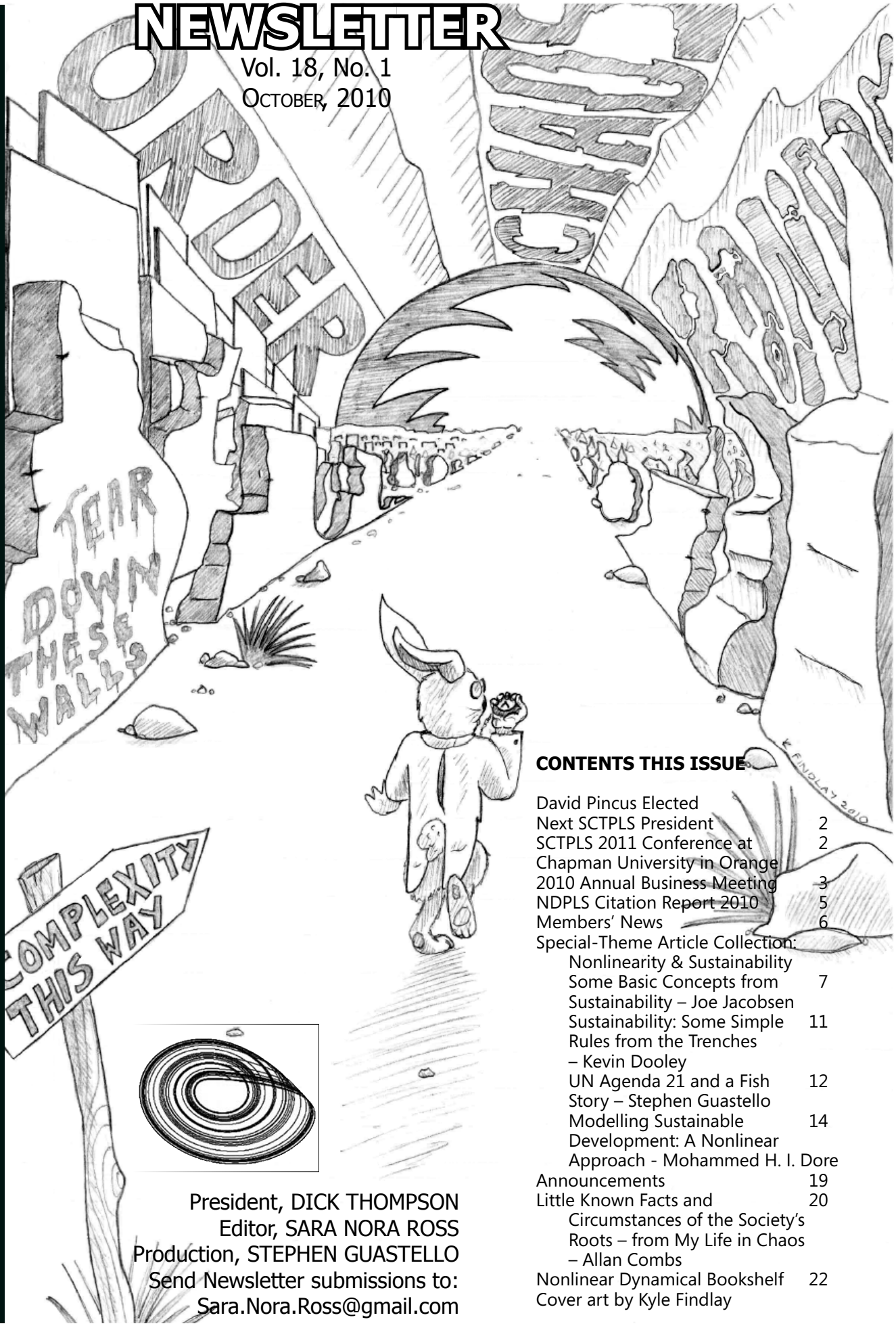
Society for Chaos Theory in Psychology & Life Sciences

NEWSLETTER

Vol. 18, No. 1
October, 2010



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Cover art by Kyle Findlay

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David Pincus Elected Next SCTPLS President

The Society's Nominations Committee reported that In a great voting turnout, Society members cast ballots for next Society President before this Newsletter went to press. On behalf of all members, we thank the two candidates who ran for office, Constance Porter and David Pincus. David was elected. His role will be President-Elect until he takes office as President later in 2011 at the Annual Meeting. His "acceptance speech" follows.

Thanks to all who participated in the fall SCTPLS election process. I am enthusiastic about the opportunities ahead. The role of president of SCTPLS reminds me vaguely of the seasons, as we in the US are moving now into fall. So much of our collective work in complexity and chaos is actually about order, particularly the elegant order that unfolds through nature's ephemeral cycles. As we move quickly toward 2011, now is a good time to appreciate the hard work of our current president, Dick Thompson (along with the rest of the executive committee of course). Our collective events of the past year carry us forward into a new cycle, our collective work is our harvest, our innovations our bounty. Dick's work will continue, as the president's role in SCTPLS moves from president-elect, through the typical two years as president, and on to past-president. So even though it is fall, I feel the excitement of springtime, and anticipation of summer…

Speaking of summer, the 2011 summer conference in my beautiful backyard here in sunny Orange California is looking very bright. Please mark your calendars for August 4 through 6 now, so that next year's cornucopia will be bountiful as well. In the next couple of months, we will be working on the program itself – conference themes such as sustainability, plenary presentations, and practical pre-conference workshops will come together. In my new role, I'll request right now your thoughts and ideas – please let me know: pincus@chapman.edu. As we pass 20 years as an organization, it is a time to celebrate, newer members together with founders. And as we're networking, I am sure there are many nonlinear researchers in the Southern California area who would attend if their "coats were pulled" over the coming winter months. Please reach out to your colleagues, collaborators, or people you'd like to meet in Orange 2011 and let them know what's happening. Or send their information to me and we on the executive committee will reach out as well. Onward and outward, and thanks again,

Sincerely,
David Pincus, SCTPLS President-Elect

SCTPLS 2011 Conference at Chapman University in Orange

Back to Orange, California for our 21st Annual Conference!

August 4-6, 2011 – Save the dates!

The 21st Annual International SCTPLS Conference will be held at Chapman University in Orange, California August 4 to 6, 2010. With just over 5,000 students, Chapman is the largest private university in Orange County. The conference will provide an opportunity to stay abreast of the latest developments in Nonlinear Dynamical Systems science, and showcase the latest accomplishments of our members. If past conferences are indicators, a wide range of areas of application for nonlinear science in psychology and life sciences will be covered, ranging from biopsychology to organizational behavior, with everything in between. The conference also features workshops for all levels of scholarly entry, where our members hone their skills in nonlinear research techniques and practical application for nonlinear ideas, and enjoy keynote presentations by leading scholars in the field. Please watch the Newsletter, the SCTPLS website, and listservers for the call for papers and announcements about our workshops and special guests this year.

At this critical point when the society reaches "adulthood," we hope that founding members will take the opportunity to attend and rekindle the excitement of the early days, that new members will come to present from the various academic and professional institutions around the West Coast and beyond, and that new student members will come to present their work and form mentoring relationships with kindred members.

Chapman University is located in the City of Orange, which is a classic college town, with 1950's style architecture and MANY antique shops (it is the antique capital of southern California). It is a favorite location for the Hollywood film industry. Nearby attractions include Disney Land (approximately 4 miles away); Southern California Beaches and beach communities including: Newport Beach (15 miles), Huntington Beach (18 miles), and Laguna Beach (21 miles); Los Angeles (many more beaches and attractions there obviously - 35 miles). This will be the second time that Chapman has been host to the annual conference; the last time being 2007. With brand-new yet affordable apartment-style residences on campus, excellent classroom and banquet facilities, numerous restaurants and stores within walking distance, the conference experience will be economical, convenient, and comfortable.

2010 Annual Business Meeting Reporting

Minutes of SCTPLS Business Meeting
July 24, 2010

Conference Debriefing

Appreciative comments highlighted the richness of the workshops and members' presentations, the noteworthy value of the three keynote speakers' talks, the overall pace and timing, and the conference size.

Logistically, when a conference location doesn't have meals on or within short walking distance of campus, the suggestion was to plan catered box lunches.

Members offered suggestions for pre-conference materials preparation. We could supply a Speakers' Bios and Glossary List in advance for aid in selecting sessions to attend. The call for submissions could stipulate that abstracts rely more on natural language than jargon so readers and tentative session attendees are more likely to understand relationship between their interests and what is offered. Further, submissions could be categorized and the program could then reflect which presentations are technical, which are metaphorical, which are quantitative and which are qualitative or mixed. The general theme of such suggestions, then, was to adjust our processes so the level of conference-content related communication is increased for everyone's benefit. To convey the nature of presentations more clearly may also attract more folks, particularly graduate students. One such student suggested that putting more emphasis on poster session in call for submissions could help attract students in conjunction with the proposed change to categorize the nature of the papers and presentations.

Treasurer's Report. Steve Guastello reported highlights from the written Treasurer's Report on the April 1 – March 31 fiscal year; report was unanimously accepted. Full report published below.

Nominations for President. Candidates were nominated and seconded, and the ballot of two was unanimously approved. The nominees are David Pincus and Constance Porter.

Committee Reports

Education Committee. No report.
Marketing Committee. Co-chairs Adhil Patel and Kyle Findlay are compiling a report to be submitted later.
Publications Committee. The report was read, unanimously accepted, and is published below.

New Business. For 2011 conference, Dave Pincus will pursue hosting at Chapman University in Orange CA and get dates. For 2012, Sara Ross will work ahead on east coast location.

Adjournment. Motion was made and seconded to adjourn, Unanimously agreed and adjourned.

Submitted by: Sara Nora Ross
SCTPLS Secretary

Treasurer's Report

This report summarizes the financial results for the Society for the fiscal year 2009 ending 31 March, 2010. The final net for this year was $9,539 after applying allocations that were encumbered from the previous year and applying encumbrances for next year. SCTPLS has been running at a modest surplus consistently since June 1994.

The three main areas of financial operation were

the annual conference in Milwaukee, WI (Line A, Table 1), the INSC in Palermo, Sicily (Line C) and the membership-journal activities (Line D). A positive net was recorded for all three areas. The total attendance at the 2009 annual conference in Milwaukee was 55, which was an increase compared to 2008. SCTPLS does not fund travel expenses for the Executive Committee members to the annual conference.

The attendance at the INSC in Palermo was 54. The conference benefitted greatly from sponsorships from the University of Palermo and regional organizations that defrayed some of the costs. The sponsorships were arranged by Gaetano Aiello, the INSC conference chair.

Table 1. Financial results for FY 2009.

Project	Net Income
A. 2009 Conference in Milwaukee	$5540
B. Deposit on 2010 Conference in San Marcos	0
C. INSC conference in Palermo	5458
D. Membership fees, institutional subscriptions, book sales, minus expenses	1332
E. Donations to special funds	435
F. Advertising	(250)
G. Royalties, permissions, special sales	767
H. Interest on accounts	3304
I. General finance and accounting office	(2000)
J. Encumbered amount for advance membership fees brought forward from FY08	4108
Net before encumbrances	$18,694
K. Donations to special funds (same as E)	(435)
L. Membership fees for 2009-10 and later years received before 4-1-10	(3720)
M. 2010 Conf revenue received before 4-1-10	0
N. Encumbrance for advertising and 2011 conference deposits	5000
Final net	**$9,539**

Line D contains receipts from membership fees, institutional subscriptions to *NDPLS*, individual book sales, minus expenses to produce the journal and *Newsletter*, produce the annual art poster, purchase books that are resold at the annual conference, and related membership operations. Our membership currently stands at 240 active members as of July 24, 2010.

Line E: The Society established two special funds in April 2004. The Student Scholarship Fund provides for waivers of conference registration fees for student members who have a technical presentation accepted for the annual conference. The International Hardship Fund provides for reductions in conference registration fees for members who have a technical presentation accepted for the annual conference and who have made a reasonable claim for hardship; travel from a currency-impaired country is the primary example of hardship addressed by the fund program. Other than the qualifications described above, applicants are given awards on a first-come first-served basis to the extent that resources allow. The funds were expended at the end of the 2009 conference, but new donations are been received for the 2010 conference.

SCTPLS has no outstanding debts in the form of bank or other loans, bonds, or accounts payable in excess of 60 days.

Submitted by: Stephen Guastello
Treasurer and CFO for SCTPLS

Publications Committee Report
July, 2010

The members of the committee are Terrill Frantz, David Pincus, Dick Thompson (ex-officio), and Stephen Guastello (Chair). The committee's purview includes the business of Nonlinear Dynamics, Psychology, and Life Sciences (beyond the purview of the editorial board), the SCTPLS Newsletter (beyond the purview of the Executive Committee), the web site, and miscellaneous publication activities.

NDPLS

The featured artist for the 2010 journal covers is Rob Harle from Australia. The cover artwork for 2011 will feature a team of artists who specialize in fractal bubble images.

The journal will publish a special issue on Medical Practice in October 2010. The Editorial Board plans to publish a special issue on Creative Behavior in 2011; the Call for Papers for the latter was released in July.

Institutional subscriptions now stand at 40, same as two years ago. This July the Publications Committee devised and announced a new product, the NDPLS ULTRAPAK which provides online access to back volumes 2004-2009 for a one-time purchase at a reasonable discount price. The ULTRAPAK is designed to encourage new subscribing libraries who would like to have a quick access to a supply of NDPLS content. The volumes in the ULTRAPAK (and price) will be augmented in 2011 and subsequent years. We sold one already.

The Publications Committee has assembled an advertising campaign for direct mail and e-mail media to encourage new institutional subscriptions to NDPLS. Most of the planned mail materials have not been released yet. For members who are contemplating how they might get their library to subscribe to NDPLS, David Pincus offers this testimonial:

As a fan and supporter of the journal, Nonlinear Dynamics, Psychology, and Life Sciences *(NDPLS), I was eager to request that my university science library add an institutional subscription. I inquired year after year, always hearing the same lament from our department chair and senior faculty - alas, the budget process only allowed for faculty requests for books - one time purchases - not for any new periodicals. 'Yes, this*

is really too bad' they conveyed with resignation. Then, while casually discussing the journal with our science librarian a few weeks ago, I mentioned the journal's high impact factor (2.596), its transdisciplinary content, and its international scope. She replied, just as casually, that she would be sure to put it at the top of their list for new acquisitions. I expressed some surprise of course - 'You can do that?' 'Sure. Sounds like a great addition' she replied.'

Morals of the story - 1) Don't believe everything you hear, especially in an academic environment. 2) It pays to ask. 3) The time is right to request the addition of NDPLS to your institution's list of subscriptions.

The 2010 Citation Report for citations accumulated by the journal 2004-2008 is published on the web site and appears below. The Impact Factor is 2.596. The report appears below with additional commentary.
NDPLS was awarded a rating of "6" from the Polish Ministry of Science, which is the highest rating they give to a journal for which ISI does not produce a Journal Citation Report.
Roberto Dieci has joined the NDPLS Editorial Board this year. Roberto is on the Faculty of Mathematics for the Social Sciences – Rimini, University of Bologna, Italy.

NEWSLETTER

The Newsletter is always looking for new feature articles from the members. Sara Ross (the Newsletter editor) is also looking for images made by SCTPLS members that can be used on the covers of the Newsletter.

WEBSITE

New items were added to "Resources" page in the fall, 2009. We are continuing to include new materials. Members are encouraged to browse what is there already and contribute new tutorials, software links and instructions, videos, and other related material.
Abstracts to the 2009 conference and 2010 INSC conference are now available on the web, and they are also abstracted in PsycEXTRA (APA). This process will continue for future conferences.

The new SCTPLS Blog has now been public for the past year on www.sctpls.org/blog .[1] The blog currently offers 25 article posts and over 400 approved comments. It is designed to feature articles written by members. The general web community is invited to post comments. One intention of the project is to develop some synergy between blog discussions and new features for the *Newsletter*. Members who would like to contribute an article should send their material to David Pincus, the Blog Editor (pincus@chapman.edu), who can provide the next instructions. Comments are moderated and filtered to eliminate off-topic material and advertisements. On July 13, 2010 we deleted our 6000th piece of spam[2].

BOOKS

The Society's new book project, *Nonlinear Dynamical Systems Analysis for the Behavioral Sciences Using Real Data* (edited by Stephen J. Guastello & Robert A. M. Gregson) will be published by CRC Press, div. Taylor and Francis before the end of 2010. Some of the chapters will be articles reprinted from NDPLS. SCTPLS will receive one-third of the royalties.

NDPLS Journal Citation Report 2010

Compiled by Stephen Guastello, Henry Boeh, & Mark Lynn, *Marquette University*

Impact and Immediacy factors are now available for *NDPLS* current through December 2009. We compiled Impact and Immediacy Factors based on information available in ISI's *Web of Science*, which encompasses a data base of approximately 4500 scientific journals plus approximately 1400 journals categorized as social sciences.

Impact Factor – We used the traditional computational method, which is the number of citations of *NDPLS* articles that were publishing over a 5-year period divided by the number of articles published during that period. Thus for the 2010 report we counted the citations to *NDPLS* articles that were published in 2004-2008 that were cited in articles that were published in 2004-2009, plus any citations that we found for those articles at the time they were in press and not yet published in *NDPLS*. *NDPLS* published 104 articles during the years 2004-2008. We found 170 citations to those articles in *Web of Science* journals, plus 100 more citations in *NDPLS* 2004-2009. The total of 270 citations divided by 104 articles produces a current impact factor of 2.596.

Compared to last year's report, NDPLS' impact factor is up 39% from last year's value of 1.871. The Impact Factor does not reflect citations to *NDPLS* articles that were originally published before 2004. Many of the earlier articles continue remain influential to works currently appearing in NDPLS and in other journals.

Immediacy Factor - This is the number of citations of *NDPLS* articles within one year of the date of publication of each article. In other words, citations for 2004 articles that would count for this index would have had to be published in 2004 or 2005, and could possibly include citations to an NDPLS article in press insofar as that information could be ascertained

from the data base. For articles published in 2004-08, there were 45 qualifying citations in the *Web of Science* data base. There were 40 additional citations within *NDPLS* for *NDPLS* articles. The total of 85 citations divided by 104 articles renders an immediacy factor of 0.817. Compared to last year's report, NDPLS' immediacy factor is up 38% from last year's value of 0.594.

Commentary – We are aware the ISI's *Journal Citation Reports*, which are produced for some of the journals in the *Web of Science* are now based on an exposure window of two years instead of five years. The earlier thinking was that the five year time period constituted the average "half-life" of an article's influence at the time it was instituted. The two-year system allows for more recent updates regarding a journal's influence with less influence of the past, but in our opinion, permits incomparable levels of fluctuation for relatively small-sized journals compared to large-sized journals. The two-year system also conflates the meaning of the impact factor with the immediacy factor.

The two-year system is accompanied by a new index of the journal's half-life, which purports to individualize the computation of the half-life. The half-life index often produces the default value of 10 years for journals that are relatively new, often less than 10 years old. We do not make a comparable computation for *NDPLS*.

Note 1: The blog address will be changing soon. Watch for announcements.
Note 2: In September, 2010, we deleted our 10,000th piece of spam. The spam filter is working like a charm.

In Memoriam ~ Benoît Mandelbrot, 1924-2010

I write from New York City where I'm attending the Cracked Orlando: drama per musica e fractals. The composer, Jonathan Dawe, was friends with Mandelbrot, who had been invited to attend and was enthusiastic. Jonathan knew something was up when Mandelbrot didn't respond to recent correspondences. He died on the eve before the premiere, and last night's performance was dedicated to him. Very sad and ironic indeed!

Terry Marks-Tarlow (CHAOPSYC list post)

Members' News

Steve Albert Dietz reports from his military stint in Afghanistan. Having a wonderful time here in Afghanistan. Well, maybe not wonderful, but I have lost close to 25 lbs. I've been applying complexity theories to almost every project I'm involved with. My days are 12-17 hours broken up with meals, working out, a few minutes each day to send some e-mails, and the occasional power nap. There are a lot of PoliSci guys here and a few History and Anthropology PhDs. Also, some Psychology guys. I was in the news as well with an AP article, which I think you will find amusing. Here's the link:
http://news.yahoo.com/s/ap/20100925/ap_on_re_as/as_afghanistan_red_team

Kevin Dooley. Arizona State University News Release Aug. 10, 2010. Professor Kevin Dooley has been appointed Interim Co-Director of The Sustainability Consortium for Arizona State University (ASU). Dooley, a Distinguished Professor of Supply Chain Management in the W. P. Carey School of Business and Affiliate Professor in the School of Sustainability, has deep knowledge and experience with the Consortium and its activities. The Sustainability Consortium develops transparent methodologies, tools and strategies to drive a new generation of products and supply networks that address environmental, social and economic imperatives. "Dr. Dooley has been an integral part of the strategy and development for The Sustainability Consortium. His renowned expertise in complex systems, business science, and entrepreneurship make him an excellent choice to co-direct the Consortium and build on its success," said Rick Shangraw, director of ASU's Global Institute of Sustainability.

Themed Article Collection: Nonlinearity & Sustainability

Some Basic Concepts from Sustainability

Joseph Jacobsen, *Milwaukee Area Technical College*

This work examines basic sustainability with respect to four dynamic areas: depletion, pollution, population and migration. The basic premise is that there exists a critical threshold for each of these four fundamentals that we need to avoid. While one of these variables can disturb economic and other social systems, combining perturbations would be devastating. Feedbacks and interactions follow where the system spirals out of control resulting in long term extraordinary effects.

Introduction

Ecological depletion and pollution combined with population growth and increasing urbanization pose an historic disruption to human species. These synchronized perils demand an emerging interdisciplinary field of study that has as much practicality as theory and calls for a new set of standards in education and information. Unfortunately, sustainability is associated with a chaotic concept plagued by multi-definitions, many of which are associated with political intent rather than scientific finding. Yet, even the research community tends to compartmentalize research, programs and personnel into distinct academic divisions that restrain originality, integration and solution. As a result, academic specializations of study rarely encounter one another and even less frequently find opportunities for synthesis or interdisciplinary programs and research.

Sustainability is a process and therefore it is not a fixed or predetermined outcome. Our concept of sustainability is consistent with the robustness and flexibility of complex adaptive systems as applied to problem solving within localities, rather than management toward certain specific goals that are preconceived outcomes. Even though there are limits to being unsustainable with respect to ecological systems, the answer to the problem of sustainability is not technology but, diffusion.

Urban sustainability is an integral part of, and not distinct from, sustainability in general. This statement requires an examination the elements of urbanization within the context of dynamic and complex social, economic, political, and ecological processes producing sustainable or unsustainable urban landscapes that depend upon a vast array of interconnected ecological systems.

Urban spaces are not containers of sustainable or unsustainable processes but rather are produced through processes that may or may not be sustainable. The supply networks of all products throughout the world are examples of sets and sub-sets of dependant sustainable and unsustainable processes. Urban sustainability does not suggest urban self-containment, isolation, or insulation from such global processes but rather the development of local–global relationships some of which are sustainable while others are not.

The local context

Sustainability is fundamentally a political rather than a technological or design problem, in the sense that the greatest barrier to sustainability lies in the absence of commercially feasible cohesive instructions for defining and implementing existing sustainable technologies and practices in local contexts. Locally, information about the existence of sustainable technologies and practices as well as their characteristics and features, flow through a system within which individuals and organizations are situated. Organizations and individuals engage in information seeking behaviors, investigating the expected consequences of adopting the technology or practice. An assessment and evaluation of this information manifests itself in the form of beliefs about it, and is therefore a proximal antecedent of behavior. It is this very concept, which helped form the backbone of the "consumer society" that has evolved and characterized much of the 20th century as we knew it. And as we situate ourselves and others, poised to investigate sustainable technologies and practices in an effort to reduce uncertainty, we will form beliefs as the evaluations of practices, technologies and outcomes develop and thereby form personal attitudes that produce behaviors that help the organization to comfortably create the sustainability plan.

The global context

For the first time in the history of the industrialized world, the US is no longer the primary mediator of the supply and demand curves of the most important resources such as steel, aluminum, energy and concrete. This shift is due in part, to developing

countries' increase in resource demand which in part, is due to people wanting to lift themselves out of poverty. The trend will weaken ecosystems resilience to a critical threshold and drop to an alternate steady state when critical levels of non-sustainable resource 1) depletion and resultant pollution occur at a specific intersection of 2) population growth and urban migration.

If we continue to extract at today's rates we are estimated to have 61 more years of copper, 45 years of gold, 13 – for indium, 40 – for tin, 29 – for silver, 59 for uranium and so on. For these same resources, if global consumption increases to just ½ of the US, per capita, these recourse availability horizons dwindle down to 38, 36, 4, 17, 9, and 19, respectively. Anyone who has been to SE Asia, China or India will be able to testify as to how deliberately these nations are moving away from poverty and moving toward a western capitalist economy and lifestyle. Nonetheless, given the vast infrastructure of global communication and transportation networks, western and eastern societies are inextricably tied to one another where economic fluctuations are now realized concurrent, as clearly realized during this recent economic downturn.

The idea that all things are interconnected and changes in one part of a structure may have an effect on another part of a structure is central to the systems thinking mindset. That one varying element rarely mediates 100% of another element and that there are likely to be many varying factors that should be considered when examining the behavior of a single variable and that it is more likely that these relationships are nonlinear than linear are important considerations. This expanded view is the basis of systems thinking. Most scientists look at the world in this way but now the manager, business person and worker should have a sense of causality such that connections between elements may have feedbacks that accelerate or slow a given process, that small movements in one place may result in sudden dramatic shifts somewhere else and that critical values exist in self organizing systems. Keeping this in mind, we will examine various systems and look closely at the emerging interest in ecosystem behavior and the implications of an ecosystem's carrying capacity.

Carrying capacity

While sustainability may mean many things to many people, everyone seems to agree that when you sustain something you are making it last. By virtue of this simple concept we must give full treatment to ecosystem longevity. However, growth in the economic since, is the increased physical scale of matter/energy that sustains economic activity such as production and consumption indefinitely. Although in economics, consumption is a misrepresentation because products are never consumed, they lose quality and/or degrade to a less useful state. There is no real consumption or production of matter/energy in the physical sense, output is really a process where low entropy materials are transformed into products and when spent, the matter/energy is reused somewhere else and the rest is high entropy waste. Production starts out with depletion and ends up with pollution while growth is the quantitative increase in the physical scale of production, so to speak (Daly, 1996). The qualitative improvement in the physical transformation process is a result of technology and/or understanding of the purpose of the transformation and this is referred to as development. Sustainable development is really an action resulting from a deeper understanding of technological processes over the long run. Nonetheless, no matter how we use resources their sum remains constant as it is explained by the law of conservation of energy and matter.

The concept of quality as economic value is central to a systems carrying capacity because instead of concentrating on whether or not resources will run out, we should be concerned about specific aspects of quality that these resources produce. For example, clean water as opposed to contaminated water and clean air as opposed to polluted air. If production is at a quantitative scale where this quality aspect of a resource cannot regenerate itself naturally, to a useful state, the root cause is a production problem, not a capacity problem. Yet, we would rather look for a way to increase capacity than adjust production (transformation).

When extraction of resource X is controlled to a level where extraction and regeneration are in equilibrium, the system is in a steady state. Minor fluctuations exist but, cause minimal disruption to the process and the resource is available over the long run. This requires a new paradigm in the way organizations within various industries that use the same resources relate to one another. They may be competitors but, businesses that use the same resources and operate within the same markets must also be cooperatives. Businesses that use that same resources and are in different markets must rely on regulatory information as well as businesses that are in different markets and different industries that use the same resources. The scope of such regulation is beyond international because it is also intergenerational!

There are many self organized systems that continue to change until some critical point is reached. At this critical value a radical disruption to the expectant probability is reached and then the system stabilizes for some determined time period. I prefer to separate the completely natural systems from

the ones that are assisted by human activity, if for nothing other than we are humans.

An example of evolutionary micro-macro engagement is reflected in food sharing among vampire bats. The individual bats generate upper level structures that feed back to the lower level structures. In the evening the bats hunt while during the day they engage in grooming and food sharing. This behavior is specific to the common good of the species. The main question is how self-organized processes within the species are developed and how can we adopt similar practices.

Adaptive forest management is similar. The use of the forest is determined by predictable interrelationships between natural forest growth and the specific demands of the timber market industries. Unlike the bats, there is no wood sharing for the common good of the species. The self-organization of the timber markets have little to do with the self-organization of the natural adaptive systems within the forest. This disconnect is at the center of our long term survival as a species. As individuals, organizations and nations, the race is on to become the wealthiest and wealth depends upon the use of resources. Under these uncooperative circumstances, it is easy to imagine how depletion is the eventual result. Consider simultaneous population growth.

Human population dynamics

The lack of concern about population dynamics is hard to believe. Although it is addressed in most articles and books about environmentalism, ecology, sustainability the green movement and social responsibility, it is usually given the status of an addendum. In this section we explore the dynamics of population. We will then expand these ideas to the interactions among the environment, the economy and human welfare.

A population is an entire group under study as opposed to a sample that is taken from a population as a subset. Statistical methods are used to gather sample data from the population to see if certain characteristics exist by statistical testing and if the results are strong enough, the investigator can generalize these findings to the population with a specific probability of certainty. Basically, the closer the sample size is to the population size, the more generalizible the findings will be to the population. This simple concept is one of the most important cornerstones of science. Within this domain, exists an indispensable tenet that researchers are very aware of throughout a given investigation. This doctrine is so imbedded within the scientific community that it shapes the scope of study. The point I'm making here is that when we have population data, we can dispense with inferential statistics.

We know how many people there are on earth, in a certain country, in a province or state, in a city, in a city district or in a household. Perhaps it is because these population numbers are facts and scientists normally engage in hypothesis testing by building models with sample data, checking to see if the data fits the given model and testing to see if the findings are significant, that population studies are in short supply. It is for these reasons that we should pay more attention to population growth because population distributions do not need testing because they are facts.

Growth in demand

It requires roughly 1/3 of the current annual world extraction of nonrenewable resources to support about 6% of the world's population in the United States at a per capita level. World travelers, demographers and the citizens of the world will attest to the fact that the majority of the world aspires to an equivalent level of comfort, lifestyle and technology to that of the US. And even if the US levels of comfort, lifestyle and technology could be instantly extended worldwide current resource flows could maximally support 18% of the world's population at the US resource use level, with little to nothing left over for the other 82%. People will not work and cannot work if they are below sustenance levels and without the labor services of the bottom 82%, the top 18% would not be so well off as this simple calculation suggests. Needless to say, this is a catastrophe for everyone involved and like it or not, everyone is involved.

Timing of growth and migration

Based upon the last several decades of data, we have an increase of about 74,686,807 people every year. This equates to an increase of 1 billion people every 13.389 years. You could think of it as an increase of 6,223,901 people per month, or 1,555,975 a week. By 2050, about six billion of the world's then nine billion people will live in cities. According to a 1994 UN report, 1.7 billion of the world's 2.5 billion urban dwellers were then living in less-developed nations, which were also home to two thirds of the world's mega-cities. The trend is rapidly accelerating. Currently, about 3.2 billion people, a number larger than the entire global population of 1967, live in cities. Developing countries do and will continue to absorb nearly all of the world's population increases between today and 2030. Meanwhile, rural populations are growing scarcely at all. By 2030, more than half of all Asians and Africans will live in urban areas. Latin America and the Caribbean will at that time be 84 percent urban, a level comparable to the U.S. As urban population grows, rural populations will shrink. Asia is projected to lose 26 million rural dwellers between 2000 and 2030.

Movement like this will lead to rapidly changing population levels in the world's cities, emerging giants

whose future depends upon rural farms and other resource extractions from outside the cities. By 2050, an estimated two-thirds of the world's population will live in urban areas, imposing excruciating pressure on space. The densely packed systems of infrastructure will lead to an unnerving sense of confinement and social disintegration combined with the everlasting horrific disparity between wealth and poverty.

In terms of metropolitan areas, the top 10 populated cities in 2009 in millions of people are Tokyo 33, New York 18, Sao Paulo 18, Seoul 17, Mexico City 17, Osaka 16, Manila 15, Mumbai 14, Delhi 14, and Jakarta 14. The good news is that the percentage growth rate has been on the decline from 1965 to the current period. For example, in 1965, the world growth rate was 2.03 percent and by the year 2000 it had dropped to 1.23 percent (Meadows et al, 2004). While the population is still growing, the point of zero growth is approaching. The bad news is that we will be over 9 billion people on the earth before the no growth point.

It has been proposed that an obvious solution is to expand total resource flows by whatever factor necessary to generalize the US per capita use of resources to the rest of the world. How much would that be? It is interesting that so many intelligent people suggest that we further expand the US economy. The well received linear model of economic theory is that the more we produce the better off we are, may have held up for many decades. But, as Daly (1996) reports, this model no longer applies because to build the infrastructures needed to be able to extract resources at the affluent levels of the post industrialized nations, such as the US, it would require a far greater amount of material resources than the world is capable of delivering. As we have seen over the past decade, resources have been increased and diverted to countries like China. Imagine if every nation grew at this alarming pace.

Externalities

Externalities emerge between producers, between consumers, or between consumers and producers. They can be negative (when one party imposes a cost to another) or positive (when one party benefits another party). In the domain of sustainability and social responsibility and our focus, externalities are negative when one party imposes a cost to another party or when this cost can be generalized to a population where negative social or environmental consequences result from some business operation. One of the most obvious examples is where a manufacturing plant dumps hazardous waste down a water drain into an ocean, lake or river. An organization or individual somewhere else will suffer the ill effects of an added expense of waste water treatment specific to the discarded chemicals or illness from using the contaminated water to swim, clean, cook or drink.

The problem is when externalities are not reflected in the market price of the product and as a result there is an economic inefficiency. Consider the business that does not include negative externality costs in the pricing of a product. Externalizing these costs to society results in an excess of production of products that damage the environment the most. We should say the marginal cost (MC) does not capture the total cost of production of one more unit when an organization externalizes costs because these costs are not included in the final cost of the product. However, the marginal social cost (MSC) is higher than the MC because MSC captures all costs.
If all externalities were captured in the final cost of all products, organizations would actively seek production chains that have the least number of externalities in order to pass these savings along to their customers and thereby become more competitive. The efficient level of output is where the price of the end product is a function of the complete costs of that product, as it should be. This simple concept would not only result in a market that promotes products that are less damaging to the environment and society, it will also drive out products that are the biggest environmental offenders. Marginal external cost (MEC) is the increase in external cost imposed by producing one more unit.

Natural ecosystem service

Hawken, Lovins and Lovins' (1999) Natural Capitalism takes a biological and social approach to the production process. They say the process of production has shifted from a human production process to a resource production process and as a result of this shift, humans have been left out (jobs) while natural resources have become the target of production worldwide. According to these authors, natural capital is defined as resources, living systems, and ecosystem services. They go on to say that the people of earth have a 3.8-billion year old reserve of natural capital and yet, if the present trajectory of use continues, there simply will not be enough to go around in the near future.

One model is brought out in Natural Capitalism that captures the essence of externalities by introducing a concept of industrial metabolism. Industry production takes in or ingests natural resources such as energy, minerals, water, wood and other natural elements. This system, in turn, excretes liquid and solid waste, just as we do. Additionally, this system also breaths in as combustion processes take place to produce heat and electricity while exhaling various gasses. This point of view captures the essence of systems thinking while making a point about how ubiquitous externalities actually are.

This leads us to the question of how much does one unit of ecosystem service cost? This question gets more complicated as time moves forward due to the dynamics associated with depletion and degradation. What will be the price of the last bottle of water? What is the value of a species that becomes extinct? What if a species' tissue is a cure for some disease, as opposed to art, leisure or recreation? Until we devise a real time derivative with respective weights for every resource that all nations and their respective organizations agree upon, disagreement will undoubtedly follow our attempts to estimate and capture the costs of externalities. No doubt, global regulation is past due.

Simple economic systems

Sense the beginning of the industrial revolution it has been recognized that if you combine labor and capital in a way that produces a product that people are willing to pay for at a price above the cost of producing such a product, the potential exists for unlimited growth. This is the basis of the world economy. Therefore, managers are understandably preoccupied with maximizing something such as profits, present value, shareholders' equity, marketing potential, expanding customer population and so on (Daly,1996). However, as we know, today we have a new set of circumstances. Not only are we making our first attempts at estimating the cost of various externalities in a dynamic (time) way, we are trying to estimate the optimal level of externalities. Because after such an accounting system is fully realized, it is not only the market forces that will drive the worst (most expensive) externalities down but, the natural regeneration of a needed resource must be specified and maintained. That is to say, each individual resource has a point of optimal performance. Further, these two constructs (externalities and depletion) must be the drivers of a global real time pricing structure.

Many economists are prescribing an unstated ethical goal of controlling pollution within the confines of profit. That is to say, control pollution only if the measurable monetary benefits of the control are greater than the costs. This could be considered an economic efficiency standard. We know that ROI is very narrow and it does not consider many important aspects of sustainability, such as the amount of resource available to continue production over the long run and protecting natural ecosystems from abrupt negative disruption.

The Iroquois Indians live under the concept of traditional directives. One of their most important and widely accepted directives is to consider the impact of decisions made on the next seven generations. Today we are in a position where basic business decisions made will not only impact the next seven generations but will impact the next generation and the current generation. In fact, in many parts of the world, including the US, there is strong scientific evidence that suggests the negative effects of environmental damage are hurting us now and the time remaining to turn around the impending catastrophe is running out.

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Sustainability: Simple Rules in the Trenches

Kevin J. Dooley

Arizona State University and Co-Director, Sustainability Consortium

I'm currently Co-Director of the Sustainability Consortium, where we are working with retailers, manufacturers, suppliers, NGOs, and government agencies to develop science and tools that improve decision making about sustainable products. Our current focus is on developing uniform standards for measuring and reporting consumer product sustainability, and our pilot projects involve computers, home and personal care items, and food and beverages. In just over a year the Consortium has grown to involve over 100 organizations and 250 active participants.

Knowing my background in complexity science, some of my colleagues ask me, "Kevin, where is the complexity thinking in what you're doing?" My reply is, "Complexity science is how I view this effort every second of every day!" It's true. I honestly can't comprehend how I would approach this effort without a complexity science perspective. I do know that in a large, multi-stakeholder environment, there is no other perspective that can provide as much insight as complexity does.

It's instructive to note that the Consortium's other Co-Director, Jon Johnson from University of Arkansas, is an expert at social networks and wrote some of the early papers on management and chaos theory. I guess it should be no surprise this endeavor attracted two complexity folk.

In my role as Co-Director, one of the most practical and impactful concepts that I use from complexity science is that of "simple rules". The concept of simple rules stems from the observation that in a complex system, a few simple rules that

define interactions amongst agents or variables can yield complex, nonlinear dynamics. Coupled with the Zipf's Law that human systems seek to minimize energy expenditure, this implies that human systems will tend to seek a small set of simple rules by which to guide collective behavior.

In an organizational setting, these simple rules can be usefully considered to be the principles or values by which members of the organization act and make decisions. In the Sustainability Consortium, our core values are:

Collaboration of diverse participants

This impacts how we compose our Steering Committee, our Working Groups, and our Advisory Boards; who we seek to partner with in research; and how we build the staff of the Consortium.

Scientific integrity

Whenever you're developing standards to be used in the real business world, there's a tension between science and economics. We are a member funded organization, so we are especially sensitive to developing systems and values that uphold this core principle. For example, each of our standards is based on an underlying research document that is peer-reviewed by academic experts, and not subject to consensus review by industry members.

Comprehensiveness and holism

One of the reasons we exist is because existing efforts to measure and report product sustainability have been fragmented and partial, in terms of their scope, the impacts of concern, or the life cycle stage being addressed. Our approach seeks to capture all environmental and social impacts across the whole life cycle of a product. Holism, and complexity science more specifically, also impacts how we develop our own decision support systems, using principles of modularity and distributed control as key design criteria.

Transparency and accessibility

To be open, to all, is an easy thing to say but a hard thing to do. Transparency impacts both how we operate, the relations that we seek, and the data and methods we seek to use. Numerous research studies have shown that transparency of data and methods is key to buyer trust of product information.

Progress and solutions orientation

Our members and stakeholders want results, our earth and society want results, and we want results, sooner than later. In a sense, this is where science becomes engineering. From a complex systems perspective, this means we strive for short learning cycles and multiple iterations, in order to adapt to good solutions.

I've seen the same thing in other organizations I have been part of, especially smaller organizations. For example, when I worked in two different, small community radio stations, our mission statements were key in every day decision making. Other research into new venture development highlights the importance of principled decision making.

In order for "simple rules" to work however, it can't just be in my mind—it has to be in the mind of all the agents (people) in the Consortium. This comes from agents co-creating the principles, and having a relatively simple set of principles so people can remember and therefore use.

UN Agenda 21 and a Fish Story

Stephen Guastello, *Marquette University*

Joseph Jacobsen's article brings back vivid memories of UN Agenda 21, launched in 2002, and the concept(s) of Sustainable Development that were circulating at the time. "Development" recognizes that if the system is alive and functional, it will grow and evolve. "Sustainable" means that it can't grow beyond the ability of the ecosystem to support it or collapse is inevitable.

The Chicago Area Sigma Xi (CASX) chapters organized a series of symposia on Sustainable Development in 1994-97 that sought to connect scientists and engineers with other interested professionals. Sigma Xi is a multidisciplinary professional society for scientists and engineers. It is organized into local chapters that are headquartered in universities. There were several such chapters in the Chicagoland regions that banded into CASX for the sustainable development seminars under the direction of Bill Gomora, who worked for Argonne Labs at the time.

The seminars met at irregular intervals averaging nine months apart. Seminar topics included food, water, energy, and mineral resources; pollution and ecology; health issues; population dynamics, public health communication, economics of developing nations; possible technology transfers from GS8 to developing nations, and of course global warming and the impending food-water-everything crisis that was expected between 2020 and 2050. We had good intellectual support from USAid, UNCSD, universities and private industry. There was a strong entrepreneurial influence as people explored new products and services that would have some benefit to developing nations in these key areas as well as domestic applications. The project dissipated, however,

when it became clear that the parts of the world that could benefit the most did not have the money to pay for the products and services, and there was no apparent international mechanism for bridging the gap.

There were some positive outcomes, nonetheless. Interesting people swapped fascinating stories. One particular crowd-pleaser was Mohammed Dore's presentation that addressed the question of whether sustainability was possible at all. We did collect an interesting cache of abstracts from the presentations to the seminars, and ran a web site on csf.colorado.edu for few years. "CSF" was an acronym for Center for a Sustainable Future, which is no longer in service, unfortunately. A good web source today, however, is the Worldwatch Institute (www.worldwatch.org). Chaos and complexity themes were prominent, and it would be interesting to explore how situations might be reinterpreted given the evolution of nonlinear science itself over the last 15 years as Joe Jacobsen has started to do. Sigma Xi the national organization did publish two documents on two symposia they ran in 1991 and 1992. Thomas F. Malone, its president at the time, was one of the lead scientists on the Biosphere project.

The CASX experience, for me, turned into a crash course in ecological economics. The tangible result was a study of the decline of oceanic harvests over the previous decade as a predator-prey function. The decline was already known to be the result of overfishing, and partially related to governments funding the production of factory ships, which harvested the oceans beyond their carrying capacity. The nonlinear dynamics analysis showed two possible scenarios: The oceans would be fished to death permanently, or the stocks could bounce back after 36 years if the harvest rates did not accelerate further (Guastello, 1996, 2002 pp. 292-296). The results of the study circulated to a reporter for the New Orleans Times-Picayune who was writing a series "Oceans of Trouble" in response to the collapse of the New Orleans shrimp fishery at the time (McQuaid, 1996). George Sugihara, a biophysicist at the Scripps Institution of Oceanography at the University of California at San Diego, and Robert Costanza, ecological economist from the University of Maryland were also featured in that article for their views on the relevance of complex systems thinking and analysis to fishery management. McQuaid received a Pulitzer prize for his series in 1997. Since that time aquaculture has grown rapidly. The Worldwatch Institute recently reported:

> The world's fisheries have remained relatively stable over the last 15 years: about 50 percent are being fished at full capacity, 25 percent are underfished, and the remainder are overexploited, depleted, or recovering. As a result, the U.N. Food and Agriculture Organization predicts that maximum wild fish capture has already been reached. Most of the stocks of the top 10 fished species are being fully fished or are overexploited, and studies have indicated that even in the most stable fisheries there have been declines in the most valuable species, such as tuna. (Jasperson, 2008).

The United Nations Development Program (UNDP) produced an e-book entitled *Encyclopedia of Life Support Systems* in 2003, with an updated edition in 2007 in both print and e-book forms. Volume 2 is replete with complexity concepts (Kiel, 2007). Authors include SCTPLS notables such as Peter M. Allen, Yaneer Bar-Yam, Chang-Hyeong Choi, Kevin J. Dooley, L. Douglas Kiel, Jeffrey Goldstein, Gottfried Mayer-Kress, William Sulis, Bruce J. West, Wei-Bin Zhang; yours truly, and many others. For more information, visit http://www.eolss.net/eolss. Sigma Xi, meanwhile, has recently reactivated its interest in sustainability at the national level focusing on water resources, water engineering, and related ecology.

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Feature Article

Modelling Sustainable Development: A Nonlinear Approach

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Abstract: We seek to enhance the dialogue between ecologists and economists, by modelling sustainable development without the specific assumptions of neoclassical economics. With the aid of very general nonlinear functions, sustainable development is defined as a dynamic equilibrium along which environmental damage is zero and the growth rate of consumption is zero. For sustainability, the zero consumption growth can be derived from a fixed resource constraint. Ecological balance requires that damage to the environment be zero. The model consists of two nonlinear differential equations: a consumption path and an ecological balance path achieved by investment in environmental repair. It is shown that an intertemporally sustainable equilibrium (ISEP) exists and that it is a saddle point. Thus there exist trajectories that lead to ISEP. However, not all trajectories lead to ISEP. Thus sustainability can be achieved by an appropriate policy response. Any positive consumption involves some environmental impact. Sustainable development therefore requires not only constraints on consumption, but also remediation of such damage that inevitably occurs.

Historical Introduction to the Concept of Sustainable Development

Sustainable development (SD) is a catch-phrase used to encompass many diverse perspectives on the desired future direction of human society and our surrounding environment. It has no unique definition - indeed it is not clear that uniqueness would be desirable. It has to embrace so many different facets of human existence. In this paper we interpret SD to include the well-being of all current and future inhabitants of the earth. The inclusion of future people necessitates the maintenance of the natural environment.

Popular misuse of the term sustainable development has muddied the meaning, so that, as Terence Corcoran puts it:

> Never have two words been used so much with so much inconsistency ...It is fast becoming a landfill site for every environmental idea ... For the most part, nobody seems to care what the words mean, or whether they even have any real meaning. Have we reached a point where sustainable development has become a hazardous concept?"(Corcoran, quoted in Miller, 1990, p. 28).

SD has its roots in the early history of the modern conservation movement in the USA which can be dated as far back as 1832, when George Catlin, a U.S. author and artist, first proposed the idea of establishing national parks. The idea received support from the botanist William Bartram and the ornithologist John James Audubon. The first textbook on conservation by George Perkins Marsh, entitled *Man and Nature*, appeared in the 1860s. In 1872 the U.S. Congress established the Yellowstone National Park, and proclaimed a role for the government in conservation. Later the conservation movement received a boost with the support of President Theodore Roosevelt and his advisors such as Gifford Pinchot, who helped establish a Forestry school at Yale University.

Any approach to SD involves contributions from many disciplines, including ecology, economics, and the physical sciences. From the economics viewpoint, probably the earliest work to attempt to analyze the formal conditions for continuing changes in well-being would be Malthus' *Essay on Population* (first edition, 1798, to sixth edition, 1826). From the perspective of current concepts of SD, the contribution of Malthus was to formalize the link between available resources, human population growth and well-being. Growth or development per se was not an important focus of economic theory over the following century, but since the mid twentieth century has emerged at the forefront of research.

Prior to the end of Second World War, few formal theories of economic development existed. Economic historians studied the ways in which Western countries had industrialized, but were not able to provide prescriptions to assist those areas of the world that were not experiencing economic growth of their own accord. From the New Deal of the 1930s and the economic prescriptions of Keynes, society learned that we could exert some control over aggregate economic activity, and by implication then could induce growth where it was not otherwise occurring. From these ideas grew the development plans of the late 1950s and the 1960s. But most economic development plans failed to recognize the integration of economic activity with the natural and social environments in which they were implemented. Georgescu-Roegen (1971) sought to draw the attention of economists to the need to accommodate economic activity to the constraints of the laws of thermodynamics. Another false start came from *The Limits to Growth* (Meadows, Meadows, Randers, & Behrens, 1972), which attracted a great deal of

attention to the issues of environment-economy interaction, even if few agreed with its predictions.

The fundamental idea behind "sustainable development" integrated the idea of conservation of planetary natural resources with a concern for future generations. Early reference to the sustainable use of land and biotic resources within ecology can be found in the literature of forestry and wildlife management (Dasmann, 1985). O'Riordan (1988) traces the modern emphasis on sustainable utilization of resources back to a series of conferences held in Africa in the 1960s, whereas Dasmann (1985) points out that the concept of sustainability received the greatest boost from the publication of the *World Conservation Strategy* (IUCN 1980). Redclift (1987), however, argues that the term *sustainable development* was already in use by UNESCO in the early 1970s when it launched the "Man and the Biosphere" program, after the international conference on environmental problems held in Stockholm in June 1972. Following the conference the United Nations General Assembly established the UN Environment Program (UNEP), which led to the publication of *Our Common Future* (also known as the Brundtland Report) in 1987 (World Commission on Environment and Development, WCED, 1990). Since then this report has symbolized the debate over the relationship between economic change and the natural resource base on which this change is grounded.

Our Common Future, rather than provide a workable definition, offered *a statement of intent* of sustainable development: "Development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs" (WCED, 1990).

Whatever its shortcomings, Brundtland has influenced many researchers in the environmental sciences who see the need to go beyond the narrow confines of economic efficiency. While some economists have sought to integrate SD within the existing theory of economic growth (e.g., Dasgupta, 1995), Solow's (1991) definition of sustainability entails a moral obligation:

> it is an obligation to conduct ourselves so as to leave to the future the option or *capacity to be as well off as we are*... Sustainability is an injunction not to satisfy ourselves by impoverishing our successors.

Later in the same paper Solow gives sustainable development operational meaning by arguing that the present generation has a moral obligation to leave behind "a generalized capacity to create well being...." This suggests that to some extent the present generation can in principle compensate future generations by leaving them a stock of both human and physical capital in return for using up some natural resources. This formulation relies crucially on the acceptance of substitutability of technological know-how for resources in limited supply. Indeed the principle of substitutability is another common feature of modern economics, and it is reflected in the treatment of sustainable development in the modern theory of economic growth.

Dorfman (1993) on the other hand is skeptical about the possibilities of such substitutability. He defines sustainable development simply as the level of well-being or *consumption* that "can be maintained for an indefinite period of time". He argues that in any sustainable equilibrium, resources will have to be diverted away from consumption and invested into protection and repairing the environment. For a given social welfare function (with standard properties), the optimum environmental quality consistent with the highest attainable consumption can be determined. However, this consumption-environmental quality pair is sustainable only if (1) resources are diverted into repair, and (2) bounds are placed on the growth and level of consumption.

The main policy implications that we derive from Dorfman's models are clear: (1) things cannot continue as they are, (2) you cannot simply 'compensate' future generations with more and better capital and know-how, (3) we must accept zero growth consumption, and (4) we must accept the responsibility to repair the damage to the environment. In the next section we present a new definition of sustainable development, and a model with very general nonlinear functions formulated without reliance on the standard convexity assumptions of economics. We hope that this approach will be fruitful in building a common language with ecologists, environmentalists, biologists and others interested in the analysis of sustainable development. At the same time our approach is an illustration of both the simplicity and power of nonlinear methods.

The Repair of Environmental Damage

The environmental economics literature has focussed largely on policy prescriptions for damage avoidance. As Dorfman notes, there are many instances in which important aspects of the degradation do not have to be permanent. Examples of environmental damage that can be in part repaired include the reinstatement of opencast mine workings or the liming of acidified lakes. This type of remedial undertaking is appropriate in only a minority of environmental problems, and in many cases can be applied to only some portion of the degradation. Nonetheless it can be an important component of our environmental management strategies.

In many instances, the repaired state may not be identical to the pristine state before the exploitation of the environmental resource. Whilst not a "first best," a repaired environment is preferable to one that is left in a degraded state. Nature itself does not exist in a stable stationary state, and many ecological systems

are in constant flux between a number of alternative states, but over *very very* long horizons. An alternative configuration of land use can in many instances yield a quite acceptable level of environmental services

Finally it should be noted that according to the U.S. Environmental Protection Agency (1991), pollution control activities alone cost 2.1 percent of GNP in 1990 and all environmental spending is expected to continue to rise. It should be clear that as long as our present industrial activity continues to degrade the environment, growing expenditures for repairing the environment are inevitable. Indeed in many countries these expenditures are now mandatory.

Long Term Growth of Consumption

We begin with a simple argument showing that the Dorfman assumption of bounds on the growth of consumption can be demonstrated, if resource supply is fixed.

LEMMA. Let consumption $C(t)$ be a function of resources inputs $r(t)$, whose total supply is fixed, as shown in equation (2) below:

$$C(t) = F(r(t)), \qquad F_r > 0 \tag{1}$$

$$\text{Let} \quad \sum r(t) = R \tag{2}$$

$$\text{Then} \quad dC(t) = F_r(\bullet)\, dr(t) \tag{3}$$

$$\frac{dC(t)}{C(t)} = \frac{F_r(\bullet)dr(t)}{F(r(t))} \tag{4}$$

Therefore if growth in consumption is to be positive, we must have

$$dr(t) > 0 \qquad \forall\, t \tag{5}$$

$$But \qquad \sum_{t=0}^{\infty} dr(t) = \infty \quad if \quad dr(t) > 0 \ \ \forall\, t \tag{6}$$

This clearly violates the finite resource constraint given in equation (2). •

We now proceed to define sustainable development and formulate the model.

Definition of Sustainable Development

We define long term sustainable development as *a pattern of no growth consumption that is non-degradationist and is compatible with a population consistent with the carrying capacity of the planet.* However, as this paper is a ceteris paribus exercise, we will take the population as a parameter p. Dynamically we refer to it as *the intertemporally sustainable equilibrium point (ISEP) at which consumption growth is zero (i.e., $\dot{c} = 0$) and environmental change is zero ($\dot{E} = 0$), for a given population p.* In short, ISEP is the pair

$$(\dot{c} = 0,\ \dot{E} = 0;\ \bar{p}) \tag{7}$$

In the next section we set up a dynamic model in which we show that ISEP is an attainable equilibrium; we demonstrate that there exist some trajectories that lead to ISEP. However not <u>all</u> trajectories lead to ISEP. We shall use very simple and very general nonlinear functions to show existence. The derivations are from first principles, and no appeal to specific functional forms is necessary. Indeed, the model does not rely on any existing theory in economics; it will be shown that only two plausible assumptions are necessary. We hope that this will make it of interest to a wider group of environmental researchers.

The Model

Assume a closed economy in which output is obtained by resource inputs alone. That is, let the production function be:

$$q(t) = q(r(t), t) \tag{8}$$

where r are resource inputs.

Let the National income identity be:

$$q(t) = c(t) + v(t) \tag{9}$$

where $c(t)$ is consumption v(t) investment into repairing the environment.

Let $E \equiv$ environmental quality. Then E is the change in environmental quality given by

$$\dot{E} = g(v, r) \tag{10}$$

where $g(.)$ is in general nonlinear. Equation (10) is in general nonlinear. We now give an economic interpretation to equation (10):

$$\dot{E} = g(v, r), \quad g_v > 0 \quad g_r < 0 \tag{11}$$

Inequalities (11) state that spending on environmental repair improves the environment, whereas using resources to produce output leads to environmental degradation. Thus:

$\dot{E} > 0$ means improving environmental quality;
$\dot{E} < 0$ means degrading environmental quality; and
$\dot{E} = 0$ means ecological balance.

Next note that consumption $c(t)$ is a function of v, r. It is in general nonlinear:

$$c = f(v, r) \tag{12}$$

where

$$f_v < 0, \quad f_r > 0 \tag{13}$$

In order to focus on v and r we abstract here from all other factors that do not alter the nature of the equilibrium.

The partial derivatives in inequalities (13) show that consumption falls as more of the net output is

devoted to environmental repair, but it grows with resource use. Thus we can summarize dynamic system with two equations characterized by the following:

$$\dot{c} = f(v, r) \quad f_v < 0, \; f_r > 0 \qquad (13)$$

$$\dot{E} = g(v, r) \quad g_v > 0, \; g_r < 0 \qquad (11)$$

Equations (11) and (13) are all we need, and their partials are the required assumptions. Note that the assumptions are very plausible on first principles.

We now seek the stationary equilibrium solution $\dot{c} = 0$ *and* $\dot{E} = 0$. That is, we would like to stabilize consumption at some (high) level, but that continuous growth (forever and ever) is ecologically unsound. We therefore write

$$f(v, r) = 0 \quad [\dot{c} = 0 \; curve] \qquad (14)$$

$$g(v, r) = 0 \quad [\dot{E} = 0 \; curve] \qquad (15)$$

To find the $\dot{c} = 0$ curve, we use the implicit function theorem:

$$\left.\frac{dv}{dr}\right|_{\dot{c}=0} = -\frac{\partial f / \partial r}{\partial f / \partial v} = -\frac{f_r}{f_v} \quad (f_v \neq 0) \qquad (16)$$

From (13) we know that $f_v < 0 \;\; \therefore \dot{c} = 0$ curve is positively sloped.

Similarly we now find the $\dot{E} = 0$ curve:

$$\left.\frac{d_v}{d_r}\right|_{\dot{E}=0} = -\frac{\partial g / \partial r}{\partial g / \partial v} = -\frac{g_r}{g_v} \quad (g_v \neq 0) \qquad (17)$$

From Equation (11) we know that $g_r < 0$. We conclude that $\dot{E} = 0$ is positively sloped.

In general,

$$-\frac{f_r}{f_v} \neq -\frac{g_r}{g_v} \qquad (18)$$

Now the Jacobian ***J*** of the equations (14) and (15) is non-zero:

$$J = \begin{vmatrix} f_v & f_r \\ g_v & g_r \end{vmatrix} = f_v \, g_r - f_r \, g_v \neq 0 \qquad (19)$$

Therefore, there exists at least one solution to the system (14) and (15).

We first prove that any solution is in the positive orthant. As *v increases* $\dot{E} < 0$, *then* $\dot{E} = 0$, *and finally* $\dot{E} > 0$. This implies that $\dot{E} = 0$ only when $v = v_0 > 0$ on the *v* axis. Similarly as *r increases*, $\dot{c} = \; < 0$ *at first, then* $\dot{c} = 0$, *and finally* $\dot{c} > 0$. This implies that $\dot{c} = 0$ only when $r \geq 0$ on the *r* axis. We conclude that the intersection ***S*** must be in R^+_2. as drawn in Figure 1.

The above argument for a positive solution can also be stated in words. To establish the existence of an equilibrium for this system, consider the relationship of the two curves in *v*, *r* space.

Looking first at the $\dot{c} = 0$ curve, it is feasible to use resources at levels that are within the carrying capacity of the environment, and without repairing any of the damage we are causing (i.e. *v=0*). This is in fact a reasonable description of the current situation. The $\dot{c} = 0$ curve is meaningful only when ***r*** is non-negative.

The $\dot{E} = 0$ curve depicts loci at which damage to the environment is offset by remedial work. There is no level of repair feasible if there is no resource-using economic activity, so this curve must have a positive vertical intercept. It follows that the two curves must intersect in the positive orthant, and intersect they must, because the Jacobian (see equation 19) is non-zero.

Next consider their relative slopes, which are crucial in determining the nature of the equilibrium ***S***. Intuitively, the higher *v*, the faster the stationary state $\dot{c} = 0$ is reached. For the same reason the greater the *v*, the slower the degradation of the environment and more *r* can be used. This suggests that $\dot{c} = 0$ is steeper than $\dot{E} = 0$, as drawn in the phase portrait in Figure 1. Later in the paper we show that the alternative (i.e., $\dot{E} = 0$ steeper than the other curve) is not plausible.

We have established that there exists at least one intersection, but as shown in Figure 1, we can envisage a pair of solutions, each with a different property. As we move in the northeast direction from the origin, the first intersection, marked U, is unstable, as all trajectories move away from it. Thus from the social point of view this unstable equilibrium U is undesirable; such an equilibrium cannot be characterized as being "sustainable." Now consider the second intersection, labelled S. It is clear that S is a saddle point; that is, there exist trajectories that can get us there, but adopting the "wrong" policies may make it unsustainable. The positive lesson is there *exist* some trajectories that could, in principle lead us to S. This analysis is summarized in the phase portrait shown in Figure 1. Note that we know the character of ALL trajectories in that phase portrait.

The point ***S*** is the sustainable equilibrium point $\{c=0, \; E=0; \; \bar{p}\}$, where $\bar{p}$ is the given population parameter. The point ***S*** on the figure is the *ISEP.*

The phase diagram shown as Figure 1 analyzes the stability of the ISEP ***S***, and shows that it is a saddle point. That is, there exist some trajectories that converge on to ***S*** but there are others that turn away from it. The qualitative analysis has shown that an intertemporally sustainable equilibrium (ISEP), as defined above, exists. Next we propose to identify the most plausible initial state or condition on the phase

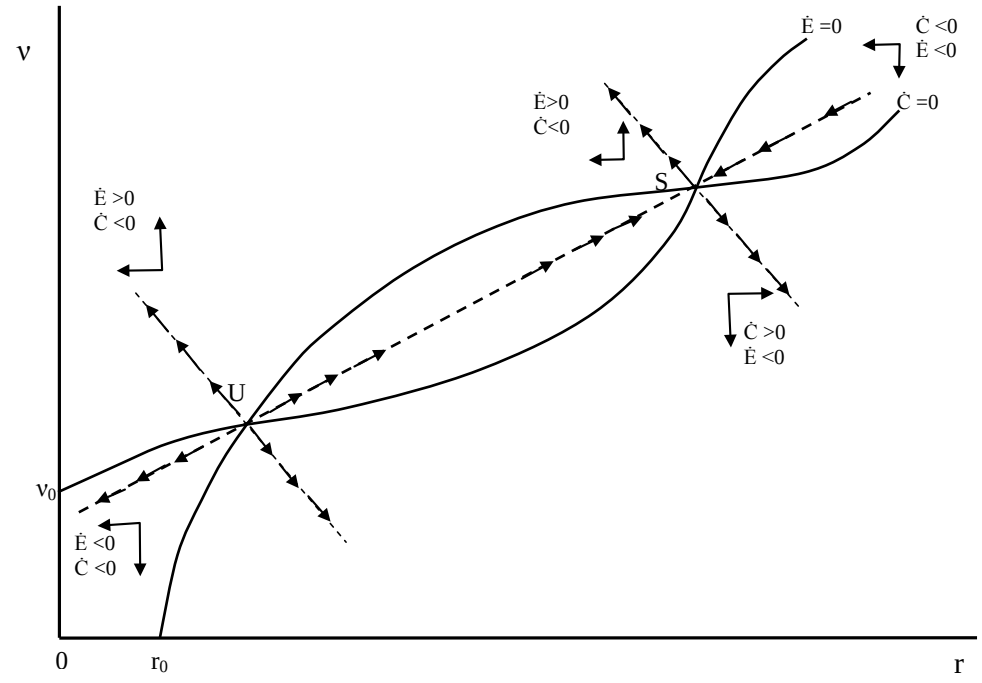

Figure 1: Phase portrait the paths of consumption and repair of the environment.

portrait. If environmental quality needs to be improved, then clearly v must be increased, which implies that the growth rate of consumption must fall. Therefore the initial state of the economy is somewhere in the southeast corner of the phase portrait.

Next, we ask what happens if the slopes of the two curves were reversed, that is if $\dot{E} = 0$ were steeper than $\dot{c} = 0$. In this case it can be shown that the intersection is globally stable; that is, all trajectories lead to the equilibrium, which suggests that there is no environmental degradation problem. In fact there would be no need to study environmental problems. Hence the phase portrait with the given slopes makes more sense.

Finally, note that as the two curves are nonlinear, there is the possibility of multiple equilibria. If the two curves intersect again, further in the Northeast direction, then the next intersection will be an unstable U, and the following intersection a saddle point S. In fact, a saddle point and a globally unstable equilibrium will alternate as we go further in the Northeast direction.

Implications of the Model

The existence of a saddle-point solution has important implications. Sustainability, in the sense discussed here, is feasible. However, it will not occur without *policy intervention*, because only *some* trajectories lead to sustainability.

We are currently failing to invest sufficient capital in the repair and rehabilitation of the environment. As Figure 1 indicates, excessive consumption of resources, combined with inadequate effort at environmental repair, puts society on an irretrievable path *away* from sustainability. That will be the case if resource consumption escalates rapidly and environmental degradation increases at an uncontrollable rate.

The conceptual nature of the analysis here precludes precise policy prescriptions. Nonetheless, we illustrate the potential for major environmental problems; these problems can be avoided only by facing up to the urgent need for remedial work to reduce the rate of environmental degradation.

Conclusions

The model shows that under the minimal and reasonable assumptions of the partial derivatives given in equations (11) and (13), there exists a sustainable equilibrium. On the other hand no restrictions were placed on the nature of the two functions, which may be nonlinear in general. Note also that the intertemporally sustainable equilibrium does not rely on a competitive equilibrium as a benchmark, as is usually the case in conventional economics. Nor does the equilibrium rely on discounting, which is ethically unacceptable to many economists and philosophers. The obtained sustainable equilibrium is such that the quality and quantity of environmental resources available can to some extent be maintained through remedial action. We have concentrated here on those (limited) instances in which some element of the environmental damage is repairable. We do not seek to suggest that such cases are in the majority, but nonetheless they are an important subset of environmental problems, and one which has received relatively little attention.

The laws of thermodynamics preclude us from leaving the world intact. For many of the environmental resources we use, some degradation is unavoidable. In these cases it is incumbent on us to use the profits accruing from the use of the resource to accumulate human-made capital that can provide alternative sources for the commodities or services yielded by the natural resource. A corollary of this is that if consumption of an environmental resource cannot yield sufficient profits (or rents, as the economists say) to meet this objective, then its use

under current technology is inappropriate. However this raises the important question as to whether human-made capital is a good substitute for natural capital. In many cases it would appear not to be the case, contrary to the general belief of neoclassical economists.

There are though many instances in which the Laws of Thermodynamics do not prevent a satisfactory reinstatement of the natural environment to a condition in which it can yield services on a sustainable basis. The natural environment cannot be restored to its pristine condition. There are, however, other instances in which we can indeed repair the damage to an extent that minimises the loss of amenity to future generations. We seek in this paper to raise the issue of restoration, and to look at its implications for environmental policy. The model in this paper suggests that sustainable development is indeed feasible but requires a *commitment* of financial resources for repairing environmental damage.

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Acknowledgement

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Announcements

Orbital Decomposition v 1.2 (by A. F. Peressini & S. J. Guastello) is now available for free downloads. ORBDE, which based on principles of symbolic dynamics, identifies recurring patterns of events in categorically-defined data. The analysis finds the optimal length of patterns, and lists the recurring patterns at that length. The final statistics include the string length, topological entropy, the (largest) Lyapunov exponent, fractal dimension, Shannon entropy, and a chi-square test for goodness of fit. See Resources for Students and Teachers, www.societyforchaostheory.org/tutorials and slide down to Menu 4. The GEMCAT program (by R. Lange & T. A. Oliva) for catastrophe analysis is also available from the same menu.

# # #

Calls for Papers

The next meeting of the **Australian Mathematical Psychology Conference** will be held on February 18-20, 2011 at Melbourne Victoria, Australia. Please visit the website at http://www.psych.unimelb.edu.au/AMPC2011/ or send to daniel.little@unimelb.edu.au. Deadline for submission of abstracts is January 15, 2011.

The 25th Annual Symposium of the **Society for Research in Adult Development** will be March 29-20, 2011. This international society addresses positive adult development from all disciplines. Positive adult development refers to development starting in late adolescence and continuing through life. The focus is on expanded capabilities and changes that improve the quality of life. Topic areas include: Measurement, Models and Methodological Issues; Professional Development; Altruism, Attachment, and Alienation; Periods, Seasons and Non-stage Development; Stage Change; Cultural and Societal Development.
Call for submissions http://www.adultdevelopment.org/

# # #

Call for Nominations for the Robert J. Glushko Dissertation Prizes in Cognitive Science

The Cognitive Science Society and the Glushko-Samuelson Foundation seek nominations for up to five outstanding dissertation prizes in cognitive science. The goals of these prizes are to increase the prominence of cognitive science, and encourage students to engage in interdisciplinary efforts to understand minds and intelligent systems. The hope is that the prizes will recognize and honor young researchers conducting ground-breaking research in cognitive science. The eventual goal is to aid in efforts to bridge between the areas of cognitive science and create theories of general interest to the multiple fields concerned with scientifically understanding the nature of minds and intelligent systems. Promoting a unified cognitive science is consistent with the belief that understanding how minds work will require the synthesis of many different empirical methods, formal tools, and analytic theories. 2011 is the inaugural year of this annual prize. Up-to-date information on the prizes can be found at http://cognitrn.psych.indiana.edu/CogSciPrizes/index.htm. Nomination Deadline: January 15, 2011

Little Known Facts and Circumstances of the Society's Roots

Editor's note: This Newsletter feature is a sp(I)ace to co-create our organizational memory by becoming (more) aware of our history and making it at the same time. Tell us about the past emergences you're aware of – research and interest groups, partnerships, new departments, all the dynamics that fed and still feed this Society's constellation. Recollections galore are especially invited from pioneers in the Society! In this issue, one such pioneer shares an excerpt from a autobiographical paper he is writing.

Excerpt from My Life in Chaos

Allan Combs

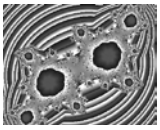
Chaos theory actually dates back to the 1890s when Henri Poincaré articulated the 3-body problem, but it really caught hold in the late 1980s when René Thom's catastrophe theory, actually developed in the 1960s, combined with the new concepts of attractors and bifurcations to create an entire nonlinear view of the physical world. It was a view that was both exciting and threatening, depending on how you liked to view the world. Some scientists, who relied on the absolute predictability of nature to ply their trade, met chaos theory and nonlinear dynamics with angst because it indicated that nature was no longer subject to precise prediction; no longer reliable. A surprising number of philosophers found themselves in the same camp. For them the comfortable reliability of the clockwork universe was giving way to the prospect of a world without order. For folks like myself, however, the idea of a cosmos in which one could not know the outcome of every single event in advance was a welcome relief from the vice grip of the traditional mechanistic worldview. Though physical events were still technically "deterministic," the whole thing seemed now much less like a machine and much more like a living organism. Free will remained a distant hope for philosophers and mathematicians, but the old mechanistic theories of the brain, mind, and behavior were dead on their feet, and for a scientific humanist like myself the situation could hardly have looked better.

In the fall of 1989 a colleague at my liberal arts college returned from an American Psychological Association meeting in Boston to tell me about an interesting session he attended there on the topic of chaos theory and psychology. He knew that I had been reading about chaos theory and systems science, and he supposed that I would be interested in attending a similar meeting the organizer, Larry Vandervert, was planning to hold at the next APA conference in San Francisco during the summer of 1990. I was indeed interested, though I had long since developed a distaste for big meetings, and I replied that I would probably not be attending this one. A few months later, however, I changed my mind, thinking that this would at least be a good excuse to visit old friends in the Bay Area. I called

Larry Vandervert at his home in Spokane to see what he was planning. Initially he told me that he had decided not to organize another chaos theory session, but a few weeks later he called back to say that he had changed his mind and was thinking of organizing a meeting. This one would not be a discussion group at the APA convention, but rather an inaugural meeting of a new organization, which we tentatively named The Society for Chaos Theory in Psychology. He hoped that the Saybrook Institute, in San Francisco, might host our gathering during the week prior to the APA convention, and I agreed to call Stanley Krippner, a faculty member there, to see what could be worked out. Over the years to come I was to discover that Larry was an excellent organizer but a very private person. I never learned how he knew that Stanley Krippner would be interested in our gathering, but I did my part and gave him a call. To my delight he was quite friendly, but he told me that he just returned from a trip to South America where he was working with a shaman and he needed a day or two to get his feet on ground. Sure enough, one or two days later he called back to say that the president of Saybrook had approved our meeting and we could use their facilities. We were off and running!

As I said, Larry was a private person, and it was years later that I discovered he had also conscripted Fred Abraham, a neural psychologist, EEG expert, and brother of GERG member Ralph Abraham, above, to help get the meeting organized. Fred had written the first book on chaos theory and psychology, which David Loye reviewed for World Futures. Larry, Fred, and I worked together to invite colleagues by phone and by email to participate in the meeting. It seemed, however, that this meeting was already just waiting to happen, because email inquiries about it came in from all around the U.S. as well as from Europe and Asia. The hundred or so folks who actually showed up ranged from California artists to European robotics engineers, but most were psychologists and other social scientists interested in applying ideas from chaos theory to their own fields. Stanley Krippner, fast becoming one of the world's leading scholars on the psychology of consciousness, gave a plenary talk on the importance of nonlinear dynamics in understanding the mind and behavior.

Another plenary speaker, Karl Pribram, already established as one of the leading brain scientists of the 20th century for his work on the holographic brain and other topics, emphasized the importance of pursuing a balance between traditional linear dynamics and the new nonlinear or chaotic dynamics. David Loye spoke about the future of the organization we were founding, and stressed the importance of gender equality in its activities and administration. During the conference I did the public introductions and Larry did most of the behind the scenes organizing. Fred sped about coordinating and gathering people into groups based on interest, generally facilitating the whole process. It was quite an exciting event, and in the end we created an enduring organization that, to include everyone present, would come to be call itself The Society for Chaos Theory in Psychology and the Life Sciences, which acquired its own professional journal a few years later titled Nonlinear Dynamics: The Journal of The Society for Chaos Theory in Psychology and the Life Sciences. Personally I would have preferred titles that were less long and awkward, but at least it was evident that everyone got in their two cents worth. During the official banquet I met Sally Goerner, a graduate student at Saybrook who would become a longtime friend. Sally (1999, 1994) has since established herself as a leading complexity theorist working in areas as diverse as city planning, green economics, and the design of creative and sophisticated educational programs for primary school children.

We want to see  **you in Orange!**

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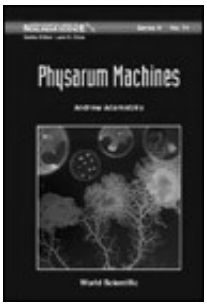
Adamatzky, A. (2010). Physarum Machines Computers from Slime Mould. ***World Scientific Series on Nonlinear Science, Series A - Vol. 74.*** ISBN 978-981-4327-58-9. A Physarum machine is a programmable amorphous biological computer experimentally implemented in the vegetative state of true slime mould Physarum polycephalum. It comprises an amorphous yellowish mass with networks of protoplasmic veins, programmed by spatial configurations of attracting and repelling gradients.



This book demonstrates how to create experimental Physarum machines for computational geometry and optimization, distributed manipulation and transportation, and general-purpose computation. Being very cheap to make and easy to maintain, the machine also functions on a wide range of substrates and in a broad scope of environmental conditions. As such a Physarum machine is a 'green'and environmentally friendly unconventional computer. The book is readily accessible to a nonprofessional reader, and is a priceless source of experimental tips and inventive theoretical ideas for anyone who is inspired by novel and emerging non-silicon computers and robots. See an account on Physarum Machines at http://www.youtube.com/user/PhysarumMachines.

-from the publisher

Hofkirchner, W. (2010). ***Twenty questions about a unified theory of information: A short exploration into information from a complex systems view.*** **Litchfield Park, AZ: Emergent Publications.** ISBN 9780984216475. [Editor's note: Emergent Publications was formerly ISCE Publishing. Kurt Richardson heads up Emergent too.]

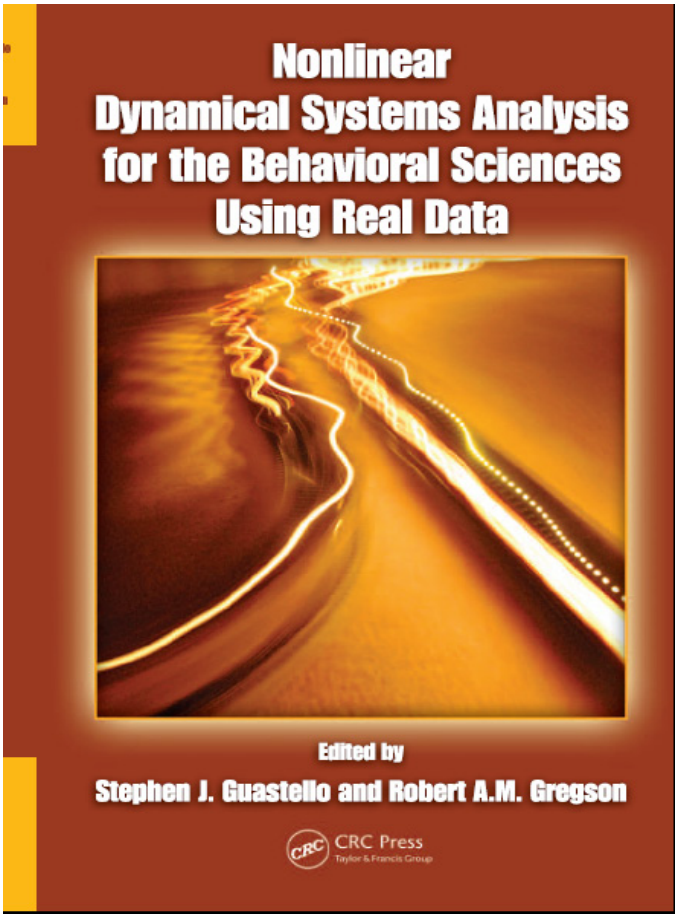
While a considerable number of scientists still today disbelieve in the feasibility of a single generic concept of information, there are several attempts to hypothesize or theorize information in a unifying manner carried out by a strong minority of scientists. However, the camp of the "unifiers" itself is heterogeneous.

The 'Unified Theory of Information', as Wolfgang Hofkirchner came to term his own approach, links information to self-organization. It elaborates on arguments of dialectical philosophy in order to avoid both the pitfalls of reductionism and dualism and seeks to reconcile the 'hard' and 'soft' science perspectives of information. Among the scholars who influenced his sciences of complexity approach are– Edgar Morin, Ervin Laszlo, Werner Ebeling, Klaus Fuchs-Kittowski, Klaus Kornwachs, Klaus Haefner, Tom Stonier, John Collier, Alicia Juarrero, Edwina Taborsky, Søren Brier, Claus Emmeche, Robert Logan. – From the publisher.

Kautz, R. (2010). Chaos: The science of predictable random motion. Oxford: Oxford University Press. ISBN: 9780199594580. Based on only elementary mathematics, this engaging account of chaos theory bridges the gap between introductions for the layman and college-level texts. It develops the science of dynamics in terms of small time steps, describes the phenomenon of chaos through simple examples, and concludes with a close look at a homoclinic tangle, the mathematical monster at the heart of chaos. The presentation is enhanced by many figures, animations of chaotic motion (available on a companionCD), and biographical sketches of the pioneers of dynamics and chaos theory. To ensure accessibility to motivated high school students, care has been taken to explain advanced mathematical concepts simply, including exponentials and logarithms, probability, correlation, frequency analysis, fractals, andtransfinite numbers. These tools help to resolve the intriguing paradox of motion that is predictable and yet random, while the final chapter explores the various ways chaos theory has been put to practical use. - from dadirect.com, by way of RMG.

Richardson, K. (2010). ***The evolution of intelligent systems : How molecules became minds.*** **London: Palgrave Macmillan.** ISBN: 9780230252493. How did we get from unconscious material forces to the dazzling intricacy of the human mind? Standard evolutionary theory has not provided us with a continuous picture of that long emergence. In consequence, psychological theories remain highly fragmented, without deeper roots or foundations, while the general public either remain confused, or invoke miracles or the hand of an intelligent designer. This book provides new concepts from dynamic systems theory, and the new evolutionary synthesis, to present a comprehensive overview of the evolution of cognition. It combines ideas about complexity and environmental structure to highlight the emergence of intelligent systems very early in evolution. Intelligent systems came to dominate evolution through increasing complexity, including cell signalling, epigenetics, developmental systems, behaviour, brain and cognitive systems, to culminate in the human cognitive and other mental systems. This volume has fundamental implications for psychological theory and our understanding of humanity. – from dadirect.com, by way of RMG.

Coming Soon from **C R C Press** www.crcpress.com *and the* **Society for Chaos Theory in Psychology & Life Sciences***



Nonlinear Dynamical Systems Analysis for the Behavioral Sciences Using Real Data examines the techniques proven to be the most useful in the behavioral sciences. The editors have brought together constructive work on new practical examples of methods and application built on nonlinear dynamics. They cover dynamics such as attractors, bifurcations, chaos, fractals, catastrophes, self-organization, and related issues in time series analysis, stationarity, modeling and hypothesis testing, probability, and experimental design. The analytic techniques discussed include several variants of the fractal dimension, several types of entropy, phase-space and state-space diagrams, recurrence analysis, spatial fractal analysis, oscillation functions, polynomial and Marquardt nonlinear regression, Markov chains, and symbolic dynamics.

A compilation of research methods and reflecting the expertise of the major contributors to NDS psychology, this book examines the techniques that have proven to be most useful in the behavioral sciences. This book is designed to develop skill and expertise in framing hypotheses dynamically and in building viable analytic models to test them. It addresses topics and methods of current interest in an application driven manner, making the book useful to the behavioral sciences community, as well as those in engineering, medicine, and other fields who are interested in nonlinear dynamics. The authors provide a generous supply of instructions for operating some of the most popular software for nonlinear dynamics analysis.

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