

# Competition

## A Multidisciplinary Analysis

Wade B. Worthen, A. Scott Henderson,  
Paul R. Rasmussen and T. Lloyd Benson (Eds.)



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# Competition: A Multidisciplinary Analysis

# TRANSGRESSIONS: CULTURAL STUDIES AND EDUCATION

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## *Scope*

Cultural studies provides an analytical toolbox for both making sense of educational practice and extending the insights of educational professionals into their labors. In this context *Transgressions: Cultural Studies and Education* provides a collection of books in the domain that specify this assertion. Crafted for an audience of teachers, teacher educators, scholars and students of cultural studies and others interested in cultural studies and pedagogy, the series documents both the possibilities of and the controversies surrounding the intersection of cultural studies and education. The editors and the authors of this series do not assume that the interaction of cultural studies and education devalues other types of knowledge and analytical forms. Rather the intersection of these knowledge disciplines offers a rejuvenating, optimistic, and positive perspective on education and educational institutions. Some might describe its contribution as democratic, emancipatory, and transformative. The editors and authors maintain that cultural studies helps free educators from sterile, monolithic analyses that have for too long undermined efforts to think of educational practices by providing other words, new languages, and fresh metaphors. Operating in an interdisciplinary cosmos, *Transgressions: Cultural Studies and Education* is dedicated to exploring the ways cultural studies enhances the study and practice of education. With this in mind the series focuses in a non-exclusive way on popular culture as well as other dimensions of cultural studies including social theory, social justice and positionality, cultural dimensions of technological innovation, new media and media literacy, new forms of oppression emerging in an electronic hyperreality, and postcolonial global concerns. With these concerns in mind cultural studies scholars often argue that the realm of popular culture is the most powerful educational force in contemporary culture. Indeed, in the twenty-first century this pedagogical dynamic is sweeping through the entire world. Educators, they believe, must understand these emerging realities in order to gain an important voice in the pedagogical conversation.

Without an understanding of cultural pedagogy's (education that takes place outside of formal schooling) role in the shaping of individual identity--youth identity in particular--the role educators play in the lives of their students will continue to fade. Why do so many of our students feel that life is incomprehensible and devoid of meaning? What does it mean, teachers wonder, when young people are unable to describe their moods, their affective affiliation to the society around them. Meanings provided young people by mainstream institutions often do little to help them deal with their affective complexity, their difficulty negotiating the rift between meaning and affect. School knowledge and educational expectations seem as anachronistic as a ditto machine, not that learning ways of rational thought and making sense of the world are unimportant.

But school knowledge and educational expectations often have little to offer students about making sense of the way they feel, the way their affective lives are shaped. In no way do we argue that analysis of the production of youth in an electronic mediated world demands some "touchy-feely" educational superficiality. What is needed in this context is a rigorous analysis of the interrelationship between pedagogy, popular culture, meaning making, and youth subjectivity. In an era marked by youth depression, violence, and suicide such insights become extremely important, even life saving. Pessimism about the future is the common sense of many contemporary youth with its concomitant feeling that no one can make a difference.

If affective production can be shaped to reflect these perspectives, then it can be reshaped to lay the groundwork for optimism, passionate commitment, and transformative educational and political activity. In these ways cultural studies adds a dimension to the work of education unfilled by any other sub-discipline. This is what *Transgressions: Cultural Studies and Education* seeks to produce—literature on these issues that makes a difference. It seeks to publish studies that help those who work with young people, those individuals involved in the disciplines that study children and youth, and young people themselves improve their lives in these bizarre times.

# Competition: A Multidisciplinary Analysis

Wade B. Worthen  
A. Scott Henderson  
Paul R. Rasmussen  
T. Lloyd Benson  
*Furman University*



SENSE PUBLISHERS  
ROTTERDAM/BOSTON/TAIPEI

A C.I.P. record for this book is available from the Library of Congress.

ISBN 978-90-8790-826-3 (paperback)

ISBN 978-90-8790-827-0 (hardback)

ISBN 978-90-8790-828-7 (e-book)

Published by: Sense Publishers,  
P.O. Box 21858, 3001 AW  
Rotterdam, The Netherlands  
<http://www.sensepublishers.com>

Printed on acid-free paper

Original cover photo by Polly Gaillard

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*In memory of Joe Kincheloe—a friend and scholar who made this book possible.*



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# CONTRIBUTORS

The contributors are faculty members at Furman University, an independent liberal arts college located in Greenville, South Carolina.

Department of Biology

*Wade B. Worthen*

Department of Business and Accounting

*Kirk R. Karwan*

*Thomas I. Smythe, Jr.*

Department of Earth and Environmental Sciences

*C. Brannon Andersen*

*Weston R. Dripps*

Department of Economics

*Nathaniel P. S. Cook*

*Kailash Khandke*

Department of Education

*A. Scott Henderson*

*Renita R. Schmidt*

*P. L. Thomas*

Department of Health and Exercise Science

*William J. Pierce*

Department of History

*T. Lloyd Benson*

Department of Philosophy

*James C. Edwards*

Department of Political Science

*Thomas A. Kazee*, Provost and Executive Vice President, Furman University

*Elizabeth S. Smith*

*Aristide Tessitore*

Department of Psychology

*Beth A. Pontari*

*Paul R. Rasmussen*

Department of Religion

*Alfons H. Teipen*

Department of Sociology

*David E. Redburn*



## FOREWORD

The 19th century Scottish philosopher Thomas Carlyle wrote, “Our life is not really a mutual helpfulness; but rather, it’s fair competition cloaked under due laws of war; it’s a mutual hostility.” A more contemporary take on competition and life came from Vince Lombardi, the legendary football coach who claimed that “winning isn’t everything, but wanting to win is.” Indeed, in modern society the notion that competition is a good thing seems largely to elude critical examination. We compete in our vocations and in our avocations; perhaps competition is intrinsic to being human. Or, extending the concept to all living things, life itself may be fundamentally a competition—for food, for mates, for territory.

But even as we recognize the omnipresence of competition in our lives, we see that it carries profound costs. Our winning often means that someone loses. In human society, losing may not only make growth and progress (*getting ahead*) more difficult, it can also shape how we are perceived by ourselves and others. “Loser” is among our most pejorative declarations. The question, then, is how to understand the nature of competition in a world that seems, in fundamental respects, governed by it. And since competition seems so relevant for all living things and the complex groups they comprise, such understanding must necessarily come from a multi-disciplinary approach.

The essays in this book were written by faculty members at Furman University, and where better to raise such questions than in a place dedicated to liberal education? The liberal arts have, at their core, the assumption that knowledge is best propagated in an environment of multi- and interdisciplinary examination. The breadth that characterizes the curriculum of a liberal arts university is fertile territory for exploring questions that cut across disciplinary boundaries. The spaces that separate the silos of social science and the arts, or natural science and the humanities, are less wide in these places; the likelihood that ideas will collide and sometimes combine is much greater—either by design or good fortune—in the literal and figurative hallways of such an institution.

There are, to be sure, ironies apparent in this project and in the context within which it was produced. Though a book about competition, this study could not have come to fruition absent a substantial degree of cooperation and collaboration. These chapters reveal a group of intellectuals joined in common cause to examine the meaning and significance of competition. But there is yet another irony. If these faculty have done their jobs well, their students will leave college better able to compete in a society that embraces and rewards competitive success. If shaping those skills also fosters an appreciation of the dignity, integrity, and interdependence of life, we have something else to celebrate.

*Thomas A. Kazee*  
*Provost and Executive Vice-President*



**PREFACE:  
DOMINANCE OF THE COMPETITION PARADIGM**

A primary current in Western civilization is the idea that competition is the best way to stimulate improvements in any given system—to progress in complexity, diversity, productivity, quality, and efficiency. Manifest in Plato's (1992) *Republic*, Adam Smith's (1776) *The Wealth of Nations* and Charles Darwin's (1859) *The Origin of Species*, this concept floods our culture so thoroughly that competitive language, models, and analyses drift easily between different cultural channels. The pervasive use of sports metaphors in politics and business may be a trivial example, but the flow of models from economics to ecology (cost/benefits analyses, bet-hedging, the principle of diminishing returns, optimization functions, etc.), and from ecology to psychology and sociology (spawning the disciplines of evolutionary psychology and sociobiology) has led to productive insights.

This book has two goals. The first is to examine the role of competition in our world—from historical and philosophical perspectives, to the mechanics of competitive interactions among organisms in natural ecosystems, to interactions among human organisms in familial, societal, and international relationships. The second goal is to critically analyze the legitimacy of the idea itself. Does competition necessarily improve a system? What are the costs of this approach, and have alternative approaches been ignored? A library has been written on competition. Many investigations offer business strategies for succeeding in competitive markets (Porter, 2008). But there are also theoretical analyses from a variety of other disciplinary perspectives, and excellent criticisms of the competition worldview (Kohn, 1992; Rosenau, 2003). The reader might well ask by what error of logic, or expression of hubris, the editors concluded that yet another treatment was warranted. To our knowledge, no single work examines competition, as mechanism and paradigm, across the full spectrum of our culture: from history to science, from philosophy to business, from individual interactions to social movements. We believe this approach will reveal interesting parallels and contrasts in the mechanics of competition, and interesting strengths and weaknesses in how it operates in different fields.

Regardless of the natural or cultural context, competitive relationships share certain characteristics. Competition becomes important when resources become limiting. Food, shelter, mates, water, minerals, jobs, goods, services, customers, money, time, power, praise, the family car, or a parent's affection can be resources for which entities (from individuals to nations) compete. Resources may become limiting because absolute supply is low relative to demand, or because *access* to supply is low relative to demand. Access can be regulated or controlled by a

parent, a government, a cartel, a bully, a social norm, a referee, or the dominant competitor in an interaction.

Competition imposes costs on the participants, and—as the discussions in this volume will illustrate—there are six strategies for absorbing or avoiding these costs. One strategy is to compete harder—invest more energy in the competitive struggle by shifting energy from another activity. A second strategy is to increase efficiency and reduce resource use. Third, competition can be reduced by shifting to a new resource or creating a new market. This may sound easy, but creating a new market or innovation can be very costly (research and development), and there are inefficiencies to overcome adapting to new environments and exploiting new resources. A fourth strategy is to co-opt the resource—regulate control, reduce or eliminate the access of other competitors, or beat them to the resource. A fifth strategy is to absorb the competitor. This can occur by changing the competitive interaction into a symbiotic, mutualistic relationship (like a friendly merger) in which both parties benefit by acquiring new resources and shedding the cost of competition. Or, one party can consume and destroy the other (as in predation or a hostile takeover) and thus benefit by gaining resources and losing a competitor. Finally, the sixth strategy is to steal the resource or acquire it by deception. Stealing is not always performed in response to competition, and it is not always the limited resource that is stolen. More commonly, stealing is used to acquire the wealth, energy, or resources needed for (or lost in) other competitive interactions.

These strategies are not independent. Through competing harder, the victor might co-opt the entire resource and be able to regulate access. Or, a merger or symbiosis might create a new market or niche, or increase operational efficiency. In addition, all strategies can stimulate and profit from innovation and creativity. A new advertising campaign may make a company a stronger competitor in the same market niche; a new product may open a new market; a creative new lobbying effort, or an innovative law drawn up by a company's legal team, might favor one sector of an industry, allow a merger, or promote a no-bid contract; and daily news reports provide examples of new ways to cheat and steal.

Although competition is costly and can have negative effects on a system, most Western cultures believe that the stress and hardship of competition will increase system efficiency, precipitate innovation, and even improve personal character. This worldview has become an entrenched paradigm—a set of assumptions perpetuated through time by new generations of proponents who assume its validity and superiority (Rosenau, 2003). The most pernicious effect of this (or any) paradigm is that it stifles the examination of alternatives that may be equally or more descriptive, efficient, productive, useful, or ethical.

Besides competition, there are other interactions in nature and culture that improve a system and increase complexity, diversity, productivity, quality, and efficiency. The most obvious example is cooperation (mutualism). In mutualistic relationships, both participants benefit. There may be costs associated with the interaction, but the net effect on both participants is beneficial rather than deleterious (as in competition). Mutualisms have also been the source of many important biological innovations, and cooperation has been advantageous in every aspect of human culture—from reinforcing family bonds to forging international

alliances. Even in the marketplace, cooperation has always been a successful way of doing business. Cooperation among companies can streamline production costs by reducing redundancy, can improve marketing efficacy by partnering with complementary products, and can lower purchasing costs by exploiting economies of scale. So, cooperation can be a successful strategy in competitive environments.

Like some good ideas (and many bad ones), the discussion that led to this book occurred at a dinner party. An off-hand exchange about birth order effects among siblings led to a broader conversation about priority effects (the advantages that accrue for accessing a resource first), resource partitioning, and different types of competitive interactions. Examining the ways competition is manifest across our culture, represented by different disciplines in academia, seemed like a worthwhile enterprise. The book is structured accordingly, beginning with an introduction that places the competition paradigm in its historical context. Four topic areas follow, examining competition from the perspectives of science, social science, religion and philosophy, and sport, business, politics, and education. All chapters were written by faculty at Furman University—a liberal arts college in Greenville, South Carolina. The university is dedicated to engaged, collaborative learning. The collegiality and friendships that extend across specializations support that mission and are embodied by this project. The editors thank our colleagues and the administration of Furman University for their contributions to this interdisciplinary, cooperative, and sometimes competitive undertaking.

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T. LLOYD BENSON

## **INTRODUCTION: COMPETITION AND CONTEXT IN THE EURO-ATLANTIC HISTORICAL MIND**

Gazing at the devastated mining village of *Deux-Cent-Quarante*, Etienne Lantier (of Emile Zola's 1885 novel, *Germinal*), pondered all that had happened: over-production putting owners near bankruptcy, colliers forced to trade their physical safety for higher wages, hollow aid promises from the Socialist International, a devastating strike, deadly mine sabotage, and children gunned down in cold blood by troops called in to quell the disorder. "Was Darwin thus right?" he wondered. "Was the world nothing more than a battle, the strong eating the weak, for the beauty and continuity of the species?" (Zola, 1885, p. 1589) In this novel, market competition and Darwinian struggle left characters and theories battered by realities but ripe for regeneration. Zola's work captures a decisive era in the competition paradigm, when academic theories of competition penetrated society and when humanists challenged these theories in their own work and thought.

Like Lantier, historians have pondered whether the paradigms of market competition and Darwinian struggle could fit to the events of the historical past. There is much potential here. Historians work like diagnostic clinicians, engaged in investigative inquiry ("How did that happen? Where did that come from?"), and identifying competing factors that might explain the disruption of normal systems in human society (Gaddis, 2002). The study of international conflicts has been a staple of the profession since its beginnings, and in recent years scholars have devoted considerable attention to global-scale "contests of cultures." Local history and biography, too, have emphasized the struggle for control of scarce community resources and the rise of persons, organizations, and ideas through "negotiations" among competing interests and identities. Thus, competition paradigms have provided interesting insights into societal change over time and are commonplace in historical practice.

Yet, historians have also identified the indelible imprint of author bias and temporal context—their "historical baggage". Researchers have been especially attentive to the ways in which academic models of competitive behavior were adapted as rationalizations to sanction exclusionary and imperialistic public policies. Historians have also themselves competed for patronage, prestige, and dominance over rivals. Conscious of this, their use of competition models have ranged from pragmatic small-scale application to open scepticism and even hostility. A long tradition in favor of narrative history and close textual reading—rather than

quantitative modelling—has also kept historians away of such empirical frameworks. Historians often criticize parsimonious theoretical explanations as being overly reductionist and monocausal. Competition paradigms, in the formal sense of systems of laws, rules, and empirically verifiable patterns of behavior, have thus been rarely incorporated into the discipline of history. This contrasts to the pervasiveness of such paradigms in the natural and social sciences (Anderson, 1991; Becker, 1932; Berry, 1999; Hawkins, 1997; Irwin, 1996; Novick, 1988; Shaw, 1999).

Historians in recent years have paid close attention to how scientists and social scientists frame their own histories and origin myths. Such stories have often been defined as much by the goals and ideals of specific disciplines as by the documentary record. Nothing has been more important to these interpretations than the view of historical “progress” and “improvement.” These twin depictions of historical change are deeply embedded in everything scholars do and believe. Implicit within these is a celebration of revision rather than continuity. The more the clock ticks, we assume, the more refined the process becomes. When scholars turn from their own investigations to writing histories of their disciplines, Progress carries the plot—providing a triumphal epic of “good” concepts supplanting “bad” rivals. Such a model is powerfully appealing to scholars, but it often obscures the complexities involved in academic research and persuasion. Sometimes these paths are linear and progressive; at other times they are subject to reversals, dualisms, paradoxes, and parallels.

What follows is a brief overview of some defining moments in the intellectual history of competition in the Euro-Atlantic world since the Renaissance. Its consideration of how social context shaped the spread of ideas will be coupled with attention to how fundamental beliefs about change over time influenced various understandings of competition, and how historians themselves have adapted interpretations of competition to revise their narratives.

#### COMPETITION AND HISTORY IN EARLY MODERN EUROPE

Competition among Italian city-states and mercantile interests in the age of the Renaissance reoriented historical scholarship. Distancing themselves from the “mere chroniclers” of the preceding era, humanist scholars such as Leonardo Bruni, Lorenzo Valla, and Francisco Petrarcha (Petrarch) defined the discipline of history as the task of providing thematically and narratively unified treatments of the past. These relied upon secular rather than divine explanations, were based on rigorous methods of evidence and source criticism, and consciously sought to give readers practical training in explicitly “civic humanist” forms of statecraft. (Cochrane, 1981, pp. 3–16, 400–404) As renaissance scholar Lauro Martines (1979) demonstrated, these scholars became inextricably linked to the interests of their patrons, even when criticizing their shortcomings. The history of elites became central while the events of “barbarian peoples” were dismissed. Renaissance historians devoted themselves to speculation about the secular flows of “Progress” and “Decline.” Their staged periodization of European history still dominates our popular understandings of the European past. The plotline of a vitally competitive,

cosmopolitan, and intellectually rich classical age of ancient Greece and Republican Rome, succeeded at first by the “Dark Ages” of rude Gothic “barbarians,” and the literal “rebirth” of intellectual vitality in their own time, is a powerful testament to the force of their model (Martines, 1979, pp. 194–199, 214–217, 310–317).

Although the insights about human nature and social change crafted by Renaissance historians could be profound, they did not include a formal empirical theory resembling any subsequent competition paradigms. Rather than a systemic principle, Renaissance scholars typically depicted competition as a manifestation of desire whose implications could be bad or good. Giorgio Vasari’s sweeping *Lives of the Most Excellent Painters, Sculptors, and Architects* for example, extolled competition as the force of progress driving art forward from its primitive rebirth under Giotto to the perfection of Michelangelo. Yet, having achieved this perfection, Vasari thought competition thereafter served only to create dissention and imitation (Clifton, 1996). Likewise, for Florentine theorist Niccolo Machiavelli, competition in a free and orderly society could produce what he labelled “wondrous” improvements for both private citizens and the public good. Yet a stable society required leaders who transcended competition’s inherent vices. Ambition, faction, rivalry and envy, he thought, disrupted states internally—long before they could be conquered by external foes. (Machiavelli, 1519, Book II, Chapter 2).

The colonial conquests, imperial wars, and religious conflagrations that followed were bold illustrations of competition’s paradoxes. Rivalries among religious traditions, nation-states and other social institutions produced no single victor but produced many different forms of resistance and innovation. As in the Renaissance, intellectual and technological improvements were often linked to state interests. Improvements in military and naval technology, printing and communications, physics and mechanics, political theory, state-level bureaucracy, new forms of imperial and finance capitalism, and even such seemingly abstract ideas as Cartesian coordinates all emerged in service to these conflicts. One of the most common early uses of the term *evolution* in the English language, for example, was to describe the reconfiguration of military units from one formation to another. Competition’s other consequences seem less laudable. Rival European nation-states sought to suppress dissent at home while accumulating allies and dominating rivals abroad, encountering in the process a host of nations, empires, and peoples outside of Europe whose own ambitions and weaknesses led to a dizzying sequence of alliances, dissolutions, betrayals, and reversals. Millions died from war, the slave trade, and other by-products of purposefully competitive initiatives. Millions more fell as collateral victims of disease and famine. Many survivors found themselves unwillingly moved from city to city, region to region, or even continent to continent. A global economic reorganization subjugated whole populations while redefining core household activities and roles. Even the most successful financial elites were subject to the torment of financial panics, commodity shortages, business frauds, and enterprise failures. From the 1750s to the 1850s, the accelerating pace of industrial transformation and political revolutions produced unparalleled dislocations and unprecedented opportunities for profit and power. (Frank, 1998; Kennedy, 1989; Marks, 2007; McNeill, 1993; *Oxford English*

*Dictionary*, 2009; Pagden, 2003; Pomerantz, 2000; Schlesinger, 1996; Shapin, 1996; Stearns, 2003).

As in the Renaissance, thinkers responded to these upheavals with sharply differing judgments of competition's value. One common reaction was to portray one's own competitive triumphs as signs of God's providence rather than secular accident, and to rationalize setbacks not as evidence of God's disfavor but as proof of insufficient labor against apathy and heresy (Bercovitch, 1978; Diefendorf, 1991; Haigh, 1988; Hibbert, 1993). Many scholars in this period cast a dark eye on rivalry and competition. Schooled by England's catastrophic civil wars, for example, Thomas Hobbes (1651) created a vivid heuristic of the "state of nature" which critiqued the "war of all against all" that would exist in a world without social cooperation or a sovereign authority (chapter 1). Even more bleak was John Milton's (1667/1961) depiction of competition in his imagined historical epic *Paradise Lost*, in which he described the depravity of humans, who "live in hatred, enmitie, and strife/Among themselves/and levie cruel warres/Wasting the Earth, each other to destroy" (II, 500:502). Others satirized the rivalry for status and privilege that was rife in the European royal courts. In this view, such aristocratic competition engendered only decadence, vice, and corruption; and would almost inevitably cause the collapse of the nation through greed, hubris, and factionalism. Building on precedents laid out by Roman historians, "Commonwealthmen" such as James Harrington (1656/1992) and Algernon Sidney (1698) idealized an agrarian alternative where landed property was widely and equally distributed and where household heads could live free of the seductions inherent to competitive urban, commercial, and imperial environments. In France, an emergent middle class—growing increasingly eager for status and increasingly critical of the indulgent aristocracy—generating a flood of tracts and theories criticizing wealth and its excess as a source of national decline (Bailyn, 1967; Blum, 1989; Harrington, 1656/1992; McCoy, 1980; Pocock, 1975; Shovlin, 2006; Sidney, 1698). There were also some foundational efforts at comparative analysis of nations, by Montesquieu, Voltaire, and others, that pointed to the influence of environmental factors in shaping political structures and offered some interesting hypotheses about the benefits of mixed governments and religious toleration. In Voltaire's (1733) famous observation about England's denominational pluralism, for example, he noted that "If there were only one religion in England, there would be danger of tyranny; if there were two, they would cut each other's throats; but there are thirty, and they live happily together in peace". Interpretations were also deeply influenced by encounters with peoples Europeans considered to be primitive and natural rather than civilized and historical. On one hand, such portrayals served to contrast the supposedly idyllic harmony and cooperation of indigenous peoples against European brutalities and inequities. On the other hand, these portrayals chastened Europeans against the temptations of idolatry, indolence, and lust supposedly inherent to those they labelled "the naturals" (Axtell, 1981; Montesquieu, 1724/1964; Schlesinger, 1966).

## INTRODUCTION OF MODERN PARADIGMS

It was in response to these critiques and crises that Adam Smith and subsequent competition theorists framed their innovations. Systematic probing of this era's scientific and academic archives and biographical studies of Adam Smith, Thomas Malthus, Charles Darwin, and Herbert Spencer, among others, has produced a fine-grained portrait of how scientists and social scientists in this foundational age developed their ideas. Fruitful debates have resulted among historians over the relative influence of *internal* disciplinary procedures versus *external* social motivations in promoting intellectual innovation, and over the significance of cultural preconceptions in shaping the diffusion of these concepts. These exchanges have refined our understanding of how methods and discourse among scientists and political economists generated theoretical breakthroughs, while also demonstrating the impact of cultural context, class interests, and influences from non-academic sources (Beer, 1962; Cohen, 1985; Dear, 2001; Himmelfarb, 1959; Hull, 2005; Schweber, 1980; Shapin, 1996).

Historians have advanced competing interpretations of the Scientific Revolution, and our understanding of scientific authority and the relationships between science and social theory have become increasingly complex. Gone is the heroic narrative of pre-Copernican Catholic superstition and dogmatism being defeated by secular, rational, empirical, and quantitative "science." What emerges is a more even-handed and humanized account of the era's intellectual work. We now recognize that the Catholic church was one of the most important sources of patronage for scientific research, as long as investigations were consistent with Aristotelian logical methods and biblical infallibility. Galileo was so obsessed with pleasing his aristocratic patrons that it retarded some of his most important discoveries. William Harvey and Francis Bacon so misunderstood female reproductive processes that their writings actually reversed scientific progress in this area for generations. Modern techniques of verification and replication emerged not to challenge ideological and theological principles, but to use "the Book of Nature" (instead of philosophy) to demonstrate God's plan. National academies of science could just as often be agents and symbols of state pride as of science, as the delayed adoption by the French Academy of Newtonian physics and smallpox inoculation so vividly illustrate. Even the numeric conventions underlying so much of modern scientific discourse developed fitfully, with some unconventional notations still in use well into the era of professional academic science. This revised chronicle of scientific accomplishment shows the mix of ambition and discipline motivating these figures as they sought to balance research and daily life in an extraordinarily volatile era (Appleby, Hunt & Jacob, 1994; Cohen 1987; Crosby 1997; Dear 2001; Jacob 1997; Merchant 1983; Shapin 1996).

It was into this cauldron of conflicting individual ambitions, social imperatives, state interests, economic disruptions, and academic rivalries that the leading architects of competition theory developed their ideas. Recent work shows the intricate tug and pull between academic theory and general society. Smith's contributions were a defense of urban commerce as a source of social invigoration. His insights about the benefits of comparative advantage in trade, and in his moral

argument for how self-interest produced wise allocation of resources, were a revelation. There was nothing inevitable or predetermined, however, in the success of ideas expressed by Smith or those he influenced. Indeed, there is much in his corpus that now seems quaint to the modern ear. As popular as his classic *Wealth of Nations* remains, today's economists have been highly selective in their usages—often skimming over the bulk of Smith's moral, religious, and social concerns. Smith's world was one of small-scale enterprises and predominantly local urban-rural exchange, coupled with a handful of merchant capitalists who traded in the context of nation-state mercantile and colonial regulation. He could not foresee the emergence of massive trans-national industrial monopolies—exploiting tens of thousands of workers—embedded in an urban-dominated transportation and communications system that linked peoples worldwide. Nor could he anticipate the role of the French Revolution and colonial resistance movements in undermining the confident enlightenment rationalism his writings encapsulated (Heilbroner, 1986; Smith, 1776/1904; book 3 chapter 4; Tribe, 1999).

Recent historical scholarship has greatly enriched our understanding of how ideas about competition were created and refined in the 18th and 19th centuries. Critics have long noted the co-evolution of Smith's laissez-faire doctrines and emergence of new industrial and commercial elites in this period. Yet, recent scholarship has emphasized how contingent and provisional such interplays were and how divergent the interests of elites could be. Even as Smith wrote, the intellectual and social landscape was trembling. Challenging the previous era's doubts about competition, his book sought to refute the policy of royal subsidies, monopolies, navigation laws, and protective trade legislation known as mercantilism. Yet even before Smith, such policies were under revision by monarchists themselves, notably in the deregulation of grain prices under French King Louis XVI in 1763–64 and the colonial trade reforms of 1765 and 1778 promulgated by Spanish King Carlos III. Advocacy or opposition to free trade doctrines by English manufacturing interests was equally circumstantial, changing its specific legislative emphasis as international competitors (particularly in the Netherlands, America, and India) proved more or less able to seize comparative advantage. Likewise, tariff advocates in the antebellum United States distinguished between fair and unfair trade, adopting the familial metaphor of “infant industries” to rationalize regulatory protection policies. Nor can these trade debates be compartmentalized from the broader political context. In both England and the United States, legislative debate over trade policy and the merits of competition became tied to discussion of patents, copyrights, territorial and colonial expansion, voting rights, legislative apportionment, the state of national finances, the status of international alliances, and to more unquantifiable but equally potent nationalist, religious, racial and gender concerns. While recent scholarship has supported the broad claim that adoption of Smith's economic theories was energized by class interests, it is clear that this process was never linear, continuous, nor formulaic (Berg, 2002; Doyle, 1980; Gomes, 2003; Heilbroner, 1986; Holt 1999; Horwitz, 1977; John, 2006; Persson, 1999).

The intensive cross-fertilization between economists and natural scientists as they reinterpreted the idea of the “struggle for existence” made debates over

competition in the 19th century unique. Perhaps the most famous illustration of this exchange is found in Charles Darwin's (1887/1902) *Autobiography*, where he describes how his reading of Malthus's *On Population* became the catalyst for his core theory of natural selection. Historians have given particular attention to Darwin's journals and social networks, showing his close contact with key political leaders, industrialists, and social theorists. In these discourses, the various scientific, political, and economic theories were so inter-dependent that their individual influences seem inextricable. This was complemented by the peculiar state of the publishing industry in the mid-19th century. Books and periodicals became cheap enough that even a modestly prosperous person could afford to build a substantial library. Yet the volume of publication was still small enough that a disciplined reader could still be professionally expert in a diversity of fields (Appleby, Hunt & Jacob; Beer, 1962; Hawkins, 1997; Porter, 1998; Richards, 1987; Schweber, 1980; Sherwood, 1985; Spengler, 1945).

Equally important to these cross-fertilizations was the increase in suffering and dislocation under 19th century industrialization, urbanization, colonization and staple-crop commercial agriculture. Crying out in their agony from Brazil to Birmingham, the poor and the enslaved of the early 19th century offered the most profound challenge ever presented to laissez faire theories of competition. In the debates over poor relief and debtor laws, family law, bankruptcy, industrial and financial regulation, workplace safety, and free enterprise that followed, elite interests often relied on quasi-scientific arguments about the "laws of nature" to justify profitable legal and policy innovations. Given this era of generally declining conditions for ordinary people, however, arguments defending the benefits of economic competition could no longer profess that Progress was inevitable. The most significant challenge, of course, came from Friedrich Engels and Karl Marx, who appropriated and inverted the arguments of their classical economist predecessors. Suggesting that technological innovation and specialization resulted only in worker dislocation and the "crisis of over-production," Engels and Marx contended that an *iron law* of diminishing profits under pure competition led inevitably to the subversion of competition by the capitalist class itself—through bankruptcy of weaker enterprises and the concentration of production in the hands of industrial and financial monopolies. The inevitable result of competition between classes would be the descent of the proletariat into conditions so abject that only revolution could restore society. And the concentration of control by the bourgeois extended to the world of ideas, as well. From education and publishing to control of business law, the capitalist classes always set the rules of the game. These insights about competition have greatly influenced subsequent historians. As with Smith, their interpretations reflected the miserable social conditions specific to the moment. Marxian theories of history and political economy, too, would be subject to revisionism as worker conditions ameliorated (Engels, 1845/1969; Heilbroner; Hobsbawm, 1962, 1975, 1987; Marx and Engels, 1848/1998; Sherwood).

Historians in recent decades have brilliantly illuminated the spread of these competition paradigms in the late 19th and early 20th centuries. Glick's (1972) study of *The Comparative Reception of Darwinism* was a landmark contribution, highlighting the impact of timing and culture in shaping adoption and diffusion. It



showed, for example, how a Lamarkian consensus among French scientists prevented acceptance, while the new biological research programs in German-speaking countries made those scientific communities more receptive. Darwinian ideas were reinforced or undermined by the spread of Herbert Spencer's Social Darwinism. Historians have long recognized the connections between the spread of Social Darwinism and the emergence of new racial theories, justifications for imperialism, and rationalizations for enduring poverty in industrial society, though never without qualifications (Hofstadter, 1955; Lefeber, 1963, pp. 97–100). In recent years, however, they have increasingly emphasized Social Darwinism's diverse, paradoxical, and often limited expressions. Quite often such adoptions were pragmatic and selective, merely appropriating the concept's symbolic power or creatively misinterpreting its core elements (Ball, 1979; Bannister, 1979; Crook, 1994; Hawkins, 1997; Richards, 1987). As Clark (1984) bluntly puts it for France, "many authors simply raided Darwinism to bolster preconceived opinions" (p. 176). One of the sharpest arguments was the question of whether the struggle for existence among species in nature was being replicated in human society, or whether humans rose above these animalistic struggles through their superior cooperative intelligence and mastery over the natural environment. Policy makers could draw opposing conclusions from this about government regulation, poverty amelioration strategies, and international affairs. An interesting side note to this scholarship has been the effort of a few scholars to use modern competition models as a framework for explaining the diffusion of such paradigms in the 19th century (Herbert, 2005; Kingsland, 1988; Richards, Appendix 1).

Historians in the late 19th century found such models highly seductive. As the discipline became professionalized in the latter half of the century, practitioners such as Herbert Baxter Adams, Woodrow Wilson, and Theodore Roosevelt in the United States, and Leo Heinrich von Treitschke in Germany, wrote nationalist histories in which they sought not only to document the causes of national greatness but contribute to its further development. Wilson's writings and policies, in particular, reveal the paradox of trying to "let the facts speak for themselves" while justifying imperialism and racial supremacy on grounds that were anything but objective. Even those scholars who dissented from this "survival of the fittest" orthodoxy (most notably Socialists, Marxists and Social Gospelers) conceded the centrality of competition in modern society, choosing instead to challenge its ubiquity, its justice, and its "naturalness," and denying its historical inevitability in human societies (Berry, 1999; Billias, Couvares, Grob, & Saxton, 2000; Hofstadter, 1955; Novick, 1988).

The horrors of economic collapse, world war, and genocide in the first half of the 20th century made historians increasingly wary of competition models. At best, such approaches became associated with pre-war idealism and naivety; at worst they carried overtones of the pseudo-science, hyper-nationalism and bigotry that inspired the era's worst atrocities. Decolonization, Civil Rights and other liberation movements in the 1960s, with their emphasis on cooperation and participatory democracy, only increased the reluctance of historians to incorporate formal competition models into their research. A series of influential studies by scholars such as Hofstadter (1966), Williams (1962), and Kolko (1963), among others,

documented how selectively and self-servingly laissez-faire and Darwinian concepts of competition had been employed in the past—even by their most ardent advocates. These critiques questioned the competition paradigm as a model for future research.

*Competition Paradigms in Contemporary Historical Research*

History is widely used as a competitive weapon—deployed in defense of one’s positions or used to demolish an opponent’s understanding of public policy, international affairs, or the economy. Contrasts drawn by different interest groups about supposed lessons of the past reveal the larger ideological conflicts dividing rival groups. In the United States, competition to seize the past (and direct the future) by shaping the content of school textbooks has been especially fierce, involving groups as diverse as local PTAs, major (and minor) religious denominations, the National Association of Manufacturers, Chambers of Commerce, unions, non-profits, political parties, and representatives of important ethnic, linguistic, and occupational groups. Claims about free market innovation, upward mobility, the virtues of meritocracy, or the legacies of discrimination and government regulation in the past are central to the rhetoric framing these discussions (Fitzgerald, 1980; Loewen, 1995). A very different but equally widespread use of history comes in the search for identity, belonging, and nostalgia within groups and families. The popularity of heritage tourism and genealogy reflects a profound hunger for meaning and personal historical context. Here, history becomes a way to escape the empty materialism of modern consumer market society. In the search for family history and group tradition we find haven from the heartlessly competitive and invasive impress of modernity. At the popular level, then, history becomes both a vehicle for competition and an antidote to its excesses (Kammen, 1997; Lasch 1997; Rosenzweig & Thelen, 2000).

Influenced by what has come to be known as the *New Cultural* or *Linguistic Turn*, recent historians have been sharply critical of what they have come to label *essentialism*—the notion that biology, environment, social class, occupation, economic utility (or any other categorical trait) has controlling influence on human behavior. Compared across time and space, these scholars contend, there has been neither uniformity of traits nor consistency of adaptive strategies within the membership of any identifiable social group in history. Such assertions raise significant challenges for any scholar using competition paradigms to explain past behavior. In contrast to biological species, the social categories established by human beings seem ever more elusive and plastic. Concepts such as gender, race, age, status, and kinship that people view as stable, uniform, and objective turn out to be shifting, internally contradictory, and arbitrary—they are *socially constructed*. Because these categories often correlate with the allocation of resources and influence, insiders and outsiders have struggled to alter the definitions to their advantage; often by invoking nature, God, or subjective “data” (Appleby, Hunt, & Jacob, 1994; Foucault, 1990; Geertz, 1977; Hoeveler, 1994; Iggers, 1997; Patriarcha, 1996; Suny 2002; Tribe, 1999).

Equally important insights about competition in the modern world have come from a debate among historians over the *rise of the West*, pitting those who stress internal factors of European *exceptionalism* against those who argue for external, *polycentric* or fortuitous/accidental explanations. Among these, Hanson (2002) attributes European hegemony to a superior culture for organizing warfare, while Landes (1969) and Jones (1987) emphasize European (and specifically) English advantages in open markets, technological ingenuity and a ethos of inventiveness. In contrast, McNeill (1977), Crosby (1972), and Diamond (1998) stress the largely unintended results of disease and biological exchange, while Frank, Marks, and Pomerantz point to Europe's leveraging of global trade through accidents of timing and contingency. Important supporting work by Cronon (1991) probes the linkages between environmental landscapes (what he calls *first nature*) and consciously rationalized market structures (what he calls *second nature*) in the 19th century Midwest. Wrestling power from rural farmers, Chicago capitalists centralized, rationalized, and regulated control of economic decisions through cooperative efforts such as boards of trade, mercantile exchange rules, standardized commodity grading methods, and urban-centered transportation systems. Their domination of rural subordinates recast the very ecology and species diversity of North America. Others working in the genre of *commodity history* have investigated the confluence of nature, state power, and private competition in provoking economic change. Dunn's (1972) pioneering book *Sugar and Slaves* and Peter Wood's (1974) landmark study *Black Majority* revealed the mutual dependence of unfree labor systems and nominally free market capitalist market structures across the Atlantic basin. Subsequent work in commodity exchange networks for products such as salt, cod, cotton and (notoriously) the human trafficking of slaves, has shown the long history and mixed blessings of globalization. (Beckert, 2004; Kurlansky, 1997, 2002).

Work on how such structures evolved in more recent centuries gives an intriguing depiction of the dynamics of cooperation, rationalization, and *laissez faire* market ideals. Notably, Chandler's (1977) pioneering study of American corporate innovation depicted a shift from small proprietor's concern with profit maximization to the managerial-dominated corporation's concern with risk management, profit stabilization, and institutional continuity. Innovations in process control, vertical integration, managerial accounting, and consumer advertising served as much to isolate enterprises from the pain and whims of competition as to give them bare-knuckled advantage over their rivals. His recent (2001) comparative work on the rise and fall of the global consumer electronics industry shows a synthesis of cooperative and competitive strategies, each understood with a time dimension. Healthy companies required sales forces with aggressive short term competitive instincts. Yet these firms buffered their research and development teams from such pressures, deferring competitive judgments in favor of collaboration and creativity. Intellectual property is another key form of deferred competition among technology enterprises, and Chandler details how patents, licenses, and copyrights operated to smother innovation in some cases while invigorating it others. Collaborative synergies were just as important in the industry's ongoing sequence of mergers and acquisitions. Companies whose divisions could internally

harmonize their knowledge bases proved to be the most sustainable over the long term, even when short term integration costs were high. Industry-wide agreement on technical standards also enhanced competition, allowing components from any manufacturer to be used interchangeably with equipment from another. As the familiar contest between VHS and Betamax illustrates, however, the standards were subject to intense contestation. Throughout the era, firms viewed regulation pragmatically, seeking strong government regulation and protection of markets in some cases, private trade association standards in others, and at times resisting it entirely. By showing how rational market motivators like profit and market share were linked to more intangible practices of corporate style and institutional memory, his work has broad implications for those interested in competition paradigms.

### LOOKING BACKWARD AND FORWARD

Chandler's observations about organizational culture lead us back to the question posed in Zola's novel. The Lantier character's framing of Darwinian struggle had two outcomes, *beauty* and *continuity*. The first, *beauty*, is surprisingly literary and aesthetic for a nominally scientific paradigm. As our brief history of competition paradigms indicates, however, the reception and diffusion of ideas about competition often involved subjective judgments expressed in culturally-laden terms. These were adapted to particular moments and communities. Empirical methods carried the mark of these historical moments, even as they sought to claim the status of universality. The second element, *continuity*, reminds us that understandings of competition are freighted with value judgments about how history happens. Terms like *equilibrium*, *evolution*, *revolution*, *progress*, *innovation*, and *success* are defined by their arcs of change over time. In giving us consciousness of the role of time, scholars of Euro-Atlantic intellectual and cultural history have alerted us to one of competition's most important dimensions.

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## **PART I: COMPETITION FROM A SCIENTIFIC PERSPECTIVE**

The two chapters that follow provide a complementary introduction to the mechanics and effects of competition, from individual to planetary scales. This pairing may seem odd because the scales are so extreme; what could competition between laboratory cultures of *Paramecium* have in common with competition between nations? The connection lies in this obvious but often forgotten truth: humans are biological organisms that require food, water, and space to survive. Through agricultural revolutions and water distribution systems, early cultures were able to satisfy the demands of isolated populations with local resources most of the time, with the occasional catastrophe of drought and famine. Through trade and industrialization, populations became connected and shortfalls in one community could be offset (ideally) with surpluses in others. Now, the extraordinary productivity of our agricultural areas and the efficient (though imperfect) distribution of resources across the planet permit permanent, high density settlements in environments that could not otherwise support them. Humanity is becoming one huge population again, over-exploiting local resources. But now, the local environment is the entire planet. Many of us access food (at the grocer) and water (from the tap) with an ease that obscures how precious these resources are to our survival, and how precarious our supplies are becoming. In this light, the dynamics between micro-organisms in a flask and human organisms overpopulating the planet may be shockingly similar, as these two chapters demonstrate.

In the first chapter, Wade Worthen describes the enduring and pervasive importance of Darwin's theory of natural selection to the primacy of competition in the discipline of ecology. Darwin's metaphor of nature as an entangled bank replaced the dominant worldview of a harmonious nature with an image of vegetation physically entwined in mortal combat for light, water, and nutrients. Darwin also emphasized the importance of competition by representing a community of species as a log filled with wedges. A new species (wedge) can only gain a place in nature by driving itself between other species and dislodging them. Darwin's hypotheses have been confirmed in many laboratory and field experiments; competition often affects certain organisms, populations, and communities in important ways. Nevertheless, like a Darwinian wedge, the competition paradigm dislodged other interpretations and research programs from serious consideration. Worthen provides examples of the effects of competition on individuals, populations, and communities, setting a foundation for comparisons and contrasts in the chapters that follow. In addition, he describes how the competition paradigm came to dominate ecology, facilitated by the cultural context of the industrial revolution, Victorian-age Europe, and the rise of capitalism. Worthen also describes how the assumed importance of competition clouded scientists' interpretations and stunted the development of other paradigms.



In the second chapter, Brannon Andersen and Weston Dripps outline the current status and future demand for the key natural resources of fresh water, arable land, and fossil fuels. They begin by pointing out the twin 800-pound gorillas in the room: we are extracting resources from the Earth at a rate that exceeds their regeneration, and our population continues to grow. So, we are depleting resources while our demand increases. There are more disturbing elements to this predicament. First, water and land are *non-substitutable*, which means we cannot shift to a different resource to avoid competitive constraints. In addition, fresh water and arable land are habitats for other organisms that we need. By drawing too much water from freshwater systems, communities risk the collapse of local fisheries that provide food and support local economies. By converting rainforest to cropland, a carbon *sink* becomes a carbon *source* and exacerbates global warming. We are starting to see the reality of finite planetary resources, and natural ecosystems are losing to the competitive pressure of the expanding and industrializing human population.

Andersen and Dripps also examine the prospects for these resources in detail. Limitations on fresh water may be solved through desalinization if we are willing and able to use the high amounts of energy required for this process. Reductions in fossil fuels might be alleviated by developing renewable energy sources and prioritizing the use of fossil fuels for transportation until the infrastructure to distribute another transportable fuel (perhaps hydrogen) is developed. The limits of arable land seem more immediate and unavoidable, particularly because of the negative impacts (fertilizer toxicity and soil erosion) of using existing land more intensively, and because of the ecosystem collapse that might occur if we convert more natural areas to agriculture. Competing for these diminishing resources may lead to international conflicts, including war.

The authors of both chapters suggest that there are alternatives to competition. The most obvious and compelling one is cooperation—or, in biology, mutualism. Long overshadowed by the competition paradigm, the importance of mutualisms as a primary source of biological diversity and innovation has gained favor only in the last three decades. It now seems likely, however, that the two most dramatic innovations in the history of life—the evolution of complex, compartmentalized eukaryotic cells and the evolution of multicellular organisms—resulted from mutualistic relationships. Likewise, while talk of competitive markets dominates modern commerce, the marketplace was originally constructed for bartering—mutualistic exchange of goods to satisfy complementary needs. To an impartial observer, the historical importance and modern ubiquity of mutualisms testify to their utility. Yet, cooperative relationships have been undervalued, understudied, deemphasized, and derided since the competition paradigm came to dominance in the Western world. Ironically, because cooperative relationships increase efficiency, they may become very important solutions to impending problems of global resource scarcity.

WADE B. WORTHEN

## 1. DARWIN'S ENTANGLED BANK: THE COMPETITION PARADIGM IN ECOLOGY

### THE BIRTH OF MODERN BIOLOGY AND THE ROLE OF COMPETITION

The central role of competition in ecology was canonized with publication of *The Origin of Species* (Darwin, 1859). Contrary to the prevailing view of a harmonious natural world, Darwin built his theory of evolution by natural selection on the Malthusian foundation of a “struggle for existence” among organisms. Darwin (1859) wrote:

A struggle for existence inevitably follows from the high rate at which all organic beings tend to increase. Every being, which during its natural lifetime produces several eggs or seeds, must suffer destruction during some period of its life, and during some season or occasional year, otherwise, on the principle of geometrical increase, its numbers would quickly become so inordinately great that no country could support the product. Hence, as more individuals are produced than can possibly survive, there must in every case be a struggle for existence, either one individual with another of the same species, or with the individuals of distinct species, or with the physical conditions of life. (p. 63)

Because individuals vary, Darwin argued, the struggle for existence affects individuals differently. Some individuals, as a consequence of their particular characteristics, are more likely to survive, reproduce, and pass on their heritable traits than other individuals. Over generations, beneficial characteristics accumulate in the population by this process of “natural selection.” Populations evolve in response to their unique environments, sometimes diverging enough to become different species.

Darwin appreciated that organisms struggle against several mortality agents, but he believed that the most ubiquitous and important factor was competition. For Darwin (1859), this principle is the central tenet of ecology (“economy of nature”):

Nothing is easier than to admit in words the truth of the universal struggle for life... Yet unless it be thoroughly engrained in the mind, I am convinced that the whole economy of nature, with every fact on distribution, rarity, abundance, extinction, and variation, will be dimly seen or quite misunderstood. We behold the face of nature bright with gladness, we often see superabundance of food; we do not see, or we forget, that the birds which are idly singing round us mostly live on insects or seeds, and are thus constantly destroying life; or we

forget how largely these songsters, or their eggs, or their nestlings, are destroyed by birds and beasts of prey; we do not always bear in mind, that though food may be now superabundant, it is not so at all seasons of each recurring year. (p. 62)

Darwin's lesson was this: all populations have the reproductive potential to increase, but finite resources will favor the survival and reproduction of organisms best equipped to garner these resources. The harmony of nature is a façade. The constancy of population size, and the progress of evolution from simple to complex organisms, is purchased by a continuous struggle for existence within and between species. He concluded *The Origin of Species* (1859):

It is interesting to contemplate an entangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent on each other in so complex a manner, have all been produced by laws acting around us. These laws, taken in the largest sense, being Growth with Reproduction; Inheritance which is almost implied by reproduction; Variability from the indirect and direct action of the external conditions of life, and from use and disuse; a Ratio of Increase so high as to lead to a Struggle for Life, and as a consequence to Natural Selection, entailing Divergence of Character and the Extinction of less-improved forms. Thus, from the war of nature, from famine and death, the most exalted object which we are capable of conceiving, namely, the production of the higher animals, directly follows. There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved. (pp. 489–490)

## THE TYPES AND EFFECTS OF COMPETITION

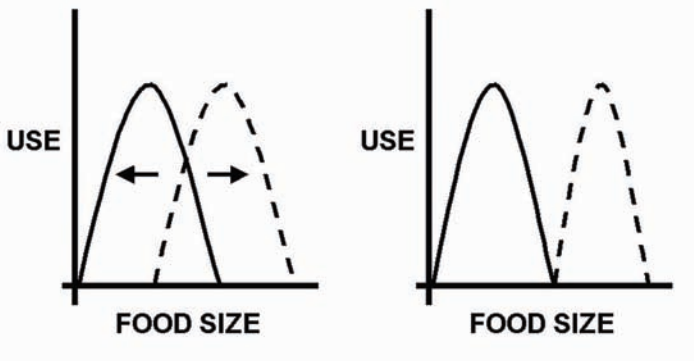
### *Types of Competition*

Competition occurs two ways. *Exploitative* competition occurs when both competitors use a limiting resource. Resources used by each are unavailable to the other, and it is possible that neither receives enough to survive and reproduce. Competition can also occur for access to resources in *interference* competition, often with winner takes all. Two examples are territoriality, where the winner gains all the resources in the area, and polygamy, where individuals of one sex compete for access to the opposite sex. Competition affects both participants negatively, though not necessarily equally. Even the winner incurs costs: the energetic and metabolic costs of display or aggression necessary to acquire territories or mates, or the energetic costs of searching for a diminishing resource.

*Individual Responses to Competition*

Organisms exhibit six adaptive responses that minimize costs of competition relative to resource gain. First, selection may favor increased investment in competitive ability if these costs are offset by garnering more resources later. Many organisms increase competitive ability by investing in early growth—particularly species for whom interference competition favors large size. Because organisms have a finite energy budget, energetic investment in growth reduces investment in immediate reproduction. This strategy is adaptive if it promotes disproportionate reproductive success in the future, or if it is necessary to secure any reproduction, at all. An oak sapling in the forest that invests in reproduction when it is 5-10 years old may produce 20 acorns in each of those five years. It will grow slowly, and may die in the shade of fast growing neighbors. A sapling that delays reproduction and only invests in growth until it is 25 years old may secure a place in the canopy and produce thousands of acorns a year for the next 350 years.

Organisms can reduce competition by shifting to different resources, using them at different times, or moving to another place. Consider two organisms with overlapping patterns of resource use with respect to food size (Figure 1). If food of



*Figure 1. Resource partitioning along a single niche dimension*

intermediate size becomes limiting, they can reduce competition by shifting to food that the other does not use (Figure 1). This shift creates resource partitioning, which becomes more likely as the environment becomes more complex and as the variety of resources increase.

As a consequence of past selection, organisms should select nutrients, habitats, and mates (and at the right time) that provide satisfactory energy and reproductive success. These patterns might be optimal relative to other options. Shifting activity to a new time, habitat, nutrient, or mate probably represents a shift to a suboptimal resource, but this can still be adaptive. The Fretwell-Lucas (1969) model describes this relationship (Figure 2). Consider two resources that differ in quality ( $R_1$ ,  $R_2$ ; Figure 2). At low density with no competition (A, Figure 2), organisms selecting

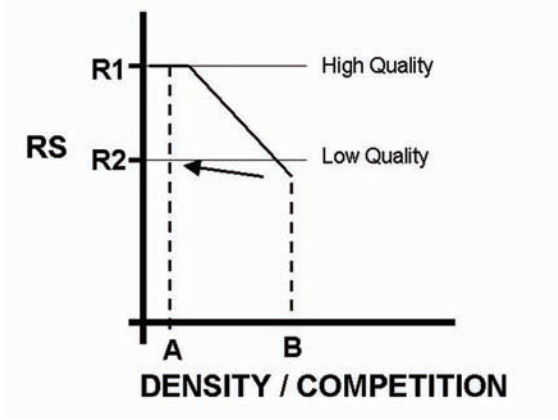


Figure 2. The effect of increasing competition on resource choice (after Fretwell and Lucas, 1969)

the highest quality resource (R1) will maximize their relative reproductive success (RS, Figure 2). As population density and competition increase, reproductive success declines because each organism gets fewer resources and the acquisition cost increases. As competition for resource 1 increases to B, its quality declines below the quality of resource 2 (Figure 2). At this density (or competitive intensity), an organism that shifts to resource 2 will increase its relative reproductive success over those that continue to compete for resource 1. In other words, selection will now favor organisms that shift to an initially suboptimal resource.

The third strategy to reduce competition is to use less. This can reduce growth or reproduction, but optimal growth and reproductive success are possible if resources are used more efficiently. Increased efficiency is adaptive in a competitive environment. As abundant resources diminish, organisms that tolerate resource scarcity have a competitive edge because organisms requiring more will be limited first (Tilman, 1977). In addition, energetic efficiency in one area can compensate for investments in increased competitive ability in another.

A fourth strategy is to co-opt access to the resource, like the examples of territoriality and polygamy described above. This can involve competing harder (strategy one), smarter, or faster. Some bacteria and fungi co-opt a resource by secreting antibiotics that inhibit their competitors. Black walnut and creosote bush release chemicals that retard the growth of other plants and give them exclusive access to immediate resources. Other organisms, like flies colonizing carrion, gain an advantage through a priority effect—consuming resources before competitors arrive (Kneidel, 1983).

Another adaptive strategy is to consume a competitor. Many species (fish, insects, snakes and lizards) consume smaller competitors (Arim & Marquet, 2004). The predators benefit from a meal and reduced competition. Rarely, the prey may persist inside the predator as an internal symbiont. In this way, competitors may

change into mutualists—like ancient archaean cells that engulfed bacteria and, as mutualists, evolved into eukaryotic cells (Sagan, 1967).

Finally, competition can be won through deception or cheating. Like most cephalopods, giant cuttlefish can change their color and surface pattern almost instantaneously. Lone males can change to a female coloration, gain entry to another male's territory in their disguise, and mate with females (Hanlon, Naud, Shaw, & Havenhand, 2005).

### *Populational Responses to Competition*

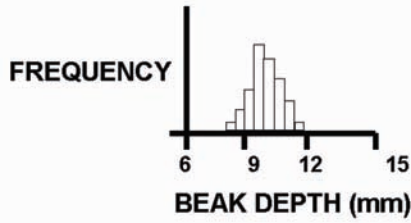
Individual organisms do not evolve; evolution is a change in the type and frequency of genes in a population. As Darwin emphasized, some organisms might reproduce more than others because their characteristics (such as metabolic efficiency, niche shifts, or increasing competitive ability) allow them to acquire resources and produce more offspring than others in the population. Their genes increase in frequency and the population evolves in response to competition.

When a population shifts to a new resource, selection favors individuals that exploit this new resource most effectively. This may result in an evolutionary change in morphology called character displacement. Finches in the Galapagos provide the classic example (Grant, 1986; Lack, 1947). On Daphne Major Island, the medium ground finch (*Geospiza fortis*) occurs alone, uses medium-sized seeds, and has a medium sized beak (Figure 3a). On the islands of Los Hermanos, the small ground finch (*G. fuliginosa*) also uses medium sized seeds and has a medium sized beak (Figure 3c). However, when the two species co-occur on the island of Santa Cruz, the small ground finch has small beaks and use small seeds, and the medium ground finch has larger beaks and use larger seeds (Figure 3b). The presence of an interspecific competitor caused both populations to evolve.

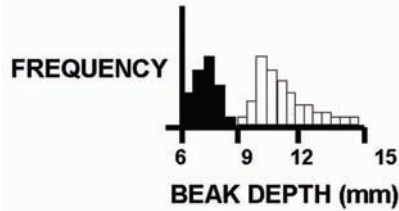
Populations have attributes not expressed by single organisms, such as population size (number of individuals), population density (number of individuals/unit area or volume of habitat), dispersion (changes in density over the species' range), population growth rate, sex ratio, and age, size, and developmental stage distributions. Competition can cause a negative growth rate by increasing mortality and/or by decreasing the birth rate. A consistent negative growth rate will result in extinction. If competition causes dispersal to a new habitat, the population's density and dispersion pattern will change.

Competition can affect the age, size, or stage structure of the population. As Darwin realized, the struggle for existence is most difficult for very young and very old organisms. An example is the self-thinning rule of plant ecology (Westoby, 1984). Consider a large population of tree seedlings growing in an open habitat with little competition. As they grow, competition increases and most die. Mature survivors are large and widely spaced. For light-limited species, the solid canopy of mature trees reduces seedling survival and skews the age class distribution to one dominated by old organisms.

**a) Beak sizes of *G. fortis* on Daphne Major**



**b) Beak sizes of *G. fortis* and *G. fuliginosa* on Santa Cruz**



**c) Beak sizes of *G. fuliginosa* on Los Hermanos**

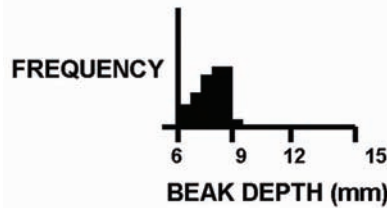


Figure 3. Character displacement for two species of Darwin's Finches (based on data from Grant, 1986)

Some species, like the herb Jack-in-the-pulpit, have nutrient-dependent sex determination. Smaller plants are typically male, and if they grow large they change into females (Bierzychudek, 1982). If competition limits growth, this may skew the sex ratio to a male bias (if all the plants are stunted) or a female bias (if only large individuals survive). So, competition can affect the size, growth rate, age class distribution, and sex ratio of a population. And although competition may select for more efficient, competitive individuals, it may also compromise the population's longevity. A population of competitively successful organisms may become extinct if they are too sparsely distributed, too old, or all of one sex.

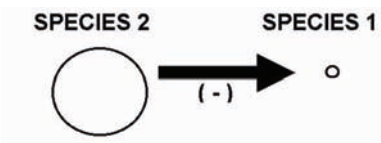
*Community Responses to Competition*

Community characteristics include the number of species in a community (species richness), their identity (membership), the equitability of their relative abundances (evenness), some combination of richness and evenness (diversity), their trophic

relationships (food web structure), and changes in these characteristics through time (succession). Because competition can reduce a species' abundance and cause extinction, it can affect every community descriptor. In communities with multiple competitors, additive effects can quickly eliminate inferior competitors. The effect may be *diffuse*—their cumulative effect may be largely independent of their relative densities. To an herb beneath a forest canopy, it is the total reduction in light that matters—not the relative abundances of oaks, maples, and hickories.

Counter-intuitively, competition can also cause coexistence. For example, suppose species 2 outcompetes species 1 when they are alone (Fig 4a). And suppose species 3 outcompetes species 2 for a different resource. When the three species co-occur, species 3 will reduce the abundance of species 2, reducing the competitive effect of species 2 on species 1. So, although species 3 may have a direct negative effect on species 1, it may have a greater, positive, *indirect* effect on species 1 by releasing it from the competitive pressure of species 2 (Fig. 4b). So, contrary to simplistic expectations, increasing the number of competitors in a system may promote the persistence of competitively subordinate species and maintain species diversity (Morin, Lawler, & Johnson, 1988; Worthen & Moore, 1991). In a complex community with many interacting species, these indirect effects may be very important for maintaining diversity (Levine, 1976).

**a) The direct negative effect of species 2 on species 1**



**b) The indirect positive effect of species 3 on species 1**

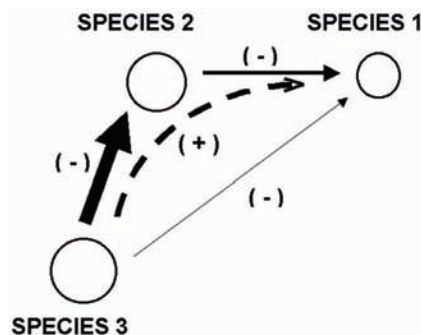


Figure 4. Counter-intuitive outcomes in communities of multiple competitors

At a community level, resource partitioning creates a pattern known as species packing, where species are arrayed in a regular manner along a resource axis.



Correlated morphological differences called community character displacement can evolve, like among five species of weasels that co-occur in Israel (Figure 5, Dayan, Simberloff, Tchernov, & Yom-Tov, 1989). These predators all eat mice and rats, and when they occur in separate sites there is broad overlap in resource use and morphology. However, where they co-occur, they specialize on different sized prey. This specialization is reflected in a non-random, regular pattern in the canine diameter in these species (Figure 5). Resource partitioning increases the breadth and efficiency of resource use in a community (Finke & Snyder, 2008). Communities change over time. As a habitat receives more colonists, competition increases and species that invest in competitive ability dominate. This succession may progress as different resources become limiting sequentially, and different species tolerating each shortfall dominate in turn (Tilman, 1982, 1986).

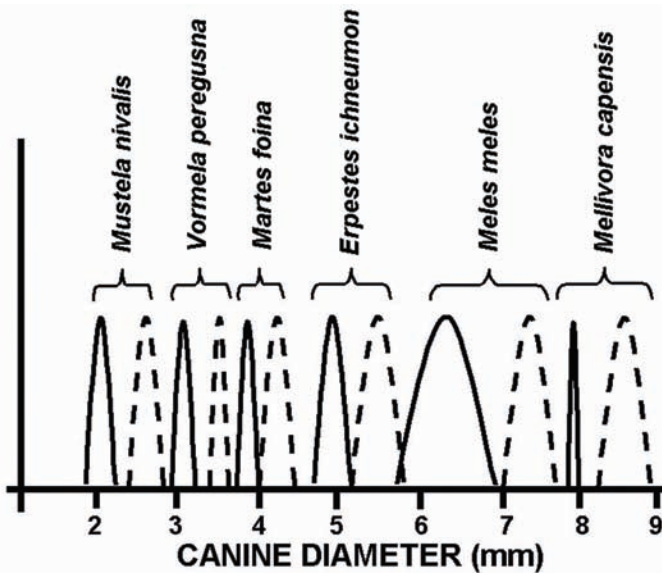


Figure 5. Canine diameters of weasel species in Israel; solid lines = female, dashed lines = male; *M. nivalis* is an extinct species (after Dayan et al. 1989)

Inferior competitors can persist through niche partitioning, indirect effects, and disturbance. Small disturbances create patches of open habitat where resources may not be limiting. Competitively subordinate species can find these patches if they produce lots of small offspring that also have high dispersal capability. Inferior competitors can avoid competitive exclusion by colonizing and exploiting open habitats as they arise by disturbance, before dominant competitors colonize and usurp the resource. In addition, historical contingencies and priority effects can influence the outcome of competitive interactions and community structure. Competition reduces reproductive success; populations go extinct or evolve in response to this selective pressure. Community structure changes as a result.

As Darwin surmised, competition affects individuals, populations, and communities. Other factors, however, are often more important.

#### ALTERNATE PARADIGMS?

##### *Non-equilibrium Theory and Null Models*

Although competition is often assumed to be important, the omnipotence of the competition paradigm has been challenged from several quarters. One significant challenge within ecology was made by Andrewartha and Birch (1954), who suggested that competition was negligible for many populations that are kept below competitive densities by disturbances such as predators, disease, fire, or storms. They suggested that the assumed importance of competition might be because many influential ecologists study large mammals and birds that are more likely to compete. This challenge was reinforced by the “null-model” (Strong, Simberloff, Abele, & Thistle, 1984) and “neutral model” (Hubbell, 2001) schools of empirical ecologists who correctly required that a proposed determinant of community structure (such as competition) be tested before it is claimed to be a major contributor. Indeed, many experiments demonstrate that competition is not the principal organizing force in some communities (Strong et al.). So, the rise of density independent, non-equilibrium theory was an important challenge to the ubiquity and primacy of competition. To paraphrase the ecologist Joseph Connell (1980), the discipline had too long assumed the “ghost of competition past” to explain existing patterns.

##### *The Mutualism Paradigm*

A broader challenge is the mutualism paradigm. In mutualisms, reproductive success of both participants increases. Many mutualisms are the iconic images of nature, like “the birds and the bees.” Birds eat fruit and benefit plants by dispersing seeds, or bees eat nectar and benefit plants by pollinating flowers. Many plants also produce nectar from glands on twigs or leaves to attract aggressive ants that protect the plant from herbivores. Animal pollination, seed dispersal, and defense are very common mutualisms, but others are more pervasive. Almost all animals harbor a diverse assemblage of bacteria and protozoans in their gut; the microbes depend on the animal for food and shelter, and they improve the animal’s digestion and nutrient absorption. Most plants have mutualistic interactions with mycorrhizal fungi that exchange water and mineral nutrients they absorb from the soil for sugars produced by the plant.

Mutualisms are more frequent and potentially far more important to the survival and reproduction of organisms than competition. They are also responsible for some of the major innovations in the history of life—such as the evolution of eukaryotes and multicellularity (Margulis & Fester, 1991). Mutualisms have not gone unstudied; mathematical models of mutualisms (Gause & Witt, 1935) are nearly as old as the iconic models of competition (Lotka, 1932; Volterra, 1926). But, although new reviews emphasizing the importance of mutualisms appear

every decade (Boucher et al., 1982; Boucher 1985a; Bronstein, 1994; Connor, 1995; Gilbert & Raven, 1975; Kawanabe, Cohen, & Iwasaki, 1993; Margulis & Fester; Sachs, Mueller, Wilcox, & Bull, 2004; Stanton, 2003), the mutualism paradigm has only recently gained traction.

Why did the competition paradigm dominate for so long? Curiously, many pre-Darwinian, western worldviews emphasized cooperation as the state of nature (Boucher, 1985b; Worster, 1997). The purpose of plants was to provide food for animals, and animals returned the favor when they died by fertilizing the plants. The purpose of herbivores was to provide predators with food, and the purpose of predators was to cull herbivore populations for their own benefit—so they would not overtax their food supplies. Theistic societies usually attributed this holistic balance to a purposeful, benevolent deity. Eventually, every aspect of each species was assumed to be perfectly and purposefully created by a compassionate God, fitting organisms to their specific role in the whole of cooperative nature. This perspective reached its zenith in the natural theology of 18<sup>th</sup> and 19<sup>th</sup> century Europe, most famously expressed by naturalist John Ray in *The Wisdom of God manifested in the Works of the Creation* (1691), and William Paley in *Natural Theology; or, Evidences of the Existence and Attributes of the Deity* (1802).

In biology, the eclipse of mutualism by competition was in part due to Darwin's powerful descriptions of vestigial structures and other obvious imperfections of design, and his convincing argument that the apparent balance of nature was purchased with the deaths of superabundant offspring. These points refuted the argument of a wholistic, compassionate, purposeful, harmonious design. The hegemony of competition was reinforced by the social context of the Industrial Revolution. Darwin might never have thought of natural selection if not for predecessors like Malthus and Adam Smith, and contemporaries like Herbert Spencer who emphasized that competitive struggle led to social progress. As such, the eclipse of mutualism by the competition paradigm was reinforced across science, society, and politics.

Feminist critiques of the competition paradigm also focus on Victorian society, where patriarchal ideas of competition and hierarchy were codified as political and scientific truths. These criticisms echo feminist criticisms of capitalism: the themes of scarcity and progress through competition are myopic, masculine views of reality emphasizing dominance, individualism, and hierarchy to the exclusion of feminine worldviews of tolerance, community, and cooperation (Gross & Averill, 1983).

Lawton, Garstka, & Hanks (1997) present several convincing cases where such preconceptions stunted ecological research programs and biased conclusions, and their arguments will be considered in detail. For example, they suggest that although cooperative breeding in birds (where offspring remain on the parent's territory and help their parents raise siblings rather than acquire territories and mates of their own) was first described by Alexander Skutch in 1935, it was considered to be a rare and ecologically unimportant interaction because it could not be explained by the competition paradigm. After kin selection was described (Hamilton, 1964), cooperative breeding was interpreted as an adaptive response for young birds to increase reproductive success (of the genes they share with their

siblings) in a competitive environment where available territories are scarce. But interpretational problems continued when these behaviors were performed in environments where high quality territories were plentiful and competition was weak or non-existent. After 50 years, behavioral ecologists finally concluded that sociality might have adaptive value independent of competition and scarcity (Lawton et al.).

Lawton et al. (1997) also present recent examples where expectations of competition, hierarchy, and male dominance completely undermine the interpretations of eminent ecologists. In their encyclopaedic treatise, *The Pinyon Jay* (1992), Marzluff and Balda provide an extraordinarily complete description of the natural history of this social species (Lawton, 1993). Unfortunately, steeped in the competition paradigm, they assumed colonies were structured by competitive male hierarchies and tried to fit their data to this model. The data were: 1) there were no fights between males in 20 years of observations; 2) there were violently aggressive battles between females before each breeding season; and 3) 'unranked' males rose to dominance when they pair-bonded with certain females (in fact, the females that were mates of previously 'dominant' males). Lawton et al. suggest that:

... even after watching [male] pinyon jays *not fight* for twenty years, the authors were constrained by theoretical expectations to find "what everyone knows" is the case; that is, social organizations are built around male dominance hierarchies. (emphasis in original, p. 69)

Finally, Lawton et al. (1997) continue with a critique of two studies on sperm storage in birds. Magpies are highly social relatives of crows. Mates pair-bond, but there are also "extra-pair copulations" (ETCs) where a pair-bonded bird mates with a neighbor. Spotted sandpipers have a polyandrous mating system where single females mate with multiple males; each male incubates the eggs laid in its nest. Females in both species have specialized organs that store sperm, potentially allowing females to choose which sperm they use to fertilize their eggs. Lawton et al. document that, in *The Magpies* (Birkhead, 1991), and in the article *Cuckoldry through stored sperm in the sequentially polyandrous spotted sandpiper* (Oring et al., 1992), the authors only concern themselves with the effects of these mating strategies on males. Males are active players and females are passive repositories for battling sperm. Although Birkhead suggests that males seek ETCs from passive females to increase the number of their offspring, Lawton et al. review Birkhead's data and find that females were the initiators of most ETCs. Lawton et al. hypothesize that ETCs could be adaptive to females by increasing the genetic variation among their offspring, and they suggest that Birkhead was blind to this possibility because he only focused on male reproductive success. With respect to spotted sandpipers, Lawton et al. state:

Clearly, there is more going on here than simple sperm precedence or competition. How do females store sperm for later use? How is the sequence of sperm use determined? Can females distinguish between halotypes [genetically different sperm], as is known to be common in plants? What are

the possible selective advantages to females of storing sperm and using the sperm of previous mating in later clutches?

Oring et al. (1992) never ask these questions. Despite the fact that their report in *Nature* is the first to document the phenomenon of sperm storage in female spotted sandpipers, females are not the focus of the report. Instead, as was the case in Birkhead's account of sperm storage in magpies, the animal that invests calories in storing sperm, the animal that uses stored sperm to fertilize her eggs, the animal that walks up to the nest and lays eggs, is not the animal of interest here. (p. 76)

The analyses of Boucher (1985b) and Lawton et al. (1997) leave little doubt that the acceptance of the competition paradigm was influenced by cultural forces, and its dominance has biased the interpretations of contemporary scientists.

### *Complexity as a Paradigm*

In complex systems like nature and human societies, it is extraordinarily unlikely that a single determinant will adequately describe the state of the system, predict its dynamics, exert only beneficial effects within the system, or be the sole source of innovation. Competition can cause increased energetic efficiency at the organism, population, and community levels, and competition is correctly applauded for spurring innovation. Mutualisms, however, have been even more fruitful at creating novel adaptations and selecting for new traits. Flowers are beautiful examples of innovations stimulated by mutualism. Sociality, itself, is another mutualistic innovation. And mutualisms spur innovation by benefitting both participants; there are no necessary losers that must bear the cost of innovation, like in competition.

Competition imposes a cost to the system—the energy used to search or battle for a limiting resource. A population may adapt and the efficiency of resource harvest may improve over time, but this improvement occurs because others get less than they need. At the community level, although indirect competitive effects among multiple species can maintain diversity and may foster resource partitioning, additive direct effects can result in the extinction of competitively subordinate species and a decline in the diversity, productivity, and stability of the community.

Of course, mutualisms do not necessarily perpetuate harmony and stability. Although engaging in a mutualism increases immediate reproductive success, the evolution of obligate dependencies between mutualists may increase the likelihood of extinction. Obligate mutualists can only persist if their partner survives—and the partner may be a very different kind of organism sensitive to different types of environmental change.

Initially, competition and mutualism seem to be completely independent interactions. Relationships are dynamic, however, and may change from mutualistic to competitive depending on the environment. Where a plant exists at low density, the flowers may be too inconspicuous for pollinators to notice. If two species co-occur at low densities, the total flower number may be high enough to encourage pollinator visitation. In this case, both plants benefit from the presence of the other

in a diffuse mutualism (Rathcke, 1984). When flowers become so abundant that pollinators cannot visit them all, the plants compete. Bertness and Calloway (1994) suggest that mutualisms will be common when physical stresses are either very low or very high. In benign environments populated by many species, predators and herbivores are common and defensive mutualisms are adaptive; even passive associations with toxic species may confer an advantage. In very harsh environments, partnerships that maximize nutrient absorption (like algal-fungal symbioses in lichens colonizing bare rock) or modulate the harsh climate (like providing shade in desiccating environments) are adaptive. And of course, mutualisms can be an adaptive solution to limiting resources and competition.

In complex systems with many participants connected through a dizzying network of direct and indirect interactions, it may be difficult to even categorize a relationship. For example, as the abundance of two invasive species (multiflora rose and Amur honeysuckle) increases, the successful establishment of native tree seedlings declines (Meiners, 2007). Although this looks like competition, it is not. All three species produce seeds that are consumed by mice. As the abundance of the invasive species increase, mice are drawn to the area and consume seeds of all species, thereby lowering the abundance of tree seedlings (Meiners). This is *apparent* competition, indirectly mediated through a shared predator.

Apparent mutualisms are also possible when two competing species are each consumed by different predator species. An increase in one predator causes a decline in its prey. This decline relaxes competition on the second prey species, and it increases. This provides more food for the second predator, which increase in turn. So, an increase in one predator benefits another, in an “apparent mutualism” mediated through competition between their prey.

Grime et al. (1987) found that the presence of mycorrhizae could increase plant diversity by maintaining competitively subordinate species. In one of the most striking examples of the complexities of nature, the presence of a mycorrhizal network connected different plants through the soil and allowed inferior competitors to persist because sugars were transferred through the mycorrhizae from dominant to subordinate species. Adding mycorrhizae changed a competitive relationship between plants into a parasitic one. Or, the mutualism between the dominant competitor and its mycorrhizae changed to a parasitic relationship in the presence of another (even inferior) plant competitor.

Competition remains a dominant theme in ecology, as it should; there is ample empirical evidence that competition affects organisms, populations, and communities in important ways. Unfortunately, over-reliance on the competition paradigm stifled an appreciation for the frequency, importance, and innovative power of other interactions like predation, parasitism, and mutualism. In complex networks, many interactions have the capacity to spur innovation and increase efficiency, diversity, and productivity.

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## 2. THE GLOBAL COMPETITION FOR PLANETARY RESOURCES

The earth we abuse and the living things we kill will, in the end, take their revenge; for in exploiting their presence we are diminishing our future. –  
Marya Mannes

The concept of the limitless noosphere (Vernadsky, 1945) is in inherent tension with the reality of a limited planet. The noosphere, the technological world as imagined by humans, theoretically could be as large we wish it to be (the infinite growth paradigm). The planet, however, is of finite size with finite resources, and is a closed system. This places the need for resources to grow the noosphere in direct competition with the need for resources to maintain the ecosphere (Mackenzie, 2005).

The size of the human population is growing, requiring increasingly more resources to maintain current standards of living for the wealthy and increase the standards of living for the poor. A number of planetary resources are necessary to make this happen, including water, arable land, and fossil fuels. However, the extraction and use of these resources affects the viability of the functioning ecosphere, which is necessary for human survival. The extent of human impact on the ecosphere can be measured via the ecological footprint (Wackernagel et al., 2002). Increased energy consumption and improved technology in the last 50 years has resulted in ever faster extraction of resources. Humanity is in “ecological overshoot”; maintaining current rates of consumption would require an additional planet Earth (Wackernagel et al.). Our single species directly and indirectly appropriates as much as 30% of the Earth’s terrestrial net primary productivity (Harberl et al., 2007). As population grows and affluence increases, demand for resources puts the viability of the ecosphere at stake. At this time, human beings are the single most dominating geological, chemical, and biological force on the planet, causing rapid, intertwined, and potentially cascading change (Vitousek, Mooney, Lubchenco, & Melillo, 1997).

Competition for limiting resources can lead to conflict, especially where population growth rates are high; competition for and exploitation of limited local resources has led to the collapse of past civilizations (Diamond, 2005). Because the demand for resources is increasing on a planet of finite size, the resource base is by definition limited. In some respect, this is the tragedy of the commons (Hardin, 1968) writ on a global scale.

Bossel (1998) describes this path of global competition as a “business as usual” scenario, whereby global competition for limiting resources, such as oil or water, leads to conflict, perhaps with winner take all. However, Bossel also describes an alternative—where cooperation leads to reduced resource use, reduced population, diminishing pressure on the ecosphere, and a sustainable relationship between humans and the environment. In effect, the cooperative path recognizes that the noosphere is limited by the resources of the ecosphere and that those resources must be shared with all other living species.

In this chapter we will examine three potentially limiting resources on planet Earth—water resources, arable land, and fossil fuels. For each resource we will address: What is the current state and limit of the resource? What is the outlook for the resource? Will competition for the resource lead to conflict? What solutions and/or alternatives exist that might mitigate conflict and/or help meet increased demand?

## WATER

Whiskey is for drinking, and water is for fighting about. – Mark Twain

We are constantly barraged with looming predictions of coming water wars. In fact, many claim that the next major world war will be fought over water, not oil. As we continue on into the 21st century, the increase in world population and its impact on the availability of clean freshwater will certainly be one of the most pressing global issues facing mankind. Water, after all, is the basis of life—the lifeblood of our existence. Our universal dependence and the lack of any known substitutes make water a truly unique resource. Our dependence, however, goes far beyond biological and domestic needs as its use underlies agricultural and industrial processes, as well. Water’s availability affects not only human well-being and survival, but also ecosystem health and functioning, economics, and even politics (Sophocleous, 2004).

The idea that a planet with a surface covered predominantly by water could be facing a water crisis seems surprising, yet despite its seemingly global abundance, only a small fraction of that water is fresh and available for use. Postel, Daily, and Ehrlich (1996) estimated the currently geographically and temporally accessible annual amount of renewable freshwater at 12,500 km<sup>3</sup>/yr, only 0.001% of the estimated global water budget. Still, this surprisingly small percentage is more than adequate to meet global per capita needs. To subsist, it is estimated that a person needs a minimum of 1,000 cubic meters of water per year for drinking, hygiene, and growing food (Rogers, 2008). Given the current world population, the amount of renewable freshwater per capita is an estimated 1,865 cubic meters of water, 86% more than is theoretically needed.

How then can an estimated 1.5 billion people not have access to a minimally adequate supply of clean water? Water problems at the global scale may not exist, as the numbers suggest (Sophocleous, 2004), but like many problems they manifest themselves at smaller scales. Global averages hide considerable spatial and temporal variability in availability, access, and demand at local and regional scales.

For example, the spatial distribution of freshwater and people are mismatched. Two-thirds of the world's population lives in areas receiving only a quarter of the world's annual rainfall (Gleick, 1993). To further exacerbate the problem, many of these people live in densely populated cities where infrastructure, cost, and pollution present an additional set of challenges, particularly for the urban poor. Temporal patterns in precipitation can also cause problems, particularly where there are extreme wet and dry seasons. Our ability to store surplus water from the rainy to dry seasons is typically limited, and much of the accessible surplus runs quickly to the ocean. This temporal variability presents additional challenges for maintaining food production.

Humans currently use 54% of the available 12,500 km<sup>3</sup>/yr of freshwater, either directly in the form of withdrawals for agriculture, cities, or industry, or indirectly in the form of pollution dilution or other instream uses (Postel et al., 1996). Several major rivers (the Colorado, Nile, and Yellow, for example) are so overexploited that they no longer reach the ocean for months at a time. This starves estuaries of freshwater, increases salinity, and destroys the productivity of these important habitats. By 2025 our share will likely surpass 70%, based on population growth alone (Postel et al., 1996), and could reach 90% if we include projected increases in per capita consumption associated with increasing wealth (Sophocleous, 2004). It is extremely unlikely that aquatic habitats will maintain their integrity, productivity, or ecosystem functions under these scenarios. Climate change could magnify these effects. The specific impacts of climate change on water resources are broadly defined at best, but are likely to have some sort of destabilizing effect on the hydrologic cycle (Sophocleous). By some accounts, climate changes will account for about 20% of the global increases in future water scarcity (Sophocleous).

What is the outlook? Since the overall supply of freshwater is finite, as the population grows there will be less water per capita. Already around the world there are now numerous signs that human water use exceeds sustainable levels. Accounts of widespread groundwater depletion, low or nonexistent river flows, and increasing surface water pollution indicate a growing problem (Postel, 2000). Consequently, the overall prognosis is not good; in fact by midcentury as many as three quarters of the world population could face water scarcity (Rogers, 2008), and more than 76 million people are projected to die over the next 20 years because they can't access enough fresh water (Jaffe, 2004). The stresses include a rising population, increased consumption levels with development, expanding agricultural production, and global climate change. Water problems are, however, not just limited to issues of quantity; many rivers and lakes are simply too polluted to drink. Water treatment is possible, but is too costly for many impoverished communities. Continued waste disposal and industrial and agricultural contamination will further diminish water quality. Together, diminishing quality and per capita quantity could lead to regional starvation, disease, political instability, and even armed conflict (Rogers).

Are claims of looming water wars well founded? Water can be a limiting resource: accessibility can be seasonally and temporally variable, it is not very portable on a large scale, and there is no substitute. Historically, however, water issues have encouraged cooperation instead of conflict (Bencala & Dabelko, 2008).

In fact, there have been no modern wars fought over water despite its growing per capita scarcity (Wolf, 2007). Water is simply too important and necessary a resource to fight over. Although there are 261 multinational watershed basins, violent water-related incidents between countries have been rare; interactions over water have been dominated by the perception of shared interests (Bencala & Dabelko, 2008). Whether this pattern will continue remains to be seen, but it does provide hope and suggest that cooperation, at least among countries, may prevail.

Where does the potential for competition and conflict reside? Water fuels all sectors of society (domestic use, industry, agriculture, and environment) and as such the potential for competition among sectors is quite high, particularly at the local scale. Water, unlike many other resources, cannot be managed for a single purpose; multi-objective management is quickly becoming the norm, and competition among users is fierce in some areas of the world (Wolf, 2007). With increasing population and industrialization, rising water demands from all human sectors seems inevitable. The finite nature of the resource means that this is ultimately a zero sum game; new demands have to be met by improving efficiency or taking it from another user (including natural ecosystems). Already cities are beginning to pull water away from agriculture (Postel, 2000). Only recently, with tragedies like the draining and salinization of the Aral Sea, have planners recognized the importance of leaving some water in aquatic ecosystems to maintain their integrity. Increased scarcity could lead to conflict, but could also stimulate cooperation. The chance of conflict seems more likely at local or regional scales where temper can drive immediate reactions, rather than at national or international levels where responses are usually more measured.

What are some of the potential solutions to the challenges that lie ahead that might mitigate conflict and/or help meet increased demand? One solution is desalination of saltwater; this could significantly augment the amount of available freshwater, but currently it is cost prohibitive and requires substantial amounts of energy. Desalination may be able to meet increased domestic demands in coastal regions, but seems unlikely to generate the immense quantities of water needed for industry or agriculture in the near future. Perhaps a more promising solution lies in demand management: techniques for improving water efficiency and optimizing water use. Small improvements in irrigation efficiency, for example, could save sizable amounts of water that could be used to meet other needs. Similarly, the concept of virtual water, whereby water intensive food crops or commodities are imported instead of produced locally, has the promise of producing real water savings in some water scarce regions. Of course this requires that these countries have the financial means and access to purchase these crops and commodities instead of producing them internally.

#### ARABLE LAND

Harmony with land is like harmony with a friend; you cannot cherish his right hand and chop off his left. – Aldo Leopold

Food, like water, is a resource necessary for human survival. The production of food requires the availability of arable land. The Green Revolution that began after World War II significantly increased global food production. However, consumption of crops for food, livestock feed, and now biofuels has been growing at an even faster rate and threatens agricultural sustainability.

What is the current state and limit of arable land? Nearly 40% of the planet's ice-free land surface is now being used for agriculture (Foley et al., 2005). Most of the remaining land is too dry, wet, steep, or cold for crop production. Currently, enough food is produced by global agriculture to feed everyone on the planet to a sufficient healthy level (FAO, 2002). Why are an estimated 854 million people worldwide—roughly 13% of the world's population—undernourished (FAO, 2006)? Like water, arable land is unevenly distributed. Access to the land, markets, or money to grow or purchase food, is limited, particularly for the urban poor. The result is widespread malnutrition, predominantly in developing countries.

What is the outlook for the future? Assuming food could be readily redistributed and available to all, will food production be able to keep up with the world's burgeoning population? By 2030, food demand is expected to increase by 30% as population and standards of living rise (Mann, 2008). Despite our current ability to meet global food demand, food reserves are in decline; global grain reserves are at their lowest level since 1960 according to the U.S. Department of Agriculture. Similarly, most of the world's arable lands are already fully utilized. The remaining unused arable land resides in marginal areas or ecologically sensitive regions like the Amazon where development will be difficult and would have significant negative environmental impacts.

Over the past 50 years, the Green Revolution has successfully increased global food production, extending agriculture into many marginal areas, and dramatically increasing crop yields through a combination of irrigation, genetically modified plants, and the widespread use of fertilizers and pesticides. However, the environmental costs have been significant, and many agricultural systems are now in decline.

Prime farmland is rapidly being lost to urbanization and soil degradation (Pimentel et al., 1995; Ramankutty & Foley, 2002). Rapidly growing urban populations are fragmenting and replacing productive cropland. For every person added to the U.S. population, approximately one acre of land is lost to urbanization and highway construction (Pimentel & Giampietro, 1994). Similarly, intensification of farming and poor management are decimating farmland soils. Roughly 40% of agricultural soils have been significantly degraded due to agricultural mismanagement (Ramankutty & Foley), with more than two million acres of prime cropland being lost annually in the U.S. due to soil erosion, salinization, and waterlogging (Pimentel & Giampietro). These losses and degradation are beginning to place significant limits on the global agricultural yield (Montgomery, 2007).

Less arable land per person implies a greater reliance on continued technological advances in food production—technology that many developing nations cannot afford (Ramankutty & Foley, 2002). Will food insecurity be caused by declining productivity associated with soil erosion and water scarcity, or will lack of new innovations be our undoing (Ruttan, 1999)? The answer probably lies somewhere

in between. Our current, and perhaps future, shortfalls of food will likely be caused more by social/political/economic problems rather than production problems; however, our ability to increase yields may be limited by the loss of arable land and the toxic impact of using more fertilizer and pesticides on existing lands (Tilman et al., 2001). In the future, soil and water will certainly become limiting at some regional and local levels, particularly in poor countries (Alexandros, 1999; Ruttan). As such, a combination of increased investment in agricultural research and development, increased policy reforms, soil protection, and improved water harvesting and usage will be required to meet the expected massive increase in production for cereal (56%) and livestock (96%) that will be needed in the decades to come (e.g., Rosegrant & Cline, 2003).

For many, the real question is not whether we can grow enough food, but if we can do it while preventing widespread negative environmental consequences such as deforestation, water pollution, and soil erosion that have broader implications for global sustainability. Increasing agricultural production could cause several ecological problems, including deforestation to expand croplands, increased fertilizer, pesticide and water usage, increased eutrophication of coastal systems, and increased loss of biodiversity (Tilman, 1996; Tilman et al., 2001). Regardless, many (e.g., Dyson, 1999; Rosegrant & Cline, 2003) remain optimistic that this can be accomplished despite falling worldwide grain yields, increased resistance to pesticides, increasing water scarcity, and growing world population.

Will competition for food lead to conflict? Overall, the global food production system is becoming increasingly vulnerable to regional disruptions because of our increasing reliance on expensive technological options to increase agricultural production or on global food trade (Ramunkutty & Foley, 2002). Recent conflicts in Nigeria and Rwanda show that lack of arable land can be a source of violent conflict in regions with rapidly growing populations. Although commonly portrayed as an ethnic conflict, the genocide in Rwanda was predominantly over inadequate land for growing food (Diamond, 2005). As populations grow in arid, semi-arid, or overpopulated regions that have high rates of poverty and a reliance on subsistence farming, more conflicts of a similar nature seem likely. Furthermore, changes in economic markets caused by the growing affluence of developing nations (e.g., China) and competing uses for food crops (e.g., increase in biofuel production) and land (e.g., urban sprawl) may create conflict as food prices rise.

What solutions and/or alternatives exist that might mitigate conflict and/or help meet increased demand? Those with an optimistic view presume that global agriculture can produce cereal grains and livestock at levels more than twice today's production. As we have mentioned, these increases are unlikely to come by expanding cropland and pastureland into marginal or environmentally sensitive areas. Rather, the solutions likely lie in intensification, policy reform, food imports, and development of a green revolution in Africa (Alexandros, 1999). Besides the socio-political difficulties that will be encountered, all of this assumes no constraints on the single factor that drives the green revolution: fossil fuel consumption.

## FOSSIL FUEL ENERGY

We have done remarkably little to reduce our dependence on a fuel which is a limited resource and for which there is no comprehensive substitute in prospect - Sir Crispin Tickell

We consider fossil fuel energy last, because without fossil fuels, extraction of the previously considered resources at current rates would be impossible. Water extraction from surface and ground water without diesel pumps or the construction of large megadams would be impossible. Industrial agriculture, which drove the green revolution, requires large fossil fuel inputs for fertilizer, pesticides, plowing, harvesting, and transportation of food. In fact, it has been estimated that every calorie of food produced requires 10 calories of energy input (Pimentel & Pimentel, 2008). In order to fuel the growth of the industrial economy, worldwide consumption of fossil fuels increased 22% for petroleum, 27% for coal, and 71% for natural gas between 1980 and 2001 (Chow, Kopp, & Portney, 2003).

Fossil fuel resources (natural gas, coal, and petroleum) have fostered the growth of modern industrial countries, resulting in the transformation of the ecosphere into the noosphere. As with all other earth resources, fossil fuels are not evenly distributed around the world, nor are consumption rates. Currently, residents of the poorest 10% of developing countries consume 60 times less oil than residents of the richest 10% of developed countries (Chow et al., 2003).

Hubbert (1971) predicted peak oil, the time of global peak oil extraction, to occur sometime in the early 2000s, and successfully predicted peaking of oil in the United States in the early 1970s (Hubbert, 1956). Even the most optimistic forecasts indicate peak oil prior to 2025 (Hirsch, Bezdek, & Wendling, 2005). Since oil fuels so much of the global economy, and since at this time there is no ready substitute for oil, particularly for transportation, the impact of peak oil will be severe. Growing industrial economies dependent on ever-increasing oil consumption will have to compete with mature industrial states for declining oil production. In particular, this may have a major impact on food production because growing, harvesting, and irrigating crops require fossil fuels. Even if biofuels produced on the farm can compensate for farm activities, transportation of fertilizer to the farm and transportation of food to distribution networks will be compromised, particularly in countries like the U.S. where food production is centralized away from urban centers. Analysis of world fossil fuel statistics suggests that fossil fuel reserves will last for at least 100 years (Lincoln, 2005), but these analyses do not account for increases in production rates. When applying the time to exhaustion equation of Bartlett (1978), which accounts for annual increases in production rates, all global fossil fuel resources are likely to reach limits within the next 100 years, most likely much sooner. More importantly for oil, peaking in production would mean that demand would greatly outstrip production, causing massive price increases and disruptions to economies (Campbell & Laherrère, 1998; Kerr, 2008). To put this challenge in perspective, to continue producing the current output of 85 million barrels per day for the next 22 years, the world needs new production of 45 million barrels per day to compensate for the current decline



in giant fields (Kerr). This amounts to discovering four additional Saudi Arabias (Kerr). Meeting this demand appears rather difficult considering that the number of oil reserves discovered each year has been declining worldwide for more than a decade (Hirsch et al.), and that production volumes have exceeded volume of new discoveries since the mid-1980s (Campbell & Laherrère).

Who is primarily responsible for the rapidly increasing consumption of fossil fuels? Here in the United States, we like to blame rising industrial nations with large populations such as China and India. However, a recent analysis (Webber, 2007) indicates that between 1996 and 2006, U.S. imports grew by 3.6 million barrels per day (MMBD), whereas Chinese imports grew by 3.1 MMBD. Since 2002, however, China's imports have grown by 2.8 MMBD whereas U.S. imports have grown by 1.4 MMBD. Today, the U.S. imports nearly 70% of its petroleum and more than four times the amount of oil imported by China, and U.S. total consumption is nearly three times that of China (Webber). Considering that oil extraction rates are declining in many parts of the world and that 80% of the oil produced today is extracted from fields discovered before 1973 (Campbell & Laherrère, 1998), who is going to provide the oil for the future growth of economies outside the U.S.? Can the U.S. continue on the path of consuming about 25% of the world's annual oil production with only 4% of the world's population? Can other countries, particularly those in Africa, expect to grow enough food to feed themselves without increased oil consumption? These questions are incredibly important to global security, particularly when we reach peak oil.

What is the outlook and potential for conflict? The data suggest that raising the standard of living in less developed countries by consuming fossil fuels, particularly oil, will be very difficult. As oil production reaches peak and then declines, the competition for remaining resources will likely become intense. Unfortunately, no alternative energy source exists with the energy density of fossil fuels, especially for transportation. Thus, the probability of continued, dramatic economic growth seems low. A switch to natural gas or coal is unsustainable and would only serve to shorten the time to exhaustion to a decade or so for natural gas or 3 to 4 decades for coal. On the other hand, if a switch to more sustainable energy resources comes before the decline of fossil fuel production, economic development (rather than growth) is possible. Already, many developing countries are bypassing the traditional energy infrastructure in favor of smaller, decentralized energy plants (Chow et al., 2003). Although biofuels will likely play a role in the mix of energy options, the percentage will likely never be high. High reliance on biofuels would require a massive increase in agricultural land, so as not to compete with food production. Already, competition for land is causing an increase in deforestation in the Amazon (Morton et al., 2006). Furthermore, biofuels cannot replace petroleum without affecting food supplies. Dedicating all U.S. corn and soybean production to biofuels would only meet 12% of the gasoline demand (Hill, Nelson, Tilman, Polasky, & Tiffany, 2006). Overall, the probability of meeting an ever growing demand for energy seems small, and the potential for conflict seems high.

## IS THERE A WAY OUT?

A major choice facing humanity in the coming century is whether to continue “business as usual” and engage in competition for increasingly scarce resources or to move towards sustainability and a path of cooperation between different sectors of society and different nations. One possibility that might help is the Millennium Assessment of Human Behavior (MAHB, Ehrlich & Kennedy, 2005). The MAHB recognizes that the steps required to address global environmental problems as determined by scientists are often politically and socially untenable by society as a whole. The reason is often that the “crisis” is looming, but still years, if not decades, away. Thus, what humanity faces is not so much a “crisis” as a “predicament.” The MAHB would focus on social science research to address such questions as how economic or gender inequality contributes to environmental deterioration or how access should be granted for scarce, unevenly distributed non-renewable resources.

Still, the results of our review would suggest that the likelihood of a population of eight billion or more all living at the level of affluence of the United States is impossible. Current measures of human impact on the planet, such as the ecological footprint (Haberl, Wackernagel, Krausmann, Erb, & Monfreda, 2004; Wackernagel et al., 2002) or human appropriation of net primary productivity (Haberl et al., 2007) clearly confirm the argument of Vitousek et al. (1997) that the human impact on the planet is already staggering. Attempting to raise the level of affluence further would result in nations competing for dwindling resources, especially for a limiting resource such as oil. Following such a path of competition will only lead to greater misdistribution of resources and potential for conflict, particularly on local and regional scales. In contrast, a path of cooperation, where as a society we begin to question “what is enough?” and seriously consider the global population issue, may lead to a long-term sustainable future. In essence, we have three choices: (1) we could accept the current unequal distribution of resources and hope that it does not lead to conflict; (2) we could redistribute current resources at a sustainable level in an equitable manner, although this would likely be rejected by affluent nations because it would lead to a dramatic decrease in standards of living; or (3) we could actively work to reduce global population and reduce consumption in the richest countries. This last scenario seems our best option as it would lead to a lowering of pressure on global resources and perhaps reduce the potential for violent conflict over what remains.

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