredited, the underlying assertion that there is a scientific basis for the inherent inequality of human races is still alive today. (See Stanton [1966] and the chapter on Morton in Gould [1996] for the full story of this earlier brand of scientific racism in America.)

proud descendants of Anglo-Saxon Protestant pioneer stock, new fields like genetics, evolutionary biology and sociology seemed to offer the same sort of fertile land for professional colonization as their ancestors had found in the New World. These new sciences gave direction and legitimated the social agenda of the eugenics movement. The socially conservative WASP defenders of the status quo could not be easily dismissed as cranks if they were girded by the mantle of empirical scientific authority.

Backed by the authority and promise of these new scientific disciplines, the disciples of the eugenics movement quickly adopted the new hereditarian, social and statistical science concepts and research methods to rationalize the study of human betterment and race hygiene. Newton's calculus and cosmology had dazzled the glitterati and educated public of his day and allowed scientific, industrial and social revolutions that fundamentally changed Europe. The modern sciences that girded eugenics, it was hoped, could be deployed to battle a host of social evils that were causing racial degeneracy in America and threatening to derail societal progress. As the first decades of the new century transitioned into the Age of Anxiety, eugenicists knew they had to recruit a coterie of medical professionals, business, educational and social leaders, as well as influential politicians and philanthropists. More problematically, they needed to educate the public and future generations of young people who would populate their brave new world.

To this end, the American Eugenics Society (AES) formed a dozen subcommittees, some tackling the social problems most pressing to the movement, such as curbing immigration and vice, and others tasked with evangelizing eugenics among the sectors of American society. Among these were the Popular Education Committee, tasked with education of the public; and the Formal Education Committee, charged with the "incorporation of eugenics as an integral part of various appropriate courses throughout the school system, in the elementary grades through high school, as well as the encouragement of special courses in colleges and universities" (Evans 1931, x).

J F Bobbitt, who later gained fame as a progressive advocate of child-centred education, wrote an early American eugenics article with profound educational implications. In "Practical Eugenics" (1909), an article featured in G Stanley Hall's journal *Pedagogical Seminary*,[2] Bobbitt implored the American public and their leaders to curb the "rampant immigration" of non-Anglo-Saxon Europeans, and argued that "little could be done for the child of worm-eaten stock" (Selden 1999, 41). Bobbitt dramatically warned that two sinister processes were at work in America. The first was the "drying up of the highest, purest tributaries to the stream of heredity," referring to the decreasing birthrate of the native Anglo-Saxon stock, which had founded the country. The second was the "rising flood in the muddy, undesirable streams," referring to the large influx and troubling higher birth rates of the more recent wave of non–Anglo-Saxon immigrants from southern and eastern Europe, as well as the slaves brought to America before the Civil War (Bobbitt 1909, 388). Bobbitt also lamented the dysgenic effect of charities and social services for working against the laws of evolution and nature:

> Where survival of the fittest had previously ensured that society's best would continue, we are now faced with civilization's retrogressive policies. Our schools and our charities supply crutches to the weak in mind and morals [and thus] corrupt the streams of heredity which all admit are sufficiently turbid. (Bobbitt 1909, 387)

David Starr Jordan nurtured Leland Stanford Junior College into one of America's largest and most prestigious private universities; it is known today simply as Stanford. He was also a prolific writer in the eugenics field, decrying the dysgenic effects of war, venereal diseases and alcohol, and championing eugenic segregation and sterilization of the feeble-minded, as well as immigration and marriage restriction laws (Engs 2005). His books included *The Blood of the Nation* (1902) and *The Heredity of Richard Roe* (1911). Another of G Stanley Hall's influential students was Henry H Goddard, director of the research laboratory of the Training School at Vineland, New Jersey, for "feeble-minded

[2] *The Pedagogical Seminary* (which became *The Pedagogical Seminary and Journal of Genetic Psychology* from 1928–1953) was edited for many years by G Stanley Hall, then president of Clark University and professor of psychology and education. Hall is probably best known for being the founder of *child study*, then a new strand of curriculum studies. Several of his students became very involved in the eugenics movement (Selden 1999, 42–43).

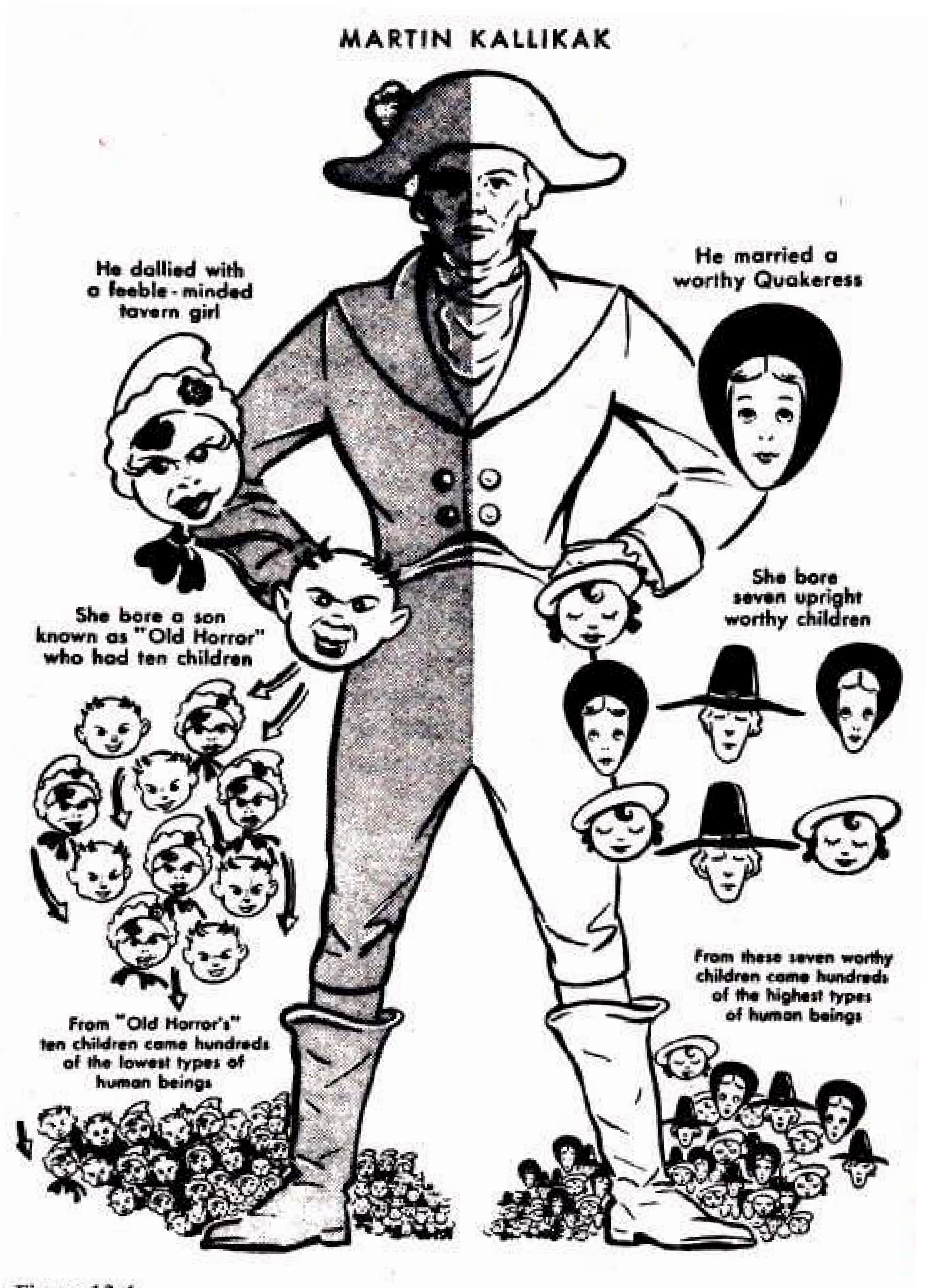


Figure 13.4
The "effects" of good and bad heredity on the descendants of Martin Kallikak

Figure 2: A graphical depiction of the "good and bad heredity" of the Kallikak family (Smith 1985, 171)

children.” Goddard translated and modified the Binet test[3] to more reliably measure the mental age of the residents at Vineland. Goddard also introduced the world to the Kallikaks in 1912—a *real* extended family in New Jersey with both a “Worthy side” and a “Degenerate side.” *The Kallikak Family* (Goddard 1912) became a staple model of eugenic pedigree studies for decades. When a later version was published in Nazi Germany, in 1935, the facial features of the “degenerate line” were altered to make them appear Jewish (Smith 1985).

Anthropology of Human Origins and Migrations Lends Scientific Rigour to Eugenics

Although most people think first of genetics and psychology when considering the scientific underpinnings of eugenics, anthropology and its subdisciplines were significant roots of the eugenics tree. Like Samuel Morton and his followers in the American School of Anthropology of the previous century, proponents forged a particular racial view of human development and progress. One of the founding fathers of American eugenics was Henry Fairfield Osborn (1857–1935). Of old-colonial Anglo-Saxon Presbyterian stock, Osborn was educated at Princeton (AB 1877 and ScD 1881 in archæology and geology) and studied anatomy and physiology at the College of Physicians and Surgeons in New York (Engs 2005, 170). He also studied embryology in Europe before his doctoral studies; received honorary degrees (LLD, ScD, PhD) from Princeton, Columbia, Cambridge, Oxford and Christiana (Oslo); and was a foreign member of the Royal Society and a senior geologist for the US Geological Survey. He began teaching at Columbia in 1891, along with a joint research appointment at the American Museum of Natural History in New York, of which he became president in 1908 and continued this position until his retirement in 1933.

Osborn joined the eugenics section of the American Breeders Association (which became the American Genetics Association in 1912), and was a founder of the Galton Society of America, in 1919. He was the chief American organizer of the First International Eugenics Congress (London 1912) and the president of the Second International Congress, in 1921, which was hosted by his museum in New York, as was the third in 1932 (Engs 2005, 170–71). Osborn was a Nativist, opposing immigration to America from non-Anglo-Saxon or non-Nordic regions of Europe (anything outside Europe or Canada would have been anathema). He disavowed birth control by middle- and upper-class “native” American women as dysgenic while the unfit (the lower classes or lesser immigrants) were flooding America with unfit offspring (Engs 2005, 171).

Osborn’s principle works in the area of anthropology and archæology were *Men of the Old Stone Age* (1915) and *Man Rises to Parnassus* (1927). *Men of the Old Stone Age: Their Environment, Life and Art*, originally a series of guest lectures at the University of California in 1914, was based on an extensive tour of Western Europe in 1911. It is dedicated to “my distinguished guides through the Upper Palæolithic caverns of the Pyrenees, the Dordogne,

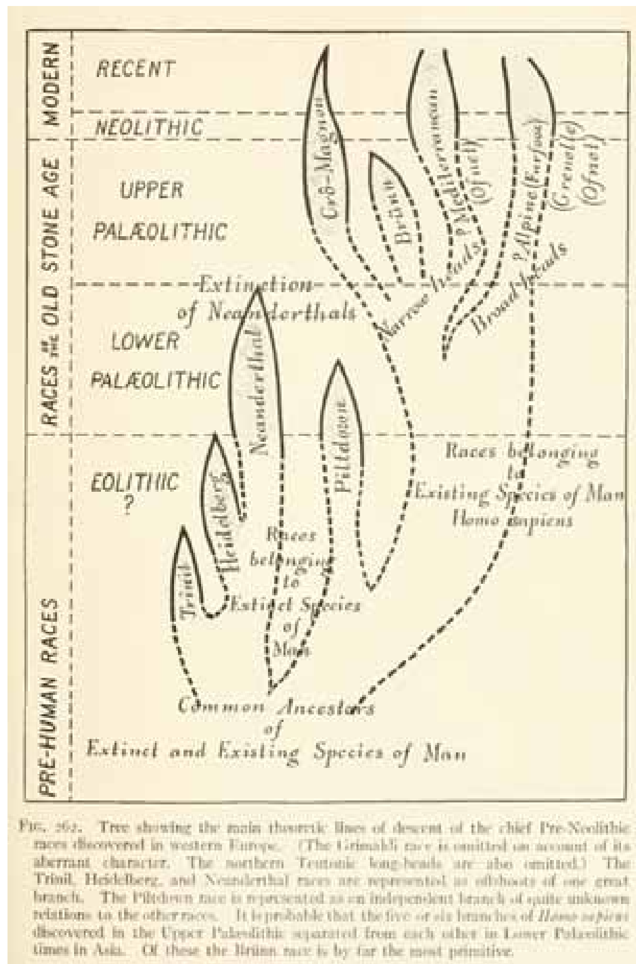


Figure 3: Chart of the archaic and palæolithic races of man (Osborn 1915, 491)

[3] *Editor’s note*: An early tool for measuring intelligence, developed by Alfred Binet, a French psychologist, in the first years of the 20th century.

and the Cantabrian mountains of Spain: Emile Carthailac, Henri Breuil, and Hugo Obermaier" (Osborn 1915). Printed on high-quality stock and profusely illustrated with photo-plates of remarkable quality, it went through three editions and fourteen printings by 1918.

Osborn hypothesizes the origin of archaic man as tracing to Asia in Eolithic times and posits the Trinil Race (Java Man or *Pithecanthropus erectus*) as the so-called "missing link" between the anthropoid apes and modern man, but cautions that *Pithecanthropus* is not a "direct ancestor of the higher races," but merely "the transition form between man and the anthropoids which the laws of evolution teach us must have existed" (Osborn 1915, 73–84).

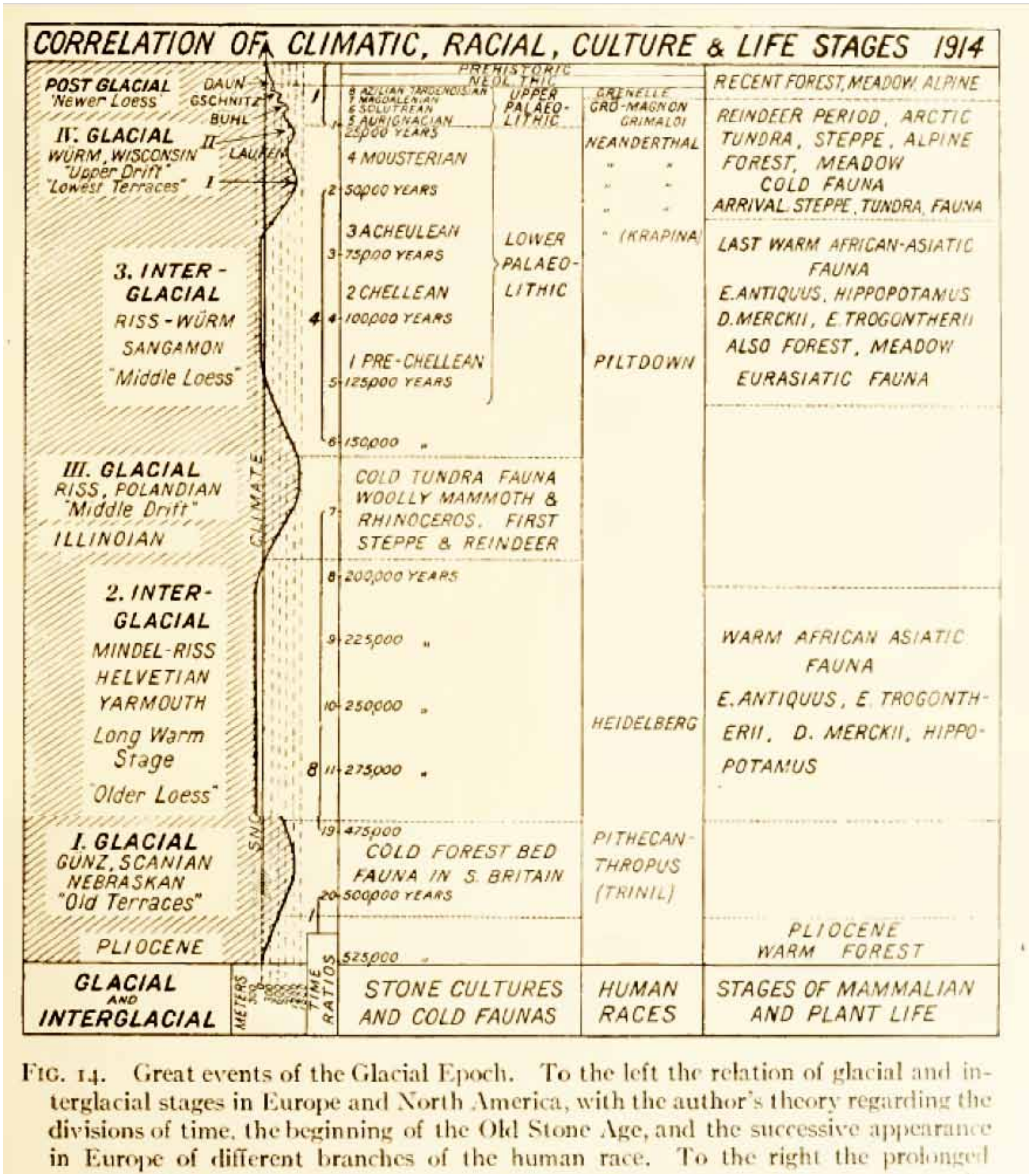


Figure 4: Chart of the events and human races of the glacial epoch (Osborn 1915, 41). (Note that the chart has been split, with the middle section excised so as to fit the page.)

Osborn devotes an entire chapter (some 70 pages) to the Neanderthals, and provides vivid descriptions, illustrations and photos of Neanderthal discoveries, implements and skeletal remains. As for their relation to modern humans, and their demise and disappearance, Osborn disagrees with Hrdlicka, the foremost scientific expert of the time, who speculated that they partly evolved into the lower races of *Homo sapiens*, and even "that traces of Neanderthal blood and physiognomy are not lacking among even modern Europeans" (Osborn 1915, 257). Instead, Osborn takes a more conventional view, even allowing for a causal decline of later races of Neanderthals, who were "not marked by any industrial progress or invention" (p 248) similar to the racial degeneration afflicting "lesser types" in his home country:

> The Neanderthals represent a side-branch of the human race which became wholly extinct in Western Europe … From Geologic evidence the date of this replacement [by the Crô-Magnon race] is believed to have been between 20,000 and 25,000 years before our era. So far as we know, the Neanderthals were entirely eliminated; no trace of the survival of the type has been found in any of the Upper Palæolithic burial sites; nor have the alleged instances of the survival of the strain been substantiated. We tend to agree with Boule and Schwalbe that the supposed cases among modern races of Neanderthal characteristics are simply low or reversional types … (Osborn 1915, 257–58)

Osborn makes no allowance for any intermingling and certainly not any interbreeding, only deadly competition and battle, even suggesting that the moderns may have possessed bow-and-arrow technologies against the Neanderthals' primitive spears, allowing for a stand-off potential:

> From this scanty evidence we may infer that the new race competed for a time with the Neanderthals before they dispossessed them of their principal stations and drove them out of the country or killed them in battle … when the Crô-Magnons entered western Europe at the dawn of the Upper Palæolithic, they were armed with weapons which, with their superior intelligence and physique would have given them a very great advantage in contests with the Neanderthals. (Osborn 1915, 258)

Despite these overviews of apes and archaic humans, the focus is on modern types, and particularly the Cro-Magnon, who are pictured as handsome specimens of rugged European men that would not be out of place in a Tolkien movie or as members of a rock group of the British Invasion. Osborn details the origins of modern humans and the various races and stages of man, along with their technology and art, and provides numerous samples of skulls, skeletons, artifacts and cave paintings in an almost seamless chronology of western and central Europe. As to how they got there—this is the fascinating part, and an essential component of the overarching racial theories of eugenics as they would be developed by other theorists, particularly in Progressive America and in Nazi Germany:

> The Lower Palæolithic industrial cycle, comprising the Chellean, Acheulean and Mousterian, seems to have been similar in evolution both around the Mediterranean coasts and in the northern portions of Europe. From the fact that the Crô-Magnons arrived with the Aurignacian industry, it appears that they came through Phœnecia and along the southern coasts of the Mediterranean, through Tunis, into Spain; also perhaps along the northern coasts through Italy. Their evolution had probably taken place somewhere on the continent of Asia, for their physical structure is entirely of the Asiatic type, and not in the least African or Ethiopian type; that is, they exhibit no negroid characters whatever. (Osborn 1915, 261)
>
> The passage of the Cro-Magnons along these coasts was, therefore, like the subsequent wave of the true Mediterranean race, dark-haired, long-headed, narrow-faced people, which followed this coast in early Neolithic times, or again, like the wave of the Arabian or Moslem advance, which pressed forward along the northern coast of Africa and into southwestern Europe. (Osborn 1915, 261–62)

Osborn also details the "Grimaldi Race of negroids" (as discovered at the *Grotte des Enfants*) as being an aberrant or degenerate species of humans, similar to but more primitive than the Cro-Magnons of Eurasia, a few of whom somehow found their way out of North Africa, but did not widely spread into Europe (Osborn 1915, 264–69). He concludes that these Grimaldi represent an intermediate type in the evolution of the white and black races. Thus, rather than an "out-of-Africa" scenario, we have an into-Africa scenario (from Eurasia), with the white and black races then evolving separately into the various Neolithic and modern races.

Osborn reserves very high praise for the Cro-Magnons of the Upper Paleolithic, including their prodigious cranial capacity "superior to the average capacity of the lesser modern European races," and devotes two chapters to their industry, art and culture (Chapters IV and V). He then turns to the "invasions of the new races" in the Neolithic (Chapter VI), the "highest" of which, the Nordics along the Baltic coast in early post-glacial times, represent the ultimate peak of evolution in the prehistoric period. It should be noted that there is no mention of eugenics anywhere in this work (this would come later in Grant's *Passing of the Great Race* [1918] and Osborn's later *Man Rises to Parnassus* [1927]). But, as with these later works, Osborn sets out a pattern of evolution and migration from east to west, with the best migrants coming in the first waves, and later followers being generally of lesser racial value, just as in the colonization of America, on which Madison Grant was to capitalize in all his anthropological and eugenic-themed works.

Madison Grant—The Rise and "Passing of the Great Race"

Madison Grant (1865–1937, Yale law degree 1890) was a stalwart of American eugenics and a close friend of Teddy Roosevelt (Engs 2005, 102–103). Grant gained fame as an early nature conservationist, leading the charge to establish several national parks and wilderness preserves. His most renowned work, *The Passing of the Great Race: Or the Racial Basis of European History* [first published in 1916], argued for the preservation of America as a sort of civilization preserve for the Nordic race and advocated for immigration only from Anglo-Saxon or Nordic regions of Europe, and only those who could demonstrate their pure bloodlines. He insisted that "the Laws of Nature require the obliteration of the unfit," and completely rejects the "maudlin" notion of the Melting Pot:

> We Americans must realize that the altruistic ideals which have controlled our social development during the past century and the maudlin sentimentalism that has made America "an asylum for the oppressed," are sweeping the nation toward a racial abyss. If the Melting Pot is allowed to boil without control and we continue to follow our national motto and deliberately blind ourselves to "all distinctions of race, creed or color," the type of native American of Colonial descent will become as extinct as the Athenian of the age of Pericles, and the Viking of the days of Rollo. (Grant 1918, 263)

Grant attracted the notice of Adolf Hitler while Hitler was in Landsberg prison writing *Mein Kampf*. After becoming *Führer*, Hitler wrote to Grant, thanking him for his momentous work and stating that the book was "his Bible" (Black 2003, 259). At the 1947 Nuremberg Trials, Grant's *Passing of the Great Race* was introduced into evidence by Dr Karl Brandt, Hitler's personal physician and nominal head of the euthanasia program, in order to demonstrate that the population policies of the Third Reich were not ideologically unique or original to Nazi Germany (Engs 2005, 102).

The University of Alberta library copy of *Passing* is a 1977 reprint of the 1918 "revised and amplified" edition, with both original and updated preface by Henry Fairfield Osborn, who gives the book his imprimatur and highest praise. Indeed, there are many portions of the work that are verbatim transcriptions of Osborn's summaries and main points from *Men of the Old Stone Age* (1915). *The Passing of the Great Race* went through four editions and thirteen printings by 1936. It was translated into German and became a sort of template for German race-hygiene texts.[4] The four-page bibliography lists a few contemporary genetics texts and many historical works dating back to Plato. However, it is dominated by Continental anthropology or archeology sources, many of them identical to Osborn's (1915), and the social Darwinism of Gobineau,[5] Spencer and Galton. Osborn's original preface (1916) is a sketch or microcosm of the whole book and, in many ways, a microcosm of the American eugenics movement at its height in the Progressive era:

> European history has been written in terms of nationality and language, but never before in terms of race; yet race has played a far larger part than either

[4] For instance, Hans F K Gunther (1926) *Rassenkunde Europas*, which was translated into English in 1927 as *The Racial Elements of European History* by G C Wheeler (London: Methuen). Gunther was a much more prolific author than Osborn and Grant combined, but credits both in this text. (See Engs 2005, 103–104.)

[5] *Editor's note*: Arthur de Gobineau's best-known work is *Essai sur l'inégalité des races humaines (An Essay on the Inequality of the Human Races)* (1853–1855); it was translated into both English and German.

> language or nationality in moulding the destinies of men; race implies heredity, which implies all the moral, social and intellectual characteristics and traits that are the springs of politics and government.
>
> Quite independently and unconsciously the author, never before a historian, has turned this historical sketch into the current of a great biological movement, which may be traced back to the teachings of Galton and Weismann … This movement has compelled us to recognize the superior force and stability of heredity, as being more enduring and potent than environment. This movement is also a reaction from the teaching of Hippolyte Taine among historians and of Herbert Spencer among biologists, because it proves that environment, and in the case of man education, have an immediate, apparent and temporary influence, while heredity has a deep, subtle and permanent influence on the actions of men. (Grant 1916, vii)

The anthropological and archeological histories outlined are essentially a summary of Osborn's *Men of the Old Stone Age* (1915), interspersed with eugenic quips and assertions. For instance, in the chapter on Eolithic man, which outlines the origins of humanity (Osborn's Java Man in Asia), we find curious and out-of-place excerpts like this:

> The progress of civilization becomes evident only when immense periods are studied and compared, but the lesson is always the same, namely, that race is everything. Without race there can be nothing except the slave wearing his master's clothes, stealing his master's proud name, adopting his master's tongue and living in the crumbling ruins of his master's palace. Everywhere on the sites of ancient

CONTENTS

PART I

RACE, LANGUAGE AND NATIONALITY

PART II

EUROPEAN RACES IN HISTORY

xv

xvi CONTENTS

Figure 5: Contents pages for Madison Grant's *Passing of the Great Race* (1916 edition)

civilizations the Turk, the Kurd and the Bedouin camp; and Americans may well pause and consider the fate of this country which they, and they alone, founded and nourished with their blood. The immigrant ditch diggers and the railroad navvies were to our fathers what their slaves were to the Roman and the same transfer of political power from master to servant is taking place today. (Grant 1916, 100)

One of the surprising departures from Osborn's anthropology is Grant's correction regarding Piltdown man, something that Osborn did not do, even in later editions and printings of his book. Grant asserts that recent evidence indicates "the jaw belonged to a chimpanzee so that the genus *Eoanthropus* must now be abandoned and the Piltdown man must be included in the genus *Homo* as at present constituted" (Grant 1918, 106). Like Osborn, Grant places a great deal of emphasis on cranial capacity and shape (brachycephalic—broad, round skulls, and dolichocephalic—narrow, long skulls), not unlike their predecessor Samuel Morton in the previous century. These measures are essentially used as genetic markers of fitness or racial quality, and unlike eye or hair colour, are seen to be more enduring and of greater diagnostic value.

The book's focus, as the contents pages indicate, is on the migrations, racial qualities and characteristics for the Neolithic, Bronze and Iron ages of the three main races of European history: Alpine, Mediterranean and Nordic. Not surprisingly, the primary focus is on the origin, arrival, expansions and contractions of the "master race" in Europe, and (briefly) in the Americas and elsewhere. This was to be greatly expanded and amplified in Grant's later *Conquest of a Continent* (1933) and other, lesser works in between. Grant largely mirrors de Gobineau's theories of racial inequality and rankings, but adds his own interpretations and emphases. Grant makes finer distinctions of these groups, especially the Nordics, who are divided into more than half-a-dozen subracial groups, with the Scotch of Viking ancestry ranking near the top (not surprising, given his own heritage).

Grant details the central role of the Nordic migrations and their influences on the great civilizations of Europe, especially Classical Greece and Republican Rome. It was Nordic migrants that put the lustre on Greek art, culture, democracy and philosophy, as well as their conquest of the surrounding regions that were populated by lesser races. It was race-mixing and gradual absorption by waves of later immigrants or lower classes—the Alpines and Mediterraneans—that explains their eventual decline and fall. In short, the heights of European history are due to Nordic blood and influence, while decline, decay and decadence are explained by the corrupting influence of Slavic Alpines (such as Attila the Hun), hordes of Mongoloid invaders (Mongols, Tartars, Tatere and so forth) and the stifling fecundity of dark-skinned Mediterraneans. One of the laugh-out-loud moments in reading this text was provided by this telling footnote:

Procopius tells a significant story which illustrates the contrast in racial character between the natives and the barbarians. He relates that at the surrender of Ravenna in 540 AD by the Goths to the army of the Byzantines, "when the Gothic women saw how swarthy, small men of mean aspect had conquered their tall, robust, fair-skinned barbarians they were furious and spat in their husbands' faces and cursed them for cowards." (Grant 1918, 189)

One can also clearly discern the influence of Galton's theories of the influence of men of genius and eminence throughout history, although it lacks Galton's and Pearson's adherence to statistical detail and biometric minutiae. This explains Grant's greater popularity and influence not only on American eugenics (including educational texts) but also with Hitler's radical *Weltanschauung* and German race-hygiene efforts. An example of Galton's "hereditary genius" influence can be gleaned in this passage, also found in the chapter on Eolithic man:

This genius producing type is slow breeding and there is real danger of its loss to mankind. Some idea of the value of these small strains can be gained from the recent statistics [by David Starr Jordan] which demonstrate that Massachusetts produces more than fifty times as much genius per hundred thousand whites as does Georgia, Alabama or Mississippi, although apparently the race, religion and environment, other than climatic conditions, are much the same, except for the numbing presence in the South of a large Negro population. (Grant 1918, 99)

These recurring racial themes came to dominate the American eugenics movement in the Progressive era and were echoed by educators, social scientists, sympathetic politicians and the native American middle and upper-class public, who flocked to eugenic displays, civic groups, and popular articles, books, and lectures. And they became a fundamental part of political debates.

Grant, Osborn, E A Ross and Immigration Restrictions

In addition to anthropologists, biologists and geneticists, other social scientists significantly added to the scientific authority of eugenics. One of the most prestigious and prodigious was Edward Alsworth Ross (1866–1951), professor of sociology at the University of Wisconsin at Madison. Ross had already published many scholarly works by the time Galton announced the dawn of the science of eugenics, including *Social Control* (1901) and *Foundations of Sociology* (1905). He became one of the founding members of the American Galton Society (1918), the most exclusive of eugenic clubs, which, like the National Academy of Sciences, featured a rigorous review process and election of members. Only the "cream" were admitted (Engs 2005, 85).

Ross's early work established his credentials as one of the most prominent American social scientists of his era, but it contained little trace of the eugenic undertones that his later works evidenced. Shortly before the beginning of World War I, the tone and content of his works changed, becoming characteristic of the Nativist faction of the eugenics movement in America. He opposed immigration from non-Nordic countries, reflecting well the views of the eugenics movement's primary racial theorists, Grant, Osborn, Harry Laughlin and Lothrop Stoddard (Engs 2005, 155–56). Beginning with *The Old World in the New* (1914), Ross begins to tirelessly advocate for immigration restrictions against the "hordes of human refuse who swarm in upon us in this last decade or so" (see Figure 6). In describing, for instance, the "bulk of South-Italian immigrants to America," he writes

> As grinding rusty iron reveals the bright metal, so American competition brings to light the race-stuff in poverty-crushed immigrants. But not all this stuff is of value in a democracy like ours. Only a people endowed with a steady attention, a slow-fuse temper, and a persistent will can organize itself for success in the international rivalries to come. So far as the American people consents to incorporate with itself great numbers of wavering, impulsive, excitable persons, it must in the end resign itself to lower efficiency, to less democracy, or to both. (Ross 1914, 119)

Grant, Osborn and Ross joined with many eugenics groups and leaders, even forming the Immigration Restriction League to lobby Congress and act as expert witnesses in committees. Their efforts were successful by 1921, when a quota system based on country of origin was established, limiting immigration from each country to 3 per cent of its American population in the 1910 census (Engs 2005, 126).

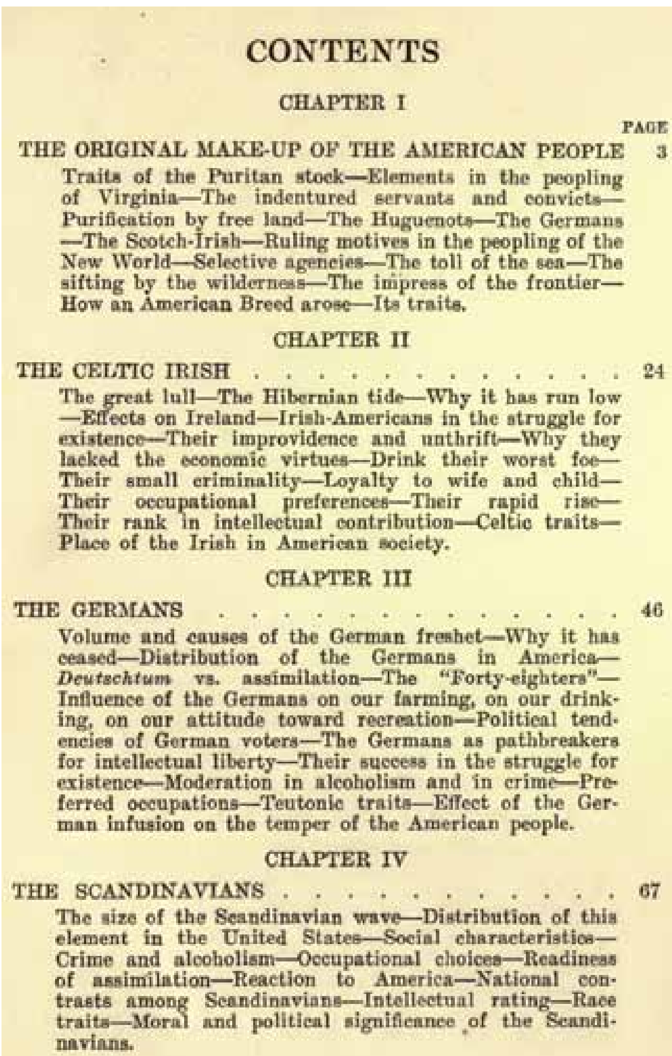
In 1924, the Johnson-Reed *Immigration Act* [subtitled "An act to limit the immigration of aliens into the United States, and for other purposes"] was passed. The act reduced the annual number of immigrants who could be admitted from any country from 3 per cent to 2 per cent of the number of people from that country who were already living in the United States and moved the base year of the quota back to 1890, greatly favouring the earlier immigration pattern, which was dominated by the Anglo-Saxon and Nordic regions of northwestern Europe (left side of Figure 6), and curtailing immigrants from southern and eastern Europe (right side of Figure 6). This law did not go into full effect until 1929, and was not repealed until 1952, although some provisions persisted until 1965 (Engs 2005, 126).

Eugenics Education for a Progressive Public

Eugenics exhibitions—at state fairs, national events, and in museum displays—were staples throughout the interwar period. These exhibits, concerned with the social perils that eugenics promised to ameliorate, as well as the potential for unbridled future progress, enthralled the burgeoning American middle-class. "Better Baby" and "Fitter Family" contests pointed the way upward—positive eugenics. The need for negative eugenics was bluntly illustrated by dire warnings of "race-suicide" through the dysgenic action of "racial poisons" such as alcohol, miscegenation (even without procreation), venereal diseases and feeble-mindedness, all leading to racial degeneracy through a sort of neo-Lamarckian inheritance of acquired characteristics. Indeed, in America (as in the Soviet Union, where it later reached ridiculous heights of absurdity under Lysenko), many early eugenicists retained these Lamarckian concepts long after scientists had embraced the contrary theories of August Weismann and Gregor Mendel.

Public exhibitions of eugenics in America followed a popular tradition established in 1915, when the Race Betterment Foundation, headed by John H Kellogg (of breakfast-cereal fame) organized an elaborate display at San Francisco's Panama-Pacific International Exhibition. It received millions of visitors. Organizers included Stanford University chancellor David Starr Jordan and Harvard University president emeritus Charles W Eliot; the "exhibit offered a brief for enacting eugenics-based legislation that would support sterilization of 'defectives' and limit immigration to Northern Europeans" (Currell and Cogdell 2006, 362). Parts of this exhibit were later used by eugenics experts, such as Harry H Laughlin [director of the Eugenics Record Office (ERO)], who testified to educate American congressmen on Capitol Hill before passage of the Johnson-Reed *Immigration Act*.

Eugenics displays sponsored by various American eugenics and social-hygiene associations were staples at many public events, which were often held in strategic conjunction with eugenics-related legislative hearings, votes or public referendums. A striking example is provided in "The Nazi Eugenics Exhibit in the United States, 1934–43," in *Popular Eugenics: National Efficiency and American Mass Culture in the 1930s* (Currell and Cogdell 2006, 359–78). This book includes provocative, well-illustrated chapters on eugenics in popular culture (movies, novels, art). In addition, there is a fascinating chapter devoted to a eugenics exhibit funded by the American Public Health Association.



CONTENTS

CHAPTER I

PAGE

THE ORIGINAL MAKE-UP OF THE AMERICAN PEOPLE 3

Traits of the Puritan stock—Elements in the peopling of Virginia—The indentured servants and convicts—Purification by free land—The Huguenots—The Germans—The Scotch-Irish—Ruling motives in the peopling of the New World—Selective agencies—The toll of the sea—The sifting by the wilderness—The impress of the frontier—How an American Breed arose—Its traits.

CHAPTER II

THE CELTIC IRISH 24

The great lull—The Hibernian tide—Why it has run low—Effects on Ireland—Irish-Americans in the struggle for existence—Their improvidence and unthrift—Why they lacked the economic virtues—Drink their worst foe—Their small criminality—Loyalty to wife and child—Their occupational preferences—Their rapid rise—Their rank in intellectual contribution—Celtic traits—Place of the Irish in American society.

CHAPTER III

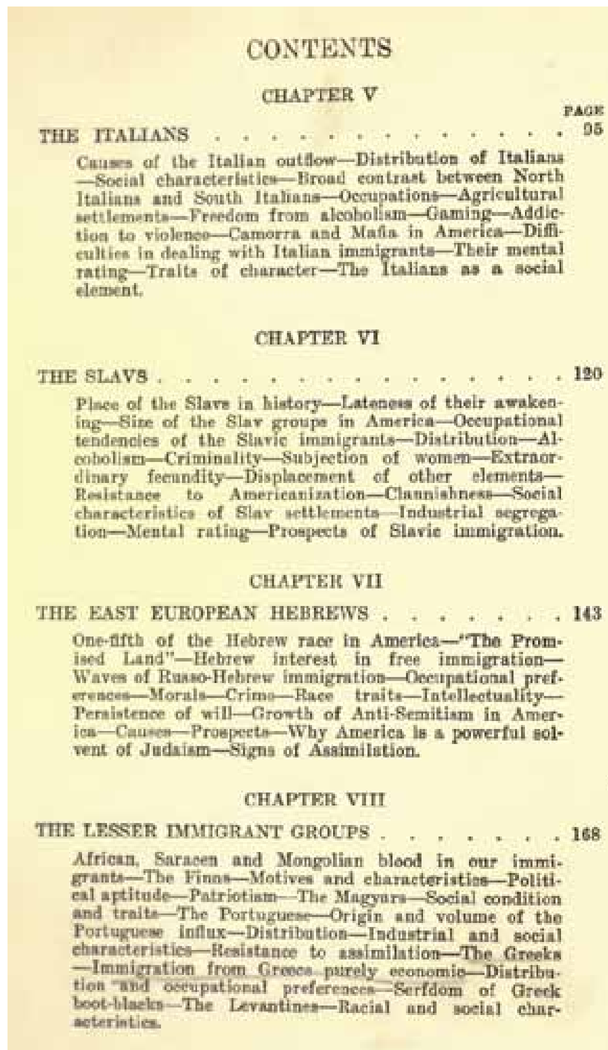
THE GERMANS 46

Volume and causes of the German freshet—Why it has ceased—Distribution of the Germans in America—*Deutschtum* vs. assimilation—The "Forty-eighters"—Influence of the Germans on our farming, on our drinking, on our attitude toward recreation—Political tendencies of German voters—The Germans as pathbreakers for intellectual liberty—Their success in the struggle for existence—Moderation in alcoholism and in crime—Preferred occupations—Teutonic traits—Effect of the German infusion on the temper of the American people.

CHAPTER IV

THE SCANDINAVIANS 67

The size of the Scandinavian wave—Distribution of this element in the United States—Social characteristics—Crime and alcoholism—Occupational choices—Readiness of assimilation—Reaction to America—National contrasts among Scandinavians—Intellectual rating—Race traits—Moral and political significance of the Scandinavians.



CONTENTS

CHAPTER V

PAGE

THE ITALIANS 95

Causes of the Italian outflow—Distribution of Italians—Social characteristics—Broad contrast between North Italians and South Italians—Occupations—Agricultural settlements—Freedom from alcoholism—Gaming—Addiction to violence—Camorra and Mafia in America—Difficulties in dealing with Italian immigrants—Their mental rating—Traits of character—The Italians as a social element.

CHAPTER VI

THE SLAVS 120

Place of the Slavs in history—Lateness of their awakening—Size of the Slav groups in America—Occupational tendencies of the Slavic immigrants—Distribution—Alcoholism—Criminality—Subjection of women—Extraordinary fecundity—Displacement of other elements—Resistance to Americanization—Clannishness—Social characteristics of Slav settlements—Industrial segregation—Mental rating—Prospects of Slavic immigration.

CHAPTER VII

THE EAST EUROPEAN HEBREWS 143

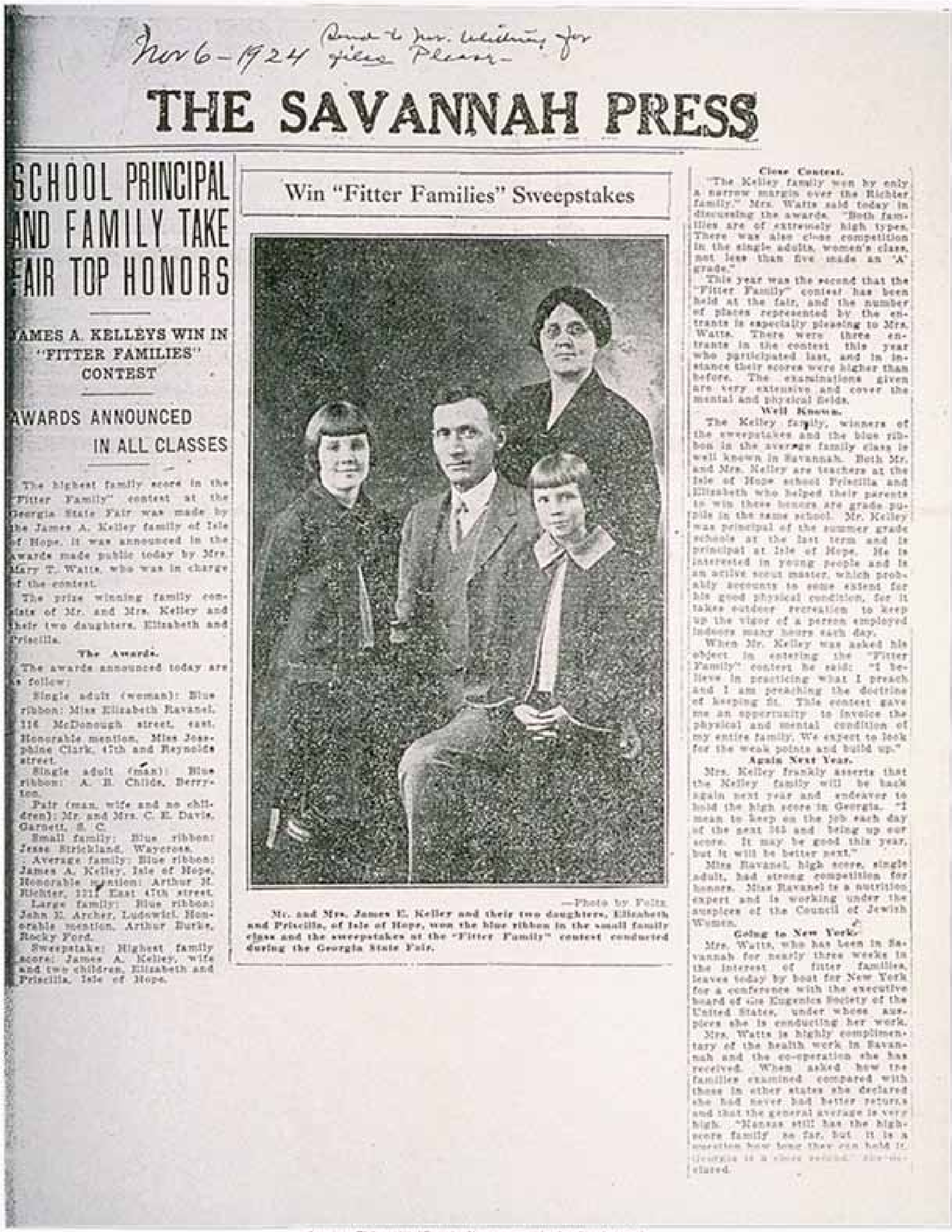
One-fifth of the Hebrew race in America—"The Promised Land"—Hebrew interest in free immigration—Waves of Russo-Hebrew immigration—Occupational preferences—Morals—Crime—Race traits—Intellectuality—Persistence of will—Growth of Anti-Semitism in America—Causes—Prospects—Why America is a powerful solvent of Judaism—Signs of Assimilation.

CHAPTER VIII

THE LESSER IMMIGRANT GROUPS 168

African, Saracen and Mongolian blood in our immigrants—The Finns—Motives and characteristics—Political aptitude—Patriotism—The Magyars—Social condition and traits—The Portuguese—Origin and volume of the Portuguese influx—Distribution—Industrial and social characteristics—Resistance to assimilation—The Greeks—Immigration from Greece purely economic—Distribution and occupational preferences—Serfdom of Greek boot-blacks—The Levantines—Racial and social characteristics.

Figure 6: Contents pages from E A Ross's *Old World in the New* (1914)



Nov 6-1924

THE SAVANNAH PRESS

SCHOOL PRINCIPAL AND FAMILY TAKE FAIR TOP HONORS

JAMES A. KELLEYS WIN IN "FITTER FAMILIES" CONTEST

AWARDS ANNOUNCED IN ALL CLASSES

The highest family score in the "Fitter Family" contest at the Georgia State Fair was made by the James A. Kelley family of Isle of Hope, it was announced in the awards made public today by Mrs. Mary T. Watts, who was in charge of the contest.

The prize winning family consists of Mr. and Mrs. Kelley and their two daughters, Elizabeth and Priscilla.

The Awards.

The awards announced today are as follow:

Single adult (woman): Blue ribbon: Miss Elizabeth Ravanel, 116 McDonough street, east. Honorable mention, Miss Josephine Clark, 47th and Reynolds street.

Single adult (man): Blue ribbon: A. B. Childs, Berryton.

Pair (man, wife and no children): Mr. and Mrs. C. E. Davis, Garnett, S. C.

Small family: Blue ribbon: Jesse Strickland, Waycross.

Average family: Blue ribbon: James A. Kelley, Isle of Hope. Honorable mention: Arthur H. Richter, 121 East 47th street.

Large family: Blue ribbon: John E. Archer, Ludowici. Honorable mention, Arthur Burke, Rocky Ford.

Sweepstake: Highest family score: James A. Kelley, wife and two children, Elizabeth and Priscilla, Isle of Hope.

Win "Fitter Families" Sweepstakes

—Photo by Foltz.

Mr. and Mrs. James E. Kelley and their two daughters, Elizabeth and Priscilla, of Isle of Hope, won the blue ribbon in the small family class and the sweepstakes at the "Fitter Family" contest conducted during the Georgia State Fair.

Close Contest.

"The Kelley family won by only a narrow margin over the Richter family," Mrs. Watts said today in discussing the awards. "Both families are of extremely high types. There was also close competition in the single adults, women's class, not less than five made an 'A' grade."

This year was the second that the "Fitter Family" contest has been held at the fair, and the number of places represented by the entrants is especially pleasing to Mrs. Watts. There were three entrants in the contest this year who participated last, and in instance their scores were higher than before. The examinations given are very extensive and cover the mental and physical fields.

Well Known.

The Kelley family, winners of the sweepstakes and the blue ribbon in the average family class is well known in Savannah. Both Mr. and Mrs. Kelley are teachers at the Isle of Hope school. Priscilla and Elizabeth who helped their parents to win these honors are grade pupils in the same school. Mr. Kelley was principal of the summer grade schools at the last term and is principal at Isle of Hope. He is interested in young people and is an active scout master, which probably accounts to some extent for his good physical condition, for it takes outdoor recreation to keep up the vigor of a person employed indoors many hours each day.

When Mr. Kelley was asked his object in entering the "Fitter Family" contest he said: "I believe in practicing what I preach and I am preaching the doctrine of keeping fit. This contest gave me an opportunity to invoice the physical and mental condition of my entire family. We expect to look for the weak points and build up."

Again Next Year.

Mrs. Kelley frankly asserts that the Kelley family will be back again next year and endeavor to hold the high score in Georgia. "I mean to keep on the job each day of the next 365 and bring up our score. It may be good this year, but it will be better next."

Miss Ravanel, high score, single adult, had strong competition for honors. Miss Ravanel is a nutrition expert and is working under the auspices of the Council of Jewish Women.

Going to New York.

Mrs. Watts, who has been in Savannah for nearly three weeks in the interest of fitter families, leaves today by boat for New York for a conference with the executive board of the Eugenics Society of the United States, under whose auspices she is conducting her work.

Mrs. Watts is highly complimentary of the health work in Savannah and the co-operation she has received. When asked how the families examined compared with those in other states she declared she had never had better returns and that the general average is very high. "Kansas still has the high-score family so far, but it is a question how long they can hold it. Georgia is a close second," she declared.

Figure 7: Newspaper article profiling a "Fitter Family" from the 1924 Georgia State Fair

First appearing in 1920 at the Kansas Fair, "Fitter Family" competitions were popular until WWII. There were several different categories and criteria for judging families, such as size of the family, overall attractiveness and social prestige of the family members' occupations, all of which were supposed to determine the likelihood of having healthy, successful children. The winners of these competitions were given a bronze medal sponsored by the Galton Society, as well as extensive coverage in local newspapers. Local medical specialists and eugenicists offered their time to judge these competitions. These contests used simplified human heredity concepts to promote better social and racial hygiene. The laws of simple Mendelian inheritance were often displayed, along with "famous" and "notorious" pedigree charts, especially Goddard's Kallikak family pedigree (Engs 2005, 78; Kevles 1995, 61).

Figure 8: A 1922 advertisement from the Human Betterment Foundation, in *Collier's*

It was prepared by the *Deutsches Hygiene Museum* of Dresden, circa 1933, shortly after the Nazi Party had gained power and passed its own compulsory sterilization law that many American eugenicists applauded for its scope and authority.[6] Titled "Eugenics in the New Germany," it featured a number of pedigree charts for famous Germans (for example, J S Bach) selected for their genius (and showing how their offspring inherited their special talents and traits). Beside the eugenic pedigrees, in stark contrast, were the dire economic and social imperatives for the efficient sterilization of the mentally unfit, habitual criminals, homosexuals and other "sexual perverts."

The exhibit arrived in California (which led all states in eugenic sterilization procedures) in the summer of 1934, where it occupied 3,000 square feet in the Pasadena Civic Auditorium and was heralded by newspaper and radio coverage. It toured several large cities for several months before moving on to Oregon, where the state legislature was considering expanding its own eugenic sterilization act to include the kind of compulsory provisions adopted in the Third Reich and in California. After additional stops, the display found a more permanent home at the Buffalo Museum of Science until, with the outbreak of war in Europe, it was moved to storage, and finally destroyed in 1943, "when it had become a distinct liability for the museum" (Currell and Cogdell 2006, 379).

Encouraging the "Mother of Tomorrow" in the Prevention of "Race-Suicide"

Although the leadership of American eugenics organizations was largely professional, middle-class WASP males, eugenics had its fair share of support from women, mostly in the form of loose alliances with various related social movements. The birth-control and temperance movements, as well as other contemporary feminist social-hygiene organizations tentatively supported eugenics, and vice-versa, in a somewhat tenuous symbiotic mutualism. One of the fundamental goals of eugenics was to re-establish the primacy of prolific motherhood among the "fitter classes" of women, especially female college graduates, while negating the problematic modern diversions of extensive career and educational ambitions. The Janus face of this situation was to suppress the reproduction of the feeble-minded "moron-girls," whose alleged precocity was equalled only by their legendary fecundity, and to combat the so-called "racial poisons" of alcohol, gambling, venereal diseases and other social vices that afflicted less desirable groups of American women. As Kline (2001) asserts in her introduction to *Building a Better Race*,

> Eugenicists promoted two opposing models of womanhood that suggested the importance of gender to eugenics ideology: the "mother of tomorrow" and the "moron." The mother of tomorrow represented the procreative potential of white middle-class women, while the moron symbolized the [dysgenic] danger of female sexuality unleashed. Together these models, which carried great symbolic weight in the eugenics movement, demonstrated that the eugenic definition of womanhood was double-edged: it portrayed women as responsible not only for racial progress but also for racial destruction. (p 15)

Teddy Roosevelt placed the blame for "race-suicide" on white womanhood. Women of "good stock" who chose not to have children were "race criminals" and jeopardized the continuance of the American empire, since "no race has any chance to win a great place unless it consists of good breeders as well as good fighters" (Kline 2001, 15). No segment of American femininity seemed to offer as much eugenic promise of being "good breeders" as those who comprised the population of women's colleges and those few universities that equally accepted women as students outside of the traditionally female schools and faculties (such as nursing and teaching). This dysgenic problem of the differential birth rate between the "fit" and "unfit" members of the white race was to preoccupy eugenic think-tanks for decades, from the time of Teddy Roosevelt's warning of race-suicide in the first decade of

[6] Harry Laughlin's downfall began in 1935, when the Carnegie Institution of Washington (CIW) [which funded the ERO] investigated Laughlin over his "embarrassing" support for eugenic sterilization in Nazi Germany. Laughlin caused further official embarrassment when he was awarded an honorary doctorate from the University of Heidelberg in 1937. He was forced to retire from Cold Spring Harbor at about the same time that C B Davenport formally retired. Ironically, Laughlin suffered from epilepsy, one of the dysgenic traits that the Nazis began to eliminate (permanently) in 1939. He died a year before the war ended (Engs 2005, 141).

the 1900s through to the last hurrah of organized American eugenics in the early baby-boom years.

By 1915, in "Education and Race Suicide," Robert Sprague charged that women's colleges were "drawing off the best blood of the American stock and sinking it in a dry desert of sterile intellectuality." Professor Roswell Johnson (the coauthor of *Applied Eugenics* 1918) warned that the "extraordinary inadequacy of the reproductivity of these [women] college graduates can hardly be taken too seriously" (Vigue 1987, 52). Johnson's coauthor, Paul Popenoe, sermonized in 1926 that it is "little less than a crime to advise girls to wait until they are 30 or more to marry, in order to get a better preparation for a career rather than marriage"[7] (Rembis 2006, 103).

> According to Popenoe, there was "probably not one such case in a hundred where the advice is really justified; but the girl, misled by the vanity of her parents and the praise of incompetent teachers who want a pupil … spends great amounts of time and money in training only to find later that there is no career for her, or, if there is, that she would have preferred a family." Eugenicists insisted that parents should help their daughters fulfill their biological destiny and become good wives and mothers; anything less would be a tragic waste of time and effort. (Rembis 2006, 103)

In addition to eugenics education for women, the Progressive era also featured eugenic education embedded into other parts of the college curriculum, for example biology and various social sciences, and in high school, most notably under the euphemism "civic biology" (Selden 1999, 63–82).

E A Hooton and the Physical Anthropology of Teeth

One recent case study of college-level eugenics education is the almost-comical story of Harvard University's physical anthropology professor, Earnest A Hooton (1887–1954), related in Nicole Rafter's "Apes, Men, and Teeth" contribution to *Popular Eugenics* (2006). Like a surprising number of American eugenicists, Hooton's parents were a Protestant minister and schoolteacher mother, but unlike most, they were recent immigrants (from England and Canada). He earned his first doctorate at Wisconsin (Madison), before travelling to Oxford as a Rhodes Scholar and earning advanced degrees in anthropology and anatomy, in 1912 and 1913. Hooton's early scholarly work in pure physical anthropology gave way as time passed to a greater passion for eugenics; he studied, for instance, the hypothetical hereditary link between crime and poor dental health.

Hooton had a career-long (1913–54) fascination with tooth decay as a metaphor for the genetic deterioration of the races of humanity. One example of his creativity for allegorizing the eugenic downfall of humanity can be extracted from this short piece of dental doggerel verse regarding the dental woes of Rhodesian Man, which was discovered in Africa in 1921, and about whom Hooton lectured extensively in his class:

> *It is the guy, Rhodesiensis*
> *With whom our tooth decay commences:*
> *Caries, abscesses, gingivitus,*
> *Otitus media and arthritis.*
> *I hardly think a brute so crude*
> *Could blame his teeth on processed food.*
> *Perhaps dental degeneration*
> *Started with germinal mutation.* (Rafter 2006, 256)

Hooton's popular book *Apes, Men, and Morons* (1937) cracked best-seller lists during the Great Depression. His professional influence lived on through the discipleship of his former students, with "three nearly identical introductory anthropology courses being taught at Columbia, Wisconsin, and Michigan, all by former students of Hooton, and apparently all based on notes taken in Hooton's popular class" (Rafter 2006, 252). Hooton's popular influence became nationwide even before his popular book hit bookstands. According to Rafter,

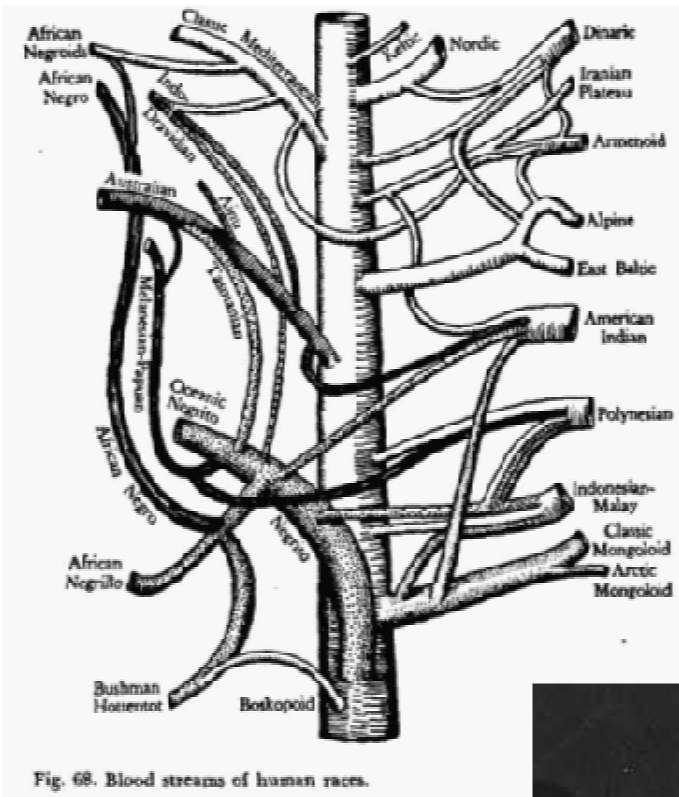
> Hooton became an early example of the professional media star, his activities reported by the *New York Times* and other newspapers and his work profiled by magazines such as *Life*, *Look*, *Newsweek*, and *Time*. A witty and stimulating speaker, he participated in radio debates, delivered distinguished

[7] Paul Popenoe (1888–1979), born into a family of old-stock Huguenots, was editor of the *Journal of Heredity* until World War I, when he served on the Surgeon General's staff as director of venereal disease control section. He became executive director of the American Social Hygiene Association and, later, the Human Betterment Foundation, which was merged into Planned Parenthood after World War II. He was also a founder of the discipline of genetic counselling. His later book, *Modern Marriage* (1925), also went through multiple editions for decades (Engs 2005, 181).

lecture series, and addressed Harvard clubs, eugenic groups, and dental associations. In addition, Hooton wrote for general-interest magazines such as the *Atlantic Monthly* and *Collier's* and for specialized dental journals, developing a pop eugenics form of essay that linked evolution—including the evolution of teeth—to eugenics (Rafter 2006, 252).

Conclusion

Although abhorrence of Nazi race-hygiene programs served as a brake on eugenics in most democratic countries, it by no means ended all entrenched programs, or support from scientists and other academics, despite some official histories that assert this as the



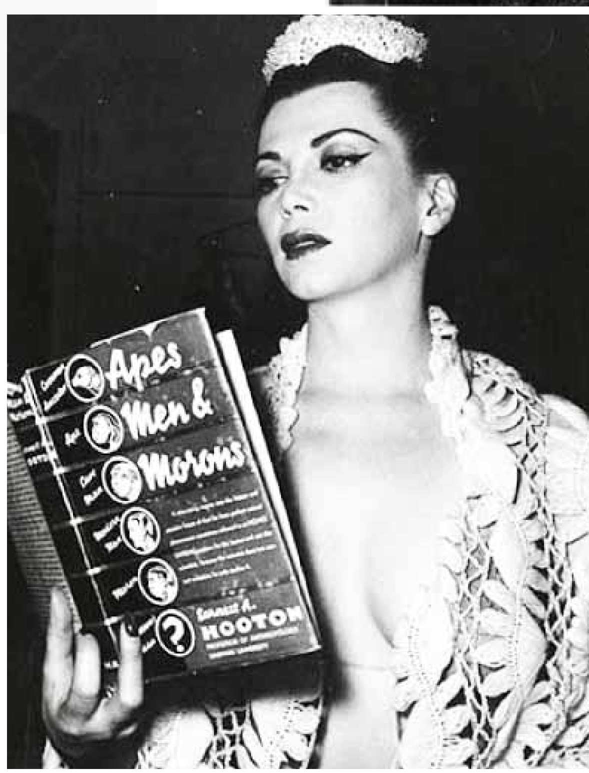


Figure 9: A collage of images of the life and works of E A Hooton (1887–1954).

Top left: Illustration of the "blood streams of human races" from Hooton's *Up from the Ape* (1946).
Top right: E A Hooton with one of his hominid skulls.
Bottom: Showgirl Sherry Britton reading *Apes, Men and Morons*, ca 1944. (This picture is also on the cover of Currell and Cogdell's *Popular Eugenics* [2006]).

end of the era. It may have marked the beginning of the end for *widespread* support by professionals and professors for hardline eugenics programs. However, there were still significant numbers of holdouts that continued eugenic practices such as forced sterilization of the "feebleminded" for more than three decades: until 1971 in Alberta, 1972 in Virginia, 1979 in California and 1981 in Oregon (Engs 2005, 54–57).

One of the reactions of American eugenics (and its British equivalents) was to rebrand itself and incorporate some elements of an environmental program (euthenics) into the movement. This trend had already begun as the Great Depression wore on, but was accelerated during and after World War II. This can be seen in the efforts and works of later American eugenic leaders, such as Yale's Ellsworth Huntington (president of the AES during the 1930s—see Huntington 1920, 1926, 1935, 1945) and Frederick Henry Osborn (H F Osborn's nephew) who was president of the AES during the early postwar years (see Osborn 1934, 1968). Both had training in anthropology but could best be described as pioneers of human geography, demography and social biology. Both were prolific authors and influential leaders. Frederick Osborn succeeded his uncle as president at the American Museum of Natural History, and was commissioned as a General in the US Army in World War II (he was director of the Moral Branch). He later served as deputy of the United Nations Atomic Energy Commission and then president of the Population Council, appointed by John D Rockefeller III in 1954. (See Engs 2005, for short biographies of both.)

This trend of relabelling organizations and retooling the agenda continued after World War II. Thus, Paul Popenoe's Human Betterment Foundation, a pioneer in eugenic sterilization, was rolled into Planned Parenthood, and Popenoe became a marriage counsellor and a founder of genetic counselling (Engs 2005, 181–82). The American Eugenics Society became the Society for the Study of Social Biology in 1973, and its journal, *Eugenics Quarterly*, became *Social Biology* in 1969 (Engs 2005, 7–8). In London, the Galton Chair of Eugenics, once occupied by Karl Pearson, became the Galton Chair of Human Genetics in 1954, and its journals and publications were similarly renamed (Engs 2005, 84–85). The British Eugenics Education Society changed its name to the Galton Institute, and its journal, *The Eugenics Review*, to the *Journal of Biosocial Science* (1968). In Germany, the Kaiser Wilhelm Institutes, including those for race hygiene and eugenics, were subsumed by the Max Planck Society and similarly rebranded, although some of the cast of characters who served under the Nazi government remained (Engs 2005, 93–98).

Some academics—even prominent, respected scientists—just would not quit, even when the tide had turned against them. One of the most interesting and bizarre cases is that of American physicist and Nobel laureate William Shockley. Best known for his contribution to the development of the first transistor, in 1947, he was serving as an engineering chair at Stanford University when he embarked on a late crusade for hardline eugenics. Shockley addressed a Nobel conference in 1965 with a presentation on "Genetics and the Future of Man" (Tucker 1994, 183). After acknowledging his lack of formal training in the area, he expressed his "long-held" concerns with both the quantity and quality of human beings. Shockley explained:

> One of the greatest threats to the future was the 'genetic deterioration' of the human race ... that improvements in medical technology, together with the abundance in American society were assuring to all the privilege of reproducing their kind, even those suffering from genetic defects that would not have allowed them to survive to the age of reproduction in a more primitive environment. (Tucker 1994, 184).

Although most of the mass media ignored him, *U.S. News and World Report* interviewed him, and published a lengthy feature article. It included themes reminiscent of old-time hardline eugenics, such as the "increasing reproduction of the inferior strains," wherein "especially in Blacks, the genetically least capable were producing the largest number of offspring" (Tucker 1994, 185). The angry reaction from Shockley's Stanford colleagues in the genetics department was spurred by the fact that the article was reprinted in the *Stanford M.D.*, the medical school's alumni magazine. The Stanford geneticists' response was unequivocal. In an open letter signed by all seven members of Stanford's genetics department, including Joshua Lederberg, a Nobel laureate himself, they repudiated Shockley's statements as

> the kind of pseudo-scientific justification for class and race prejudice [that] that we would not ordinarily have cared to react to. However, Professor Shockley's standing as a Nobel laureate and as a colleague at Stanford, and now the appearance of

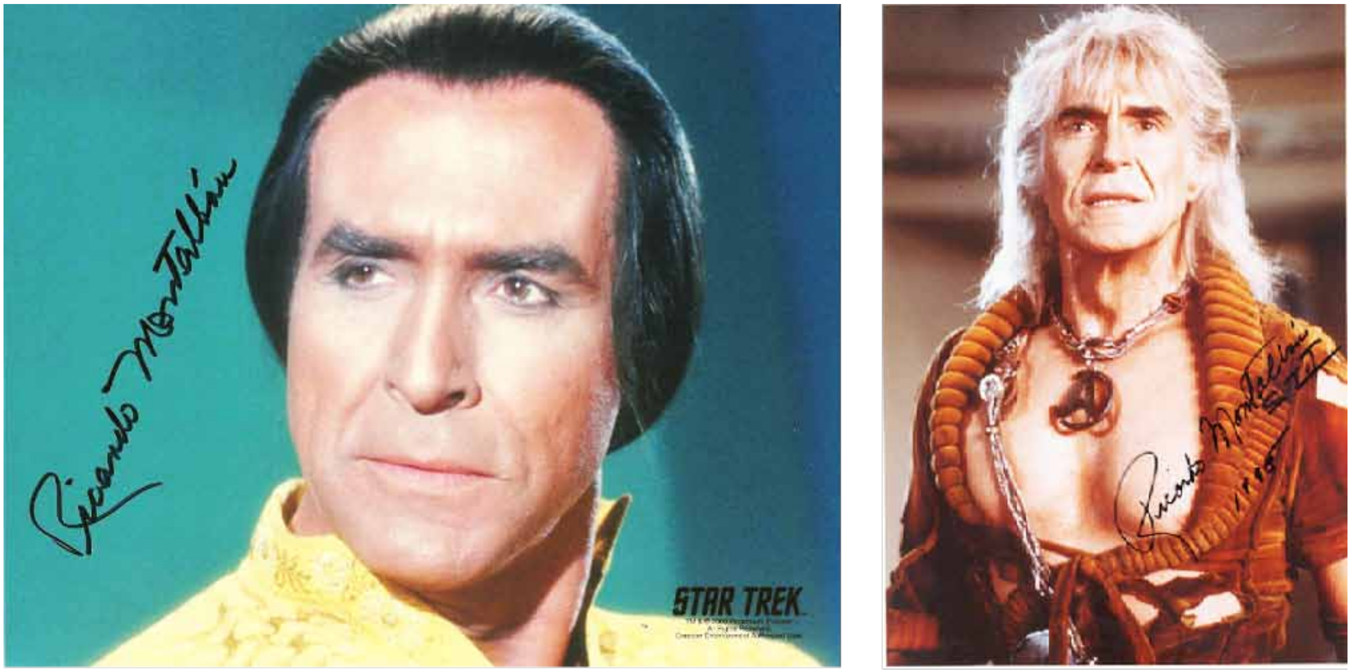


Figure 10: Ricardo Montalban as Khan in the original *Star Trek* series (1967), and then in the 1982 feature film *The Wrath of Khan* (see Footnote 8, page 52). Note that both are signed—very valuable eugenic relics.

> his article with a label of Stanford medicine, creates a situation where our silence could leave the false impression that we share or acquiesce in this outlook, which we certainly do not ... [we] deplore the tone of his entire discussion about 'bad heredity.' (Tucker 1994, 185)

Shockley's critics mockingly asked why he had not used Goddard's old Kallikak study as part of his "scientific documentation." Not to disappoint, Shockley later did just that. Shockley also appealed to the National Academy of Sciences, making urgent annual "pleas for the study of racial aspects of the heredity-poverty-crime nexus" (Tucker 1994, 186). He proposed a system of tax credits for "eugenic desirables," similar to previous incarnations of eugenicists going back to Francis Galton. Shockley attacked his critics as being "undemocratic" and "totalitarian" in nature, and even proffered that "the lesson to be learned from Nazi history, was the value of free speech, not that eugenics is intolerable." Shockley's crusade continued for decades. He received significant funding from the Pioneer Fund, established in 1937 by philanthropist Wickliffe P Draper and eugenicists Harry Laughlin and Frederick Osborn. The fund's main objective was to "provide grants for research into the study of human nature, heredity and eugenics (Engs 2005, 179; Tucker 1994, 2002). The Pioneer Fund largely replaced previous financial support from the Rockefeller Foundation and Carnegie Institution of Washington. Shockley was also a popular speaker for white-supremacist groups, segregationists or other reactionary groups, and was even praised by right-wing mass media, including the *Wall Street Journal* (Tucker 1990, 183–95).

If this attempted eugenic revival was limited to one embittered scientist, the nails could perhaps be driven into the coffin of hardline eugenics. The list goes on, however, notably with Arthur Jensen (Berkeley psychologist), his protegés Hans Eysenck and R B Cattell (another second-generation eugenicist), or other members of the International Association for the Advancement of Ethnology and Eugenics, with continued generous financial support from the Pioneer Fund (Tucker 1990, 194). The eugenics movement continues to this day, with such notables as Herrnstein and Murray, authors of *The Bell Curve* (1994), or J Philippe Rushton, professor of psychology at the University of Western Ontario, another Pioneer Fund beneficiary (Tucker 2002, 195–291) and its current chairman. While mainstream academia may view them as pariahs, they continue to publish, and attract a great deal of publicity and support from the fringes of society. Other mainstream scientists who should know better, like Cold Spring Harbor's James Watson, another Nobel laureate, get themselves into hot water with ill-advised public comments. (For example, in 2003, Watson said that "low intelligence is an inherited disorder and that molecular biologists have a duty to devise gene therapies or screening tests to tackle stupidity. 'If you are really stupid, I would call that a disease,' says Watson, now president of the Cold Spring Harbor Laboratory, New York." [Bhattacharya 2003].)

With the public re-emergence of various forms of neo-Nazis, the Ku Klux Klan, and other white-supremacist groups, the end of eugenics is nowhere in sight. Under pseudonyms, it is a key component of the export of Western science and technologies to the developing world (from abortion, birth control and sterilization to theories, models and statistical techniques dating back to Galton and Karl Pearson). This is not even to mention the neo-eugenic elements of modern molecular biology that are embedded in such ventures as the Human Genome Project (Kevles 1995) and similar modern biological big-science initiatives, corporate spinoffs and societal memes. If nothing else, the future health of eugenics (by whatever name) is rosy, gauged by the prevalence of eugenic themes in science fiction story lines—from the original *Star Trek* series, through all its sequels, to *Star Wars*, *Stargate* and a host of other franchises. Eugenics may just survive as a popular meme longer than *any* current human race, or *its* sequels. [8]

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[8] My first exposure to the idea of eugenics was compliments of the original *Star Trek* series. In an episode titled "Space Seed," a young Ricardo Montalban guest-starred as Khan, the leader of a band of genetically senhanced supermen (in the Nietzschean sense). They were rescued from a century-old derelict spaceship (the *Botany Bay*) by the *Enterprise* crew. In short order, Khan and his followers betrayed their rescuers and attempted to commandeer the ship for their own sinister purposes. In the process they revealed their lack of concern for ordinary humans, who were thought of as mere cattle compared to their own "enhanced humanity." Needless to say, Captain Kirk and crew saved the day, dropped off the mutineers on the nearest habitable planet and deployed a warning buoy to alert any passing ships to the danger. Twenty years later the embittered survivors of this group of eugenic *übermenschen*, including Khan, again played the arch-antagonists for Admiral Kirk and the Enterprise crew in *Star Trek II—The Wrath of Khan*, featuring an older, but remarkably preserved, Ricardo Montalban. I don't think I really appreciated the eugenic angle until after formal study of the subject.

The subject of future eugenics programs and trans-/post-humanism (such as The Borg) in the age of advanced biotechnologies (cloning and genetic manipulation of humanoids to achieve super-strength and endurance, super-intelligence, and artistic abilities) became recurring motifs in later *Star Trek* franchises. It was also the subject of a complete story arc over two seasons in the prequel series *Star Trek: Enterprise*. Most other long-running sci-fi franchises (including *Star Wars*, with its Clone Wars) have continued to flog the eugenics theme. Although they have almost always been explicitly intended as cautionary tales, each version has excited new generations of fan-boys and fan-girls to the possibilities of modern eugenics and biotechnology. Actress Jeri Ryan's "Borg-babe" Seven-of-Nine is the quintessential example, inspiring perhaps more rabid fan-worship than any previous *Star Trek* character, Captain Kirk included. The longevity and continued popularity of the theme in science fiction and pop-culture is a virtual guarantee of the continued relevance of eugenics as a meme in future societies. Whether or not Francis Galton or his Progressive-era followers would approve, the new electronic media of recent decades have popularized eugenic memes more effectively than Galton and all his societies could ever have dreamt.

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How Can We Incorporate Famous Surprises in the History of Science into the Science Curriculum?

Arthur Stinner, Juergen Teichmann, Barbara McMillan and Ian Winchester

There is still a widespread and pervasive belief that scientists use a specifiable and teachable method in going from observation to establishing laws and theories, namely, the *scientific method*.

This picture of science found its way into science textbooks and versions of it were perpetuated by generations of textbook authors and most science teachers. This method is supposedly known, can be fully described and guarantees success in discovering scientific laws. Most textbooks generally present science, implicitly or explicitly, as essentially an empirical–inductive enterprise that has four characteristics:

1. Science has achieved a superior kind of truth.
2. Science is characterized by inexorable progress.
3. Science is in the possession of the only method of interrogating nature, namely the empirical–inductive method (the scientific method).
4. This method can be simply described and easily taught.

In the physics text that Stinner, as a fledgling high school science teacher, used (Eubank, Ramsay and Rickard 1963), we find the following steps of the scientific method presented to the student:

1. There is a question or a problem.
2. Collect all the facts about the problem.
3. Propose a theory or possible explanation.
4. Test the theory with an experiment.

Historians of science, however, generally believe that in scientific discovery there is a spectrum of scientific involvement that ranges from identifiable mechanical procedures to high-grade activities involving the educated scientific imagination of the research scientist that cannot be captured by any "scientific method."

To lay the groundwork that will guide our proposed discussion, we will follow the arguments of scientists and historians of science, especially those of Freeman Dyson (1958), and Thomas Kuhn (1962). Putting these ideas together, we propose a framework or model (see Table 1) that replaces the old scientific method and allows us to investigate the role played by well-known surprises in scientific thinking.

As early as 1958, in an article in *Scientific American*, Dyson wrote "The reason why new concepts in any branch of science are hard to grasp is always the same: contemporary scientists try to picture the new concept in terms of ideas which existed before."

Clearly, Dyson (1958) anticipates Kuhn's notion of incommensurability (1962) and the accompanying "new way of seeing" that produces a new language of discourse for those who are working with the new paradigm. The appearance of a new concept or theory in science, then, is often accompanied by a language barrier. This barrier can be daunting and sometimes difficult to overcome for the science student as well as the scientist. If there is no specifiable scientific method that can be taught, how can we describe what scientists do?

One way to show that the so-called "scientific method," as described in many science textbooks, gives a very limited picture of scientific thinking is to present a number of case studies that involve well-known surprises in the history of science.

We argue that we should picture scientific thinking along a spectrum of activities that can be described. The complexity of scientific activity entails a process better described as a *continuous spectrum of activities on three levels*. These activities are seen to ascend from specifiable mechanical procedures that can be learned, to those scientific activities that working scientists normally engage in, and finally to the high-grade scientific activity of a few who finally resolve the puzzle that the surprise presented (see Table 1).

According to Kuhn (1962), the need to abandon a research tradition in favour of a new one is signalled by the accumulation of long-standing problems. These unyielding problems, called *anomalies* by Kuhn, do not allow solutions based on the research methods of old traditions, however cleverly applied by the most skillful normal scientists or puzzle solvers. Eventually, one scientist's idea, based on a new set of experiments or observations, metaphysical assumptions and new methods of solution, wins the allegiance of most other scientists. What counted as scientific knowledge in the old tradition is reconceived, re-evaluated and sometimes discarded; the scientist now sees the world differently. Not surprisingly, the new way of seeing, based on the new paradigm, produces a new language of discourse.

Kuhn does not distinguish between what he labels an *anomaly* and what we call a *scientific surprise*. A scientific surprise such as the ones we are discussing we distinguish from what Kuhn labels an anomaly. A Kuhnian anomaly appears as part of the research conducted, but a scientific surprise (like the discoveries made by Oersted, Fraunhofer and Mendel that we

Table 1: Scientific Methodology Spectrum
(based on Kuhn's work [1962])

Specifiable mechanical procedures	**Scientific activities of "normal" science**	**High-grade activity of scientists working on the edge of a paradigm** (this activity cannot be captured by "method")
Ability to use traditional scientific instruments to make measurements, carry out testing procedures, make observations, etc. These procedures can be complex but they can be taught. Note: Even the more sophisticated methods of obtaining data from instruments and many of the interpretations of these data can be taught and then done routinely. However, the judgment of whether or not the data fit the requirements of the paradigm must be made by the scientist.	This region of activity involves trained scientists. Their activities mainly involve the "mopping-up operations performed within the confines of a paradigm": a) increasing the precision of agreement between observations and calculations based on the paradigm; b) determining the values of universal constants; c) formulating quantitative laws in order to extend the articulation of the paradigm; and d) deciding which alternative ways to apply the paradigm to new areas of interest are most satisfactory. Normal science, then, is an activity that spans the range from involving specifiable mechanical procedures to complex but traditional scientific judgments.	In this region of high-grade activity, a new way of seeing is required—what Kuhn would label as a *new paradigm*. This also refers to new instruments to be used or unexpected experiments or observations. This activity produces a new language of discourse. Scientists who have grown up with the old paradigm find it difficult to communicate with the young generation who have been converted to a new way of understanding.

explore in this article) appears unexpectedly from outside the research program. This notion of scientific surprise also includes, for us, newer theories and the idea that offshoots of experiments and experimental programs can have a life of their own within the scientific process.

To conclude this introduction, it is necessary to mention some general factors in the resistance to and rejection of the importance of a surprise such as the kind we speak of. The scientist-historian Ernest B Hook has summarized these in his 2002 book:

1. Scientists are unaware of it.
2. Having reviewed it, they judge it to be of no immediate relevance to their current work and therefore ignore it.
3. They harbour an inappropriate prejudice against some aspect of the claim.
4. The claim appears to clash directly with their observation or experience—for instance, it is based on an experimental finding they cannot reproduce.

Each of the four presenters in this paper will concentrate on one well-known surprise in physical science, astronomy, biology and, finally, modern physics/cosmology. First, Stinner will describe the role that surprise played in establishing a new theory in electromagnetism based on Oersted's famous discovery. Then, Teichmann will tell the story of Fraunhofer's famous discovery of the dark lines of the spectrum of the sun and why this discovery was not accepted as an astronomical research program until much later, in the work of Kirchhoff and Bunsen, who laid the groundwork for modern spectroscopy. McMillan will discuss the story of Mendel's discovery of the basic laws of heredity, arguably one of the best-known surprises in the history of science. Finally, Winchester will discuss the two greatest surprises in physics and cosmology today, namely *dark matter* and *dark energy.*

Oersted: An Electric Current Produces a Magnetic Field

Although his scientific achievements are well known today, it took a long time for Hans Christian Oersted to secure a chair in physics at the university level. He was actually refused a position in 1803 because of his strong interest in philosophy, which was seen at the time as a detriment to the education of a physicist. Being well-to-do, he travelled a great deal and studied with natural philosophers on his own. In Germany, he was impressed by the ideas of the philosopher Schelling, who believed that nature is systematic and unified. He also met J W Ritter, who had similar ideas about the unity of nature but also emphasized an empirical approach. The dynamic relationship between philosophy, intuition and empirical evidence turned out, in the end, to be the key to Oersted's success in physics, even though it delayed his finding a physics teaching position.

Most textbooks present Oersted's famous surprise discovery in the following way. During the presentation of a lecture at the University of Copenhagen on April 21, 1820, Oersted made an unexpected discovery. As he was setting up his materials to test the heating effect of an electric current on a thin platinum wire, he noticed that a compass needle deflected from magnetic north when the electric current from the battery he was using was switched off and on. This deflection, according to many textbooks, convinced him that a magnetic field radiates from all sides of a wire carrying an electric current, just as light and heat do. Textbooks say that he was then able to show that there was a direct relationship between electricity and magnetism, and then they explain it.

In actual fact, however, the story is somewhat different. Was the discovery an accident (as some of the students attending the lecture claimed) or did Oersted deliberately test the relationship? Students claimed that he was only interested in the heat generated by thin platinum wire and a compass needle just happened to lie in the vicinity of the wire. The effect of the electric current on the compass at first apparently confused Oersted.

On the one hand, Oersted was aware that both Ampère and Thomas Young believed that electricity and magnetism were different phenomena. On the other hand, he also knew that seamen observed that the magnetic needle of a compass was affected when ships were struck by lightning.

After three months, Oersted returned to a consideration of the surprise discovery. In his notes of the time he wrote about the April 21 experience:

> I called attention to the variation of the magnetic needle during a thunderstorm. And I set forth the conjecture that an electric discharge could act on a magnetic needle placed outside the galvanic circuit. Since I expected the greatest effect from a discharge associated with incandescence, I inserted

> in the circuit a very fine platinum wire above the place where the needle was located. The effect was certainly unmistakable but it seemed to me so confused that I postponed further investigations. (Oersted 1852)

When he investigated the phenomenon three months later he found that the wire carrying an electric current affected a magnetic needle located below the wire by causing it to swerve to a position perpendicular to the wire. His initial interpretation was that magnetic effects radiate from all sides of a wire carrying an electric current, as do light and heat. He thought that the force he observed was an attraction of some sort. But he soon realized that this force was not a Newtonian force. (It should be noted at this point that the current produced by a voltaic cell is very small. I am estimating that 10 voltaic cells, or a voltaic pile [of the type available to Oersted] would produce a current of about 0.1 A. In my own demonstrations of the Oersted experiment I found that you need at least a current of 1 A to show the effect on a nearby compass.)

His discovery in 1820 of the complex magnetic effect of electrical current was immediately recognized as an epoch-making advance in our understanding of the relationship between magnetism and electricity. Oersted also discovered that not only is a magnetic needle deflected by the electric current, but the live electric wire is also deflected in a magnetic field.

André-Marie Ampère quickly repeated Oersted›s experiment, and measured the force between two parallel conducting wires. By 1821, Michael Faraday demonstrated the electric motor principle with his rotating magnet experiment—but not until 1831 did Faraday demonstrate the electromagnetic induction principle. Why did it take 10 years to show that a magnetic field can produce an electric current?

Electromagnetic Theory After Oersted

In order to answer the above question more fully, I will suggest that the evolution of our understanding of electromagnetism follows well-defined levels of symmetry. The first level was based on the question, Is electricity (static and current electricity) related to magnetism and, if so, how can we discover this? Oersted discovered this relationship, which was later more thoroughly investigated by Ampère, Faraday and others. The second level was based on the question, If an electric current (flow of charge) can produce a magnetic field, can a magnetic field produce an electric field (current)? This question was answered about 10 years later by Faraday. He showed that a magnetic field will indeed produce and electric effect, but *only if the magnetic field strength is made to vary in a periodic way*. The third level of symmetry was based on the question, If the four equations of Maxwell describe all electromagnetic phenomena, why are the last two not symmetrical?

Maxwell himself answered that question by assuming that there is a displacement current in the equation based on Ampère's law. Finally, the fourth level of symmetry is based on the question that Einstein asked in the first paragraph of his famous paper on the special theory of relativity (STR): "In the classic Faraday demonstration of producing an electric current by having a magnet move into a solenoid or a solenoid move over the magnet there is an obvious asymmetry, described by two different e-m laws. Why is this?"

Einstein argued that his STR could deal with this asymmetry and showed the reason why only the relative motion in this demonstration counts.

Clearly we cannot discuss these levels of symmetry beyond the first two with high school students. However, physics teachers should be encouraged to study all four levels so that they can elaborate on these in a senior high school physics class and thus make this important topic more interesting.

Implications for the Science Classroom

The story of the transition from static to current electricity, from the electrostatics of the early 18th century to the development of the voltaic cell by 1800, is not well told in textbooks. Ideally, before presenting the Oersted effect on a compass, one should discuss the confrontation between Galvani and Volta, which lasted about 20 years and gave Volta the idea of a battery based on Galvani's work with animal electricity. Volta finally decided that there was only one kind of electricity, rather than the three kinds (static, lightning and body) proposed by Galvani. Primitive voltaic cells can be made and tested for the presence of electric current, using a voltmeter. (Of course, Volta could not test for presence of an electric current this way—there were no galvanometers or voltmeters until about 30 years later. Instead, he used sensitive electroscopes.) Students seem to accept the explanation that the

20-year delay between the voltaic cell and Oersted's discovery was hindered by two factors: a large current had to exist, and the magnetic force turned out to be non-Newtonian force.

Fraunhofer: A New Landscape of the Invisible—Dark Lines in the Spectrum of the Stars

The discovery of dark lines in the spectrum of the sun as well as in some fixed stars by William Hyde Wollaston, Joseph Fraunhofer and Johann Lamont radically changed our understanding of the physics of the macrocosm—of course, only in small steps and after about 1859.

Wollaston's simple representation of sun's spectrum, from 1802, can be seen as a simplification and reduction of the phenomenon by a seemingly clear connection to contemporary knowledge. On the other hand, Fraunhofer's famous colour copper plate of the dark lines, from about 1817, can be regarded as a meticulous and painstaking representation of the known facts, taken to a high aesthetic level. Finally, Lamont's spectra of the fixed stars, in 1836, can be regarded as the first sketches of these phenomena.

What was common to all of these representations was the general belief that something new and unimaginable could now be established as a scientific subject. These observations also met remarkable interest at other cultural sectors, for example, in Alexander Humboldt's understanding of nature and in Johann von Goethe's theory of light and his interest in pictorial representations of nature.

The Visible and Invisible Sky—A New Visual Culture Is Born

Fraunhofer's hand-made copper etching depicting the dark lines of the sun's spectrum is certainly well known to students, scientists and historians. There are two coloured examples at the Deutsches Museum in Munich and another at the Goethe *Nationalmuseum* in Weimar. In the publications of Fraunhofer in different journals since 1817 there are only black-and-white pictures.

It could be argued that Fraunhofer's coloured spectrum—with about 350 painstakingly represented lines—has attained an almost metaphoric significance as the beginning of the modern period of astrophysics that emerged after 1859. Nothing similar can be claimed for the effect made by Wollaston's scanty drawings of a few dark lines in 1802. In making such a comparison we should also include the unpublished sketches of spectra of the fixed stars by Lamont, made in 1836.

For all those (and other) pictures of the sky we use the term *landscape*, as an extension of the concept that Alexander von Humboldt (1849–58) defined in a geomorphological and metaphoric way at the beginning of the 19th century—for example, when he looked at and admired "the gracefulness of the landscape of the whole firmament" unfolding, or when he contemplated "the picturesque effect of the landscape of the milky way." Those concepts are part of his philosophical intentions to offer a descriptive painting of nature.

But with the spectra of stars there began a totally new, almost abstract landscape of the sky. This was the main reason that it took more than 40 years for this "landscape" to become accepted by astronomers. This occurred after 1859, when Gustav Robert Kirchhoff had explained these strange dark lines by absorption as an analogy to emission in the also-strange bright lines from flame spectra.

Fraunhofer became world famous in the 1820s, but not because of his dark lines—he made the best telescopes of his time. For example, his largest telescope, a refractor, was placed 1824 in the Salvatorkirche in Munich for eight days for public viewing. This large telescope was designated for the observatory at Dorpat, in Russia (today Tartu, Estonia). The public viewed this display of technical and artistic achievement with great mystical awe. People realized that they were looking at the world's largest refractive telescope, to which were attached a number of other remarkable innovations—for example, a very precise and continuously running clockwork, to move the instrument against the earth's rotation. [1]

On the other hand, in the Romantic period, the telescope often became a metaphor for all invisible power that is foreign and destructive, as portrayed by the German poet E T A Hoffmann in 1822 in his novel

[1] *Editor's note*: more information about Fraunhofer and his workshop is available at www.fraunhofer.de/en/about-fraunhofer; see especially the pamphlet titled "Fraunhofer in Benediktbeuern."

Meister Floh. Here we witness a confrontation between the two magicians Leuwenhoek and Swammerdam (the two famous early scientists from the history of microscopy) as they argued, using two telescopes representing swords.

The scientifically educated romantic poet Novalis, around 1800, used the metaphoric concept of the telescope more in a positive way, as a "revelation of a higher world." To both interpretations, positive and negative, it was clear that the telescope was a specific instrument to penetrate the invisible.

To sum up, we can say about the poetic reflection of the telescope in German literature from Romantic to Biedermeier that the telescope becomes an apparatus for producing a (new) reality for the individual. It is no longer the instrument for the discoveries of an admirable objective sky as a work of God, as it was in the Baroque era. The invisible sky was changed to a vehicle for self-examination and deep reflection on man's relation to the universe.

In 1852, the astronomer Johann Heinrich von Maedler speaks explicitly of a new "Astronomy of the Invisible" (Maedler 1852, 104); by that he did not mean the curious pictures of the spectrum of the sun or the spectra of fixed stars, but the potential discovery of new planets. For example, the planet Neptune and a companion of Sirius were discovered by exact calculation of the gravitational effect of the neighbouring celestial objects. But this was not really new; similar predictions based on celestial mechanics existed much earlier—for example, the prediction of the return of Halley's Comet in 1759. Maedler's objects also belonged to the landscape of *positional astronomy* (Maedler 1852, 19). Positional astronomy was the essential condition for the exact predictions of celestial mechanics. All of its objects testified to a sublime aspect of the verified sky that connects us to the order that is mirrored by nature—completely in contrast to the chaotic dark lines that Fraunhofer first presented in 1817.

Positional astronomy meant that only points of light and their position and movement were officially recognized as scientifically important objects that could be exactly observed, and—at least in the cases of planets and double stars—where the motion and position could be exactly calculated using the power of the newly developed celestial mechanics (from Euler to Gauss). Even the colour of the celestial objects was irrelevant.

The new science of spectral analysis (which began in 1859) that now used the not-yet-well-understood landscape of spectral lines as a symbolic language did not render classical positional astronomy obsolete. Not surprisingly, though, it severely limited the importance of positional astronomy progressively after about 1900 by extending the new landscape of the spectral method. It showed and classified many different identifiable spectra of stars (and other objects in the sky, such as nebulae), but was not understood in detail until about 30 years later, with the advent of atomic physics (1910–1926) and modern quantum mechanics, after 1926. Photography and the use of diffraction gratings, after about 1880, aided in identification of star spectra by allowing the comparison of lines to be made easier.

The first extensive classification of star spectra as pictures of a really new astronomy already existed around 1890, with about 10,000 photographs of star spectra in existence. By 1918, this number had grown to more than 200,000. Until the 1940s, difficult spectra of giant stars and white dwarf stars were now classified according to their spectral impressions as pictures.

This new astronomy revealed the physical and chemical structure of the luminous celestial objects. Using spectra, it was now possible to place stars on the laboratory table of the astronomer. This went far beyond the expectations of most astronomers. Admittedly, the strict requirement of precision and accuracy of positional astronomy had to be sacrificed. As late as 1950, the calculations of the amount of chemical elements in stars, taken from spectra, could be wrong by as much as 100 to 200 per cent, and as late as 2002, one could find in publications inaccuracies as high as 50 per cent. Around 1960, only 18 chemical elements of the sun, together with fewer than 300 Fraunhofer lines, had been quantitatively identified to an exact amount. Every astronomer of the 19th century would have refused to recognize such results as science.

This was the second big problem for accepting the new landscape of the Fraunhofer lines before 1859 and even, for many classical observatories, up to about 1900. The landscape seemed too chaotic for 19th-century astronomers, who wished to remain at the top of all exact sciences.

Implications for the Science Classroom

It is difficult even to see a scientific problem if the phenomenon studied is totally different from all familiar knowledge. This is the first thing that should be made clear, using examples of scientific surprises like those presented here. The teacher may start by showing the drawings and copper etchings by Wollaston, Fraunhofer and Lamont and ask how students think this phenomenon can be related to the physics and chemistry of stars (students today are familiar with bar codes in shops and with those of DNA research). In addition, the teacher can add some information about the Morse code of telegraphy, which was invented in the 19th century. Finally, it should be emphasized that what was known in the first half of the 19th century about the sun and stars was almost nothing. Even the great astronomer Herschel (around 1800) believed that sunspots were holes in the hot luminous atmosphere of the sun, which suggested that under the solar atmosphere there was a cool surface.

Continuing the story, students should be shown examples of star charts to illustrate that only points of light were interesting. Now we can ask students how it would be possible to become interested in such chaotic bar codes of stars, which at the time was an unsolvable puzzle. The teacher can then state that the "bar code" of the sun, at least, was very helpful in optical technology (for finding exact values for refraction and dispersion). Moreover, astronomers were by no means interested in physics or chemistry. They remained an arrogant species of scientists, who believed that they alone knew what exact science should be. To end the lesson, ask the students if there are any analogous situations in modern developments in science/technology.

Mendel in School Science

If students learn about Johann Gregor Mendel, and not simply his name or that he is known as "the Father of Genetics," it is either in the context of heredity and patterns of inheritance, or as an introduction to classical genetics before a study of the molecular basis of inheritance and how genes control metabolism. In Canada, these topics generally follow a study of the cell in Grade 8 general science and a study of the cell cycle (mitosis and cytokinesis), asexual and sexual reproduction, and the formation of sperm cells and ova by meiosis in a Grade 9 general science reproduction unit. If the learning focused less on knowing and applying science knowledge and more on how this knowledge came to be constructed—through experimentation followed by analysis and interpretation of experimental data—students would have opportunities to work and think like scientists and to recognize, first-hand, that the "scientific method" poorly captures what is involved in scientific discovery, particularly surprise discoveries like Mendel's.

Breeding Garden Peas

According to Mendel's biographers Iltis (1932) and Henig (2000), Mendel's scientific and personal papers were burned in a bonfire set in the courtyard of St Thomas Abbey in Brno (then known as Brünn) soon after his death, on Saturday, January 6, 1884. What remains are Mendel's two papers on plant hybridization and nine papers on meteorology published in the journal of the Brünn Society for the Study of Natural Science between 1836 and 1871 (Orel 1984). Unlike Charles Darwin of the same era, very little specific information about Mendel exists; we do not have the detailed notes and meticulous records he must have made during his eight years of research breeding the garden pea, *Pisum*. Even with access to the two papers on plant hybridization published by the Brünn Society as the monograph *Versuche über Pflanzen-Hybriden*, in 1866, Henig (2000) claims

> We can only speculate about what really happened. We do not know exactly how the experiments were done, in what order, during which seasons, even precisely where in the wide courtyard of the St. Thomas monastery in Brünn. We do not know for sure how many generations Mendel squeezed into a single growing season, or how often he grew plants in the greenhouse and how often in the garden. (pp 130–31)

There are also questions about Mendel's reasons for beginning these experiments in 1856. Henig speculates that Mendel's *Pisum* experiments began after Mendel failed the oral examination that would have qualified him for a career as a high school teacher. Eduard Fenzl, director of the Vienna Botanical Gardens and member of Mendel's examining committee, was a spermist; he believed that the preformed plant embryo resided in the pollen and passed into the ovary through the pollen tube. Mendel, in contrast, believed that the embryo formed at fertilization with equal contributions from the male and the female. Fenzl was the first to question Mendel and asked about generation. According to Henig (2000), Fenzl disagreed with Mendel's answer and an argument ensued. Rather than back down, Mendel chose "failure over capitulation" and walked out of the examination knowing he had a battle to resolve (p 62).

In the minutes of an 1837 meeting of the Brünn Society, Napp[2] is reported as saying, "The question for discussion should not be the theory and process of breeding, but *what* is inherited and *how*?" It was Mendel, Mawer states, who took up Abbot Napp's challenge (Mawer 2006, 51). His success is attributable, in no small part, to the teaching he encountered as a student, particularly during the two years he attended the University of Vienna. Corcos and Monaghan (1993), in fact, claim "the man who went to Vienna to become a better teacher of physics and natural history acquired from his teachers the techniques of a scientific researcher" (p 22). Plant physiologist Franz Unger's mechanistic and hard-science view of botany helped Mendel to regard the development of living things as being directed by physical and chemical laws (Corcos and Monaghan 1993). Experimental physicists Christian Doppler, Andreas von Baumgartner and Andreas von Ettinghausen exposed Mendel to the mathematical analysis of physical problems and statistical knowledge (Olby 1966), through Ettinghausen's combination theory and his lectures on combinatorial analysis—"the mathematics of probability and outcome" (Mawer 2006, 53). Mendel came to understand that all phenomena were governed by laws, "that the laws of nature were written in the language of mathematics" and that the task of a scientist was "to reveal these laws and create theories, experimentally proved" (Orel 1984, 30).

Mendel began his experiments in the spring of 1856, and it is at this point that he devised a strategy for experimentation that was considered more effective than those of all of his predecessors. Rather than look at the "difficult, complex and messy" whole, Mendel—"with the scientific outlook of that of an ultimate reductionist," focused on one trait at a time (Carlson 2004, 47). He wrote "The object of the experiment was to observe these variations in the case of each pair of differentiating characters, and to deduce the law according to which they appear in successive generations (Mendel 1865, 4). Roberts (1929) described this as "pitting one character in an individual against a single *contrasting character* in another individual" and from his perspective this decision "revealed Mendel's scientific genius and analytical insight" (p 293).

In rows specific to one type of a contrasting trait, Mendel planted the seeds from the pairs of seven traits in his garden plot. When the flowers for each pair of a specific trait developed, but were still immature, he removed the anthers of each flower from one of the two types before they had time to produce pollen. For example, he removed the anthers from the plants that would be producing seeds with a white coat, but left intact the anthers in the flowers of the plants that would be producing seeds with a grey coat. He then used a camel hair brush to transfer pollen from the intact anthers to the stigmas of the emasculated flowers. Thus, the plants that would through self-fertilization have created seeds with white coats had been cross-fertilized with pollen from plants that through self-fertilization would have created seeds with grey coats. For each pair of contrasting traits, Mendel carried out from 23 to 60 (mean of 39) cross-fertilizations on an average of 10 emasculated plants, or 287 fertilizations on a total of 70 plants (Mendel 1865, 6).

At the end of this first season, Mendel collected the seeds, labelled and dried them, and stored them until the following spring (of 1857), when they would be planted and grown to maturity. In this first hybrid generation [F_1], Mendel observed in each of the seven crosses that "the hybrid-character resembles that of one of the parental forms so closely that the other either escapes observation completely or cannot be detected with certainty" (Mendel 1865, 7–8). He labelled those traits that "pass into the hybrid association entirely or almost entirely unchanged, thus themselves representing the traits of the hybrid … dominating" and those traits "that become latent in the association, recessive" (Corcos and Monaghan 1993, 77). For the seven pairs of contrasting traits, the following were determined to be dominant: round seed, yellow seed albumin [cotyledon], grey seed coat, inflated pod, green pod, axial flowers and longer stem. With this experiment, Mendel also confirmed an observation that Gartner had made about the source of the dominant trait in the hybrid and the form of the hybrid being identical whether the source was the seed bearer or the pollen parent (Corcos and Monaghan 1983, 8). He also "meticulously noted" a stem condition that today

[2] *Editor's note*: Napp was abbot of the monastery at St Thomas, where Mendel had begun studying to be a priest in 1843. Abbott Napp sponsored Mendel's attendance at the University of Vienna from 1851 to 1853.

is known as hybrid vigour; hybrids can have a greater height than the parental lines (Mawer 2006, 57).

The generation bred from the F_1 hybrids, whether through self-fertilization or reciprocal crosses, showed that these hybrids had not bred true even though the trait apparent in each case had been the dominating one. The F_1 hybrids had to be variable, because their offspring were not all like the parents. Regardless of which of the seven traits Mendel studied (see Table 2), he found "that among each four plants of this [F_2] generation three receive the dominating and one the recessive characteristic" (Corcos and Monaghan 1993, 82). Moreover, when Mendel collated the results of the all-F_2 experiments, he found that the average ratio between the dominating trait and those with the recessive trait was also 2.98:1, or 3:1.

Three items related to this experiment are of particular interest. First, Mendel mentions that he did not observe any transitional forms. This suggests that whatever the heritable factor for the recessive trait might be, it had not been diluted in any way by coexisting with the dominating factor in the F_1 hybrids. Second, Mendel recognized that the dominating traits have what he called *double significance* (a true-breeding parental form vs a hybrid form). As such, even though the parental and hybrid dominating traits had the same appearance, they did not behave in the same way and the only means of determining in which form the dominating trait exists would be to examine the next generation produced by self-fertilization. This would be the experiment he carried out in 1859. Third, Mendel reduced the thousands of seeds he had sorted and then counted to the whole number 3:1 ratio. Corcos and Monaghan (1993) suggest that Mendel was the first person to adapt and apply ideas and methods from the physical science to biology.

In the spring of 1859, Mendel planted offspring of his second experiment (the second generation bred from the hybrids) and let them self-fertilize. His aim was twofold: to determine if the plants with a recessive trait were true-breeding, and to determine if the plants with a dominating trait were true-breeding (possessing the parental dominating form of a trait) or non-true-breeding (possessing the hybrid form of a trait). He found that recessive offspring always bred true, and that approximately one-third of the dominating offspring of the hybrids bred true and approximately two-thirds behaved exactly like the hybrid generation. At this point, Mendel began to denote the pure-breeding dominating trait as *A*, the pure-breeding recessive trait as *a*, and the hybrid as *Aa*. He also began a series of two-trait hybrid crosses and three-trait hybrid crosses. These experiments led to two results that will be mentioned here. The first was Mendel's claim that "the relation of each pair of different characters in hybrid union is independent of the other differences in the two original parental stocks" (Corcos and Monaghan 1993, 19). Although we now realize that it is not true for all cases, Mendel recognized that the traits he was focusing upon in *Pisum* were inherited

Table 2: Results from the F_2 Generation

Trait/Character	Total	Dominating	Recessive	Ratio
Seeds				
Shape of Seed	7324	5474	1850	2.96:1
Colour of Seed	8023	6022	2001	3.01:1
Whole Parts				
Colour of Seed Coat	929	705	224	3.15:1
Shape of Pod	1181	882	299	2.95:1
Colour of Pod	580	428	152	2.82:1
Flower Position	858	651	207	3.14:1
Height of Plant	1064	787	277	2.84:1

independently of other pairs of traits. Not surprisingly, his work with such multi-trait hybrid crosses led to an interest in discovering whether the experimental results (the products of all combinations of possible hybrid traits) would match the combination series he could generate by knowing the number of each pair of differing traits (Corcos and Monaghan 1993, 19). Mawer (2006) claims "the real significance of this finding [which Mendel verified could be and actually was accomplished] was missed," even in 1900. It represented "precisely the inherited variation that Darwin needed to make his theory of natural selection work" (p 62).

One of the final topics that Mendel addressed in *Experiments in Plant Hybridization* was his study of the reproductive cells of the *Pisum* hybrids. It is Mendel's comments on "fertilizing cells" and "potentially formative elements" in "Concluding Remarks" to which Stent (2002) has gone to illustrate Mendel's mention, albeit implicitly, of the particulate nature of heredity. This (Mendel 1865, 35–36) is also a section about which Mawer writes, "… Gregor Mendel was shining a light into the darkness ahead: he had actually understood how inheritance worked. His tragedy was that there was no one to step forward with him" (Mawer 2006, 67).

Dark Matter and Dark Energy: Contemporary Surprises in Science

Of the unexpected developments in astronomy and physics, perhaps none is more unexpected or more puzzling than the discovery that if our general theories of gravitation are more or less right then there must be much more matter and much more energy in the universe that surrounds us than can be seen through electromagnetic interactions and their detection.

The first person to notice this was Fritz Zwicky, a Swiss national, who was working at the University of California, Berkeley in 1934, when he discovered that in order to account for missing mass in orbital clusters of galaxies he had to postulate a source of non-visible (or non-electromagnetic) mass, which he termed *dark matter* (Braccesi 1990). Although his work was neglected for a long time, a number of other developments astronomically have pointed to the same conclusion, namely, that a great deal of the mass of the universe is not within the electromagnetic realm but is purely gravitational.

Subsequent observations of a variety of kinds have suggested that not only is the universe not stable, but it is in fact expanding at an accelerating rate. The main kind of evidence for this is connected with Hubble's law that the farther a star system or galactic cluster is from the earth, the faster the star system or cluster is moving relative to us. Careful measurements were taken by a joint Harvard/Berkeley team looking at thousands of galaxies near a new moon and some weeks later when they could identify supernovae as they were starting to brighten. Following the light variation using ground- and space-based telescopes, they found that the form of Hubble's law for the expansion speed of the distant supernovae versus their distance curved upwards confirms the view that the expansion of the universe is accelerating.

In order to account for this apparently convincing conclusion, there has been a return to Zwicky's dark matter and its closely analogous *dark energy* as postulated entities that cannot be detected directly, as can stars and galaxies by using electromagnetic phenomena with our various kinds of telescopes. (Because of the Einstein equivalence of matter and energy, $E = mc^2$, one has to recognize a gravitational effect of energy as well, even when it does not appear in a mass-like form.) As it happens, the dark energy component of interstellar space appears to make up about 72 per cent of the gravitating material, and dark matter another 23 per cent, leaving only roughly 5 per cent for the stars, planets and ordinary matter.

In 1996, by a peculiar process of competition and consensus, a large cosmology conference in Princeton arrived at the view that Michael Turner's Lambda-CDM model gave the best account of these experimental results. (*Lambda* is just the Greek letter for Einstein's cosmological constant, and CDM is *cold dark matter*.) (The conference proceedings are published in Turok [1997].) Essentially, the model reinstates Einstein's old cosmological constant as an antigravitational effect, with the assumption that the expansion of the universe is very close to the critical rate as predicted by inflationary theories. It includes a tiny positive value for the cosmological constant that can be tweaked to match the measured data for expansion rate. The peculiarity is that this constant is of the order of 1/10 to the 120th power, or as near to zero as can be without actually being zero. (Other considerations deriving from quantum mechanics of fundamental particles tend to conclude that this ought to be not a number very near zero, but identically 1. This difference is one of the deepest puzzles in contemporary physics and is awaiting its Einstein.)

When Einstein initially formulated his general theory of relativity, that is to say his theory of gravitation, he initially included a constant (the so-called cosmological constant) in his equations so that the universe would be stable. He soon abandoned it and considered it one of his major blunders. However, in recent years something like his cosmological constant has reappeared in the thinking of many physicists who are tackling the puzzles surrounding dark energy and dark matter.

The peculiar situation we have today is that the visible universe, which is likely to be a tiny part of an exceedingly diverse "multiverse," is accelerating along lines suggested by George Lemaître more than eighty years ago (Lemaître 1931). This acceleration is well described by adding to Einstein's equations a cosmological constant of the kind that Einstein originally introduced and then abandoned, which we now interpret as the *vacuum energy* of the universe, following Lemaître's initial suggestions. The resulting picture of the universe has, as mentioned before, 72 per cent of its energy density in this gravitationally repulsive vacuum form and the remaining 28 per cent or so in forms of dark and luminous gravitationally attractive matter.

This accelerating universe appears to have some peculiar properties. For example, if it continues an accelerated expansion as it is presently doing, there will come a time that star formation and galaxy formation will cease since the universe will be expanding at a rate too great for any physical processes to keep up. Thus the future is likely to be one of dead stars and isolated elementary particles. There will be a horizon beyond which any observer or any device designed to observe will be unable to see.

This also leads to the conclusion that, at some point in this future expansion, if stars and galaxies cannot form then carbon-based life or any other imaginable kinds of life will also be unable to form. The conscious universe will no longer be a possibility and the universe will no longer know of its own existence as it does now. "Once was the time of Man," the old 1960s refrain, will have a point.[3]

Implications for the Physics Classroom

Students today are very interested in modern physics, especially as it relates to astronomy and cosmology. They may be familiar with the Bohr model of the atom and even with the rules used to describe the electron structure of an atom based on the Schroedinger version. If the teacher has good understanding of the basic ideas of Einstein's theory of relativity, students may even learn the basic assumptions and testable consequences of both special and general relativity. The physics teacher should have sufficient background knowledge to discuss the phenomena of dark energy and dark matter along the lines discussed. The teacher should be able to discuss Zwicky's work by simply calculating the collective motion of stars in a galaxy, using Newton's laws of motion and the inverse square law of gravity. Hubble's law is easily understood since it is simply a linear relation. To make sense of the expanding universe the acceleration can be compared with a rocket leaving earth with the escape velocity of about 11 km/s. If the rocket is found later to accelerate after all power is turned off, one has to postulate a mysterious force pushing it—fascinating stuff for high school students.

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[3] *Editor's Note*: "Once Was the Time of Man" was written by Travis Edmonson in 1961; it was sung and recorded by Travis and Bud (the folk duo founded by Edmonson) and also by the Limeliters.

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Millsap Is Steamed!

Wytze Brouwer

"Brouwer, I'm steamed!"

Bert Millsap came storming into the Faculty Club, where we were sitting discussing the recent visit of the university president to our faculty. After an hour and a half during which other people did most of the talking, we naturally got thirsty, so we—Brian Adams, an astronomy colleague; Jenny Platt, our friend from Botany; and Joseph I Joseph, who was an expert in complex variables—wandered over to the Faculty Club.

Everybody knows Bert Millsap, of course, my tubby colleague from Psychology who livens up the Faculty of Science due to the various scrapes he has gotten into over the years. He had just returned from a European conference, where he had been inducted into the Bavarian Academy of Science and, with the headline "*Sie haben Hanky-panky gemacht*," made himself famous to a lot of German readers (see the archives for the details).

"Well, Bert, sit down and relax for a bit. You look like you're going to have a conniption. What can I get you? The usual?"

"No, not the usual. I need something stronger. Get me a large martini, made with orange gin."

"Orange gin? I don't know if they have it. They usually make martinis with plain gin or lemon gin."

"The Faculty Club has everything. Just ask the bartender."

So I ambled over to the bar and asked for a martini made with orange gin.

"And the usual for Professor Millsap, I presume?"

"No, the martini is for Professor Millsap. He's upset and he thinks the usual just won't do it."

For those of you who haven't been following the misadventures of Millsap, the recipe of his usual is available on request, but contains copious amounts of Scotch, Drambuie, and grenadine syrup. We've never met anyone who actually wanted the recipe, but it's there for the asking.

"Dr Brouwer, we don't have any orange gin. What shall we do?"

"That *is* a problem. You know how Millsap can be if he's thwarted. He may be only 5 feet 6, but he can bellow like an offensive lineman. But there's the manager. Maybe he knows a solution."

The club manager wandered over and asked us what he could help us with. He was very understanding and nodded quietly.

"We'll just make the martini with orange vodka. Professor Millsap won't taste the difference."

Problem solved … hopefully. I brought it over to our table and presented it to Millsap.

He took a deep draft and sighed.

"Excellent. I often have to tell you, Brouwer, have a little faith. The Faculty Club can make any drink you want."

"You're absolutely right, Bert—I'll never doubt you again. Now tell us what you're so steamed about. Although actually, we're steamed too, because you skipped a faculty meeting that we had to sit through to the bitter end."

"Never mind the faculty meeting. If the dean doesn't see me, he leaves me alone. What actually happened to me is that a colleague in Education sent me a document on grade inflation in high schools in Alberta and it upsets me. I think we should do something about it."

Something triggered my memory. "I remember we were concerned about grade inflation in the high schools a couple of decades ago, in the early eighties, and we decided to contrast high school grading practices with our grading practices in the Faculty of Science. However, we found the same amount of grade inflation in our own faculty, so we stopped complaining."

One of the compensations of age is that you've saved up a lot of experience during a long life and, unless your memory has gone, you can use your experience to get a bit of perspective on problems that may seem new but have been with us since the Middle Ages, as an old dean of mine used to say. But back to Millsap.

"No, no, Brouwer, this is different. This isn't simply old-fashioned grade inflation—it's the difference between the school marks the teachers give the students and their final exam marks."

"So what do we care?" asked Brian Adams. "It's got nothing to do with us, does it?"

"Doesn't it? We get these students entering university and depend on their high school grades telling us something real about their potential."

"Well, don't we just compare their provincial exam marks?"

"No, no, Brian, we get a mark that is 50 per cent school based and 50 per cent provincial exam based."

"So what do we care if the two marks are a bit different? You can't expect perfect agreement between a teacher grade and the grade on a provincial exam." Jenny is always our compromiser and quite accepting of other peoples' foibles. "These differences will all come out in the wash, won't they?"

Millsap was not satisfied. "Think a bit. How much of a difference would you accept between a teacher-assigned mark and the provincial exam mark?"

"I would accept, say, a difference of 10 to 15 per cent between the teacher mark and the exam mark," suggested Joseph Joseph. "That way, the grade fluctuations from one student to another in a class should average out pretty close to the provincial average exam."

"Well, what would you do if the class average of the teacher-assigned mark was 25 per cent above the average this same class got on the provincial exam?" Millsap leaned forward aggressively as if to say, "Have I got a surprise for you guys!"

Joseph replied first. "That would be like a teacher giving his students a class average of around 67 per cent and his class averaging, let's see, averaging 42 per cent on the provincial final. I predict that can't happen, and if it did I would fire the teacher."

"I suppose it could happen once, to a new teacher, I suppose," ventured Jenny, "but it should happen only once, because a principal or a superintendent would want something to be done about it—help the teacher, for example, or, if necessary, place a better teacher in that classroom."

I was sitting back trying to understand the implications of what Millsap was setting up. Surely the Department of Education wouldn't simply send us at the university a blended mark that would average 54.5 per cent for these students?

"Bert, you're obviously setting us up. You seriously mean that there are students coming to university from schools that grossly inflate student marks so their poor results on the provincial exams don't prevent them from coming to university?"

"Brouwer, Joseph doesn't believe there would be one class in Alberta where a teacher gave a class average 25 per cent higher than the provincial exam. Let me show you what the situation is in Physics 30. In 2011, there were 17 high school classes whose school-based grades were more than 25 per cent above the provincial exam average. The highest deviation above the exam average was 38.9 per cent. The lowest among these 17 schools was 25.2 per cent above the exam average."

At this point we signalled our waiter to refresh our drinks. From our faces you would guess that we couldn't believe it. One class of students in Alberta would have been given a school-based average of perhaps 75 per cent in Physics 30 and these same students would average … 75 per cent − 38.9 per cent, that's, eh, let me think, 36.1 per cent on the provincial final? And this kind of thing is happening to quite a degree at many other schools?

Jenny had the solution. "Of course, it's physics! We know there is a shortage of physics teachers across the province. I'm sure this isn't happening in biology, or English, where we have many more qualified teachers."

"Don't be so sure, Jenny." Millsap had more ammunition. "In Social Studies 30, there are 24 high schools in which the school-based average grade is more than 20 per cent above the examination average grade, and in English 30 there are 33 high schools whose assigned grades are more than 20 per cent above the exam average."

Brian was so upset, he upset his beer stein. While he was brushing off his clothes he blurted "But this is just ridiculous. These blended marks from Alberta high schools are just useless for university admission. We should pass these figures on to the dean and use only the examination marks for university entrance."

Jenny was not quite ready to go that far. "I agree this is scandalous but before we punish the students for this, we should try to find out who is responsible for this situation and why the Department of Education is not doing anything about it. I heard somewhere they might be investigating a couple of private schools, but this kind of blatant cheating is going on in many places.

Something should be done to hold the educators themselves responsible."

I was pretty shocked myself. If you look at the provincial data on school-based and final examination-based grades you find that the vast majority of schools give school-based marks more than 10 per cent above the examination average, although a few academic schools give school-based grades very close to the exam average. So, in a sense, we are discriminating against accurate reporting of students' grades.

"I have a solution," said Millsap. "If the school-based average grade is less than 10 per cent above the exam mark, we give the student the 50–50 blended grade. If the school-based grade is between 10 and 20 per cent higher than the exam grade, we give the students a blended grade that is weighted 66.7 per cent towards the examination grade, and if the school-based grade is more than 20 per cent above the exam grade, we give the students just the examination grade. That should make school officials more careful about the grades they report to the Department of Education!"

Well! No one can deny that Millsap doesn't have strong opinions.

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