YLEM

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Artists Using Science and Technology

CHAOS, COMPLEXITY, AND ACCIDENT

from the editor

Chaos, Complexity, and Accident

Last year when I guest edited the Ylem Newsletter, I found myself waxing nostalgic. I had put together a collection of pieces from the issues of Ear Magazine that I had edited in the early Eighties.

I found myself writing in that editorial: “Back then there was wide-spread belief in revolution, and in progress in art. Now, we have anything goes, but the hope of changing the world through art is gone.” (The printed version of this gloomy pronouncement said “word” instead of “world”, a manifestation of chance operations.)

At that time, I was showing my film painting work in restaurants, which I didn’t think were the right venue for my work. And I felt very isolated from the art world. While most of the artists I met were concerned with self-expression, I was finding in my work, which was created at almost a microscopic level, another world of mystery and enticement that I was gingerly exploring.

My negative attitudes were severely shaken, however, when I attended an Ylem Forum organized by Trudy Myrrh Reagan in May of this year. Showing slides was Grant Elliott, who explained that these were images he discovered accidentally while employed by Hewlett Packard as a scientist charged with eliminating the defects in crystals being grown for use in computers.

As I wandered about San Francisco’s art district the following Thursday night, I found myself haunted by Grant’s images, which seemed to me to overshadow in power and complexity the paintings and photographs in the galleries. Grant’s pictures suggested a world that continued on infinitely, and that was filled with endless wonder.

I looked forward to the next Ylem Forum, and saw in the announcement that it would feature Ralph Abraham, professor of Mathematics at the Visual Math Institute of U. C. Santa Cruz, and author of the book ***Chaos, Gaia, Eros***. I grabbed the book and read up. I found that there had been a revolution in science that I had not heard about in the art magazines I had been reading.

It seems that science has throughout its history been reductivist, seeking to master the universe by reducing it to a few mathematical formulas. The new trend in science is toward celebrating chaos and complexity, expanding rather than contracting into specialization. In the process of these explorations, which have been made possible by the computer, scientists have discovered that their higher mathematics has a visual component, and that the resulting images just happen to be gorgeous. Here again is a world of mystery and intricacy, which was waiting for science to create the tools to discover it.

Powerfully excited by what I saw as the first valid trend in art in the last fifty years, I began putting out feelers for an issue of the Ylem Newsletter on Chance Operations in the Visual Arts. I asked Grant and Ralph for pieces, and they gave me write-ups based on their Ylem Forum presentations.

In the process of browsing the Ylem web page <www.ylem.org> I discovered a web page belonging to Cliff Pickover, a member of Ylem’s advisory board. His page was full of fractals, the graphic representation of chaos theory. I asked him for an article, which he faxed me immediately. Rather than being about fractals, Cliff’s article described virtual creatures which he had discovered/created as the result of an error in a computer program.

In the process of reading the article, I discovered that Cliff is an IBM programmer from Yorktown Heights, NY, who has written umpteen books which consist of amalgams of fractals, equations, science fiction, and whimsy. He suggested other contributors, and opened up to me the vast fractal universe.

Many people sent me articles, too many manuscripts for one issue of the Newsletter, so I’m holding them in abeyance for further issues. But the three articles in this issue are a good introduction to the concept of chance in art, dealing as they do with phenomena outside the self which artists of the modern period have been so concerned with expressing.

Loren Means
http:// www.slip.net/~means

I show my work regularly at Artisans Gallery, 78 E. Blithedale Ave., Mill Valley, CA. My son Daniel (my PhotoShop guru) and I will have a two-man show at Pacific Grove Art Center, 568 Lighthouse in Pacific Grove, CA, Jan. 14-Feb 12, 2000.

Cover: A. Grant Eliot. *Star Burst. 1995.* Photomicrograph:Ilfochrome Print. 13”x19.”

members' news

Barbara Plowman at the control panel of a scanning electron microscope. The electron microscope is the cylinder to the far right. Ylem field trip, October 30, 1999. Photo by Robert Ishi.

In November, Ylem members visited the Electron Microscopy Lab at the Dental School of the University of the Pacific run by **Barbara Plowman**. After reviewing the several instruments in her cloister, we gave her the small specimens we had brought, which she mounted and coated with a thin platinum-paladium film. Then we viewed them on the screen of the scanning electron microscope (SEM) at various magnifications. Goose down, alpaca yarn and a paper wasp nest section all held surprises for us. She made Polaroid photos of each specimen for the participants.

Craig Newmark (recently featured in *Time*), founder of Craig's List, spoke at the Computer Professionals for Social Responsibility conference called "The Internet Gold Rush of '99" at Stanford University. His topic: the challenge of following socially responsible goals in an industry drowning in venture capital.

Nina Cohen was awarded the Volunteer Recognition Award at SFMOMA funded by Carole and Robert McNeil. It consists of a certificate, $25,000 donated in the volunteer's name and the gift of a commissioned work of art. The McNeils are interested in encouraging volunteer work. This is the first time that it has been given and Nina's work in the library was selected. Nina initiated a sale of material not needed by the museum library and has been conducting it for ten years.

(Continued on page 7)

forum and meeting

Ylem Membership Meeting Wednesday, January 26, 7:30-8 pm. in the Big Classroom (follow the signs) at the Exploratorium, 3601 Lyon St., San Francisco. There will be a progress report from President Trudy Myrrh Reagan on Ylem's new long-term plans plus voting for Ylem's Board of Directors. Please be there and vote! We need a quorum!

The Ylem Forum 8:00 pm

Program:

Hey, Listen Up!, an urban eco-literacy project that **JoAnn Gillerman** has co-developed, includes a multimedia CD-ROM and high-school curriculum about environmental racism. To create it, the team conducted on-site multi-media workshops in inner-city Los Angeles, CA and a locally-produced interactive CD-ROM created in partby the participants of the L.A. communities involved. ***Hey, Listen Up!*** is sponsored by the Urban Habitat Program of Earth Island Institute, S.F., CA is an Urban Eco-Literacy Project produced by JoAnn Gillerman and Belvie Rooks.

JoAnn Gillerman, Professor of electronic arts at California College of Arts and Crafts, is a media artist working with Interactive Multimedia Exhibits, Installation, CD-ROM and Internet, Video, and Performance. For many years, a passion has led her to continually produce many multimedia works and video tapes of total solar eclipses and active volcanoes that she chases and records on location. She recently co-produced an interactive multimedia ***Innovation Forum*** exhibit (installed permanently in The Tech Museum of Innovation, San Jose, CA.) which provides information and solicits real-time visitor's comments on issues of Innovations in technology, new explorations, how technology has changed the quality of our lives and surrounding ethical issues that accompany innovations. She has had other recent shows and installations in Dallas, Montreal and Paris.Website: <http://www.viper-vertex.com>

(Continued on page 7)

Accident, Evolution, and Art

Clifford A. Pickover

One sign of an interesting program is that you cannot readily predict its output. Brian Hayes

Controlled Accident

A few years ago I generated a number of protozoa-like forms that started as a pure accident -- a computer programming bug. Since then, many researchers and hobbyists around the world have written about these forms. Even the Scientific American has reported on the subject. I wonder how many researchers and readers realized that it all started by mistake.

I have always been fascinated by the idea of "controlled accident" in science and art. Only relatively recently has the break between artistic and scientific pursuits become so apparent. Whereas earlier thinkers such as Leonardo da Vinci pursued science and art in the light of guiding principles such as harmony and proportion, today some hold the view that the scientific way of life stifles the artistic spirit.

Nevertheless, the computer is a machine capable of creating images of captivating beauty and power. In this short article, I include visually interesting forms discovered in the course of studying certain iterated equations; the process can be thought of as mathematical feedback loops. In somewhat the same spirit of the paintings of Jackson Pollack and Louis Daguerre, and the music of John Cage, these figures represent controlled accidents. The notion of using mathematical feedback loops on real or complex numbers to produce artistic results is not new -- as evidenced by the growing number of papers in the scientific and popular literature The secret or "trick" often is to find just the right equations to produce interesting behavior.

As review, recall that computer graphics provides a way to represent natural objects. Algorithms are now available for these representations, and many involve the use of random numbers to obtain irregularity and fuzziness. Fractals, for instance, have been useful in the generation of mountains with startling realism.   The peaks and valleys of these mountain ranges, as well as the texture of their slopes, are determined using controlled randomness.

Other natural inanimate objects successfully generated by algorithms employing random perturbations include wood grains and stone walls. Researchers have also explored the use of rules based on the laws of nature, such as logarithmic spirals for sea shells or tree branching patterns determined from the study of living specimens. In this article, I describe an algorithm (which uses neither random perturbations nor natural laws) to create very complicated forms resembling invertebrate organisms. The iteration, or recursion, of mathematical transformations is used to generate biological morphologies. I call them "biomorphs." Interestingly, at the same time I coined "biomorph" for these patterns, the famous evolutionary biologist Richard Dawkins used the word to refer to his own set of biological shapes that were arrived at by a very different procedure. More rigorously, my "biomorphs" encompass the class of organismic morphologies created by small changes to traditional convergence tests in the field of "Julia set" theory. These methods are described below. For a detailed description and

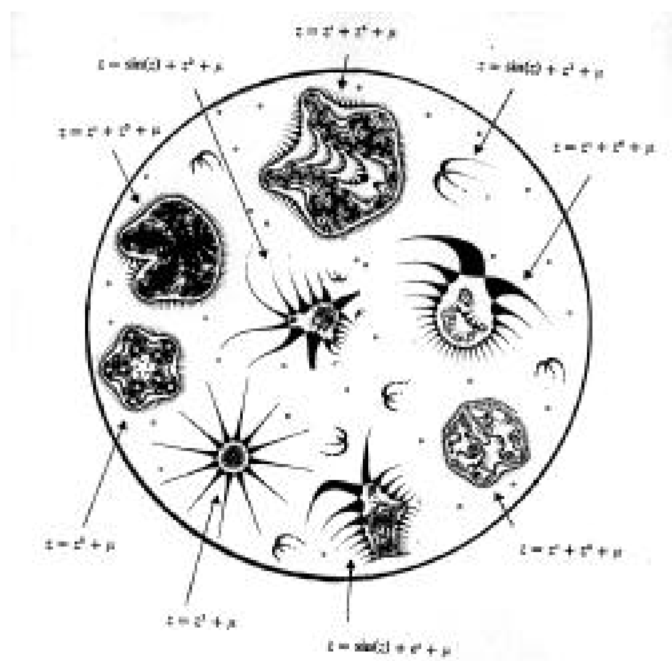

Figure 1. The Biomorph Zoo [1]

application of Julia set theory, see Benoit Mandelbrot's *The Fractal Geometry of Nature:* In this article, I chose illustrations as examples of the diversity of biological structures which result from this technique.

Mathematical Framework

Let's discuss the algorithm that generates of patterns with striking beauty and complexity. The mathematical principles underlying the graphics generation involved the iteration of algebraic transformations in the complex plane.

Consider, as an example, the polynomial transformation in the complex plane:

$$f(Z) = Z^Z + Z^6 + \quad [1]$$

where   is a constant. Both Z and   are complex numbers. For each initial point, Z_0, the function $f(Z)$ is iterated as follows:
.

$$Z_0 = Z,$$
$$Z_1 = f(Z),$$
$$Z_2 = f(f(Z)),$$
$$Z_3 = f(f(f(Z))),$$
$$\ldots$$

$$Z_z = f(\ldots f(f(Z))) \quad [2]$$

The mathematical repetition reminds me of Russian dolls within dolls. The sequence of numbers produced by this mathematical feedback loop may grow ever larger (i.e., they diverge to infinity) or may remain bounded (i.e., they do not diverge). The behavior of the sequence depends on the coordinates of Z_0 and .

I test the behavior of the mapping by determining whether or not resultant Z's in the equation get above a particular threshold value . The black regions in the graphic displays represent those initial points (Z_0) that do not eventually explode to infinity. I considered points in the Z plane to have bounded behavior if either the real or imaginary component of Z is small after z iterations:

$$|Z_{real}| < \quad \text{or} \quad |Z_{imag}| < \quad [3]$$

The application of the strange criterion in Eq. 3, which started as a computer programming accident, gives rise to the cilia and various appendages seen in each of the figures, and without this specific test, most of the figure disappears. The number of iterations, z, for the pictures is 10. Typical parameter values are: (= 0.5,   = 0.0), for the real and imaginary components of the complex constant;   = 10, ($-2 < Z_0$(real) < 2) and ($-2 < Z_0$(imag) < 2).

Creation and Search in the Manifold Dimensions of Space

In order to search for biomorphs within an infinitely large parameter space, I developed software tools that allow users to explore the complex plane in an interactive manner. I normally start by setting large picture boundaries ($-10 < Z_0$(real) < 10 $-10 < Z_0$(imag) < 10). With this "magnification," often a small biomorph or other indistinct "dust speck" appears that can subsequently be examined under higher magnification (i.e., for smaller regions of the complex plane). A mouse-driven cursor enables the user to magnify regions of interest in the display in an interactive manner. Variables such as z and   may be entered at the terminal keyboard, and all parameters are printed and updated on the graphics screen.

Currently, the search is performed manually, and it is initially started at low resolution to save CPU time. It also might be possible to design a program to automatically search abstract geometric space for "signs" of structures resembling living forms, and this task is an interesting future research issue.

I chose the structures shown in Figure 1 (page 3) to give you an idea about the variety of organismic morphologies produced by this technique. While the resemblance of the "creatures" to their natural counterparts is only in spirit rather than details, many resemble unicellular protozoa with their various organelles, or aquatic crustaceans. The bilateral symmetric Z^Z shapes resemble ciliated larval forms of several marine organisms. The radial 12-armed symmetric structure (Z^3) is similar to the Sarcodines protozoa with thin pointed pseudopodia.

Note that identical equations can give rise to very different looking biomorphs since the biomorph structure depends on parameters such as the value of as well as the particular equation used.

In nature, organisms are constructed upon patterns of organization that have been tested and proved through immense periods of competition and differential survival. In the biomorph sets, biological shapes are generated in certain pockets of geometric space from mathematical feedback loops. The biomorph zoo (Figure 1, page 3) has a mysterious quality, partly due to the fact that in some sense the mathematical creatures exist. These objects inhabit the complex plane -- though they resemble microscopic organisms that we could easily imagine flourishing in a drop of pond water. The complex shapes in nature and in the biomorph zoo result from repeated application of simple dynamic rules. A natural question is whether "higher" life shapes can be found by searching spaces defined by more complicated equations, in other words, by examining pockets of more intricate abstract geometric space; this too provides a provocative avenue of future research.

In summary, I have described an algorithm that can be used for the creation of diverse and complicated forms resembling invertebrate organisms. The shapes are complicated and difficult to predict before actually experimenting with the mappings. I hope these techniques will encourage you to explore further and discover new forms, by accident, that are on the edge of science and art.

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http://www.pickover.com

Footnote
1.
Figure 1. The biomorph zoo. I chose several examples to illustrate the diversity of biological forms that can result from the iteration of mathematical transformations. The forms were found in the abstract geometric space indicated by the equations. I should emphasize that their organic quality was not produced through the use of random perturbations, explicit rules based on the laws of nature, or artistic intervention by hand. A mouse-driven cursor allows me to search for and magnify particular pockets in a vast mathematical space which literally teem with these forms. Interestingly, within the "belly" of many of the forms reside tiny baby replicas of the host biomorph. Within the baby-forms reside additional organismic shapes, and so on to infinity...

References

Mandelbrot, B. B. 1982. ***The Fractal Geometry of Nature***,Freeman, San Francisco.

Some of my own books on fractals include:
Chaos and Fractals: A Computer-Graphical Journey (Elsevier, 1998),
The Loom of God. (Plenum, 1997),
Fractal Horizons: The Future Use of Fractals: (St. Martin's Press, 1996),
The Pattern Book: Fractals, Art, and Nature (World Scientific, 1995),
Keys to Infinity (John Wiley, 1995),
Chaos in Wonderland: Visual Adventures in a Fractal World (St. Martin's Press, 1994)
Mazes for the Mind: Computers and the Unexpected (St. Martin's Press, 1992),
Computers and the Imagination: Visual Adventures from Beyond the Edge (St. Martin's Press, 1991),
Computers, Pattern, Chaos, and Beauty: Graphics from an Unseen World:ehp1., (St. Martin's Press, 1990).

Please see my web page, <http://www.pickover.com> for more examples of accident and art. xxxxxx

For the latest in news and events see our site: www.ylem.org/NewSite/news/Calendar.html

Some calendar items are reprinted from Art Calendar (the monthly marketing and career management journal for artists, P.O.Box 199, Upper Fairmont, Md; Subscriptions $32/yr), Artweek, Leonardo Electronic Almanac, Artech <artstech@the city. sfsu.edu>, and Fine Arts Forum Online <paulbrown@siggraph.org>.

We cannot verify all information sent to us. Please inform us of incorrect information.

All events and exhibits are in the San Francisco except where noted.

We want your announcements!

To insure that they appear in the next newsletter send 6 weeks before the publication date. Announcements may be e-mailed to Lewis Bangham at Banghaml@ hotmail.com. Also send notices to the Ylem website, mariusj@pacbell.net where they can appear on shorter notice. Please see web site guidelines.

For a more comprehensive and up-to-date calendar, please visit our web site at http://www.ylem.org Click on News and Events and then on Calendar.

Conference

The International Society of the Arts, Mathematics and Architecture (ISAMA 2000) is having their Second Annual Conference August 21-25, 2000 at theUniversity of Washington Seattle, Washington. ISAMA 2000 will bring together artists, mathematicians, and architects as well as teachers, computer scientists, musicians, writers, choreographers and poets to explore the opportunities at the intersections of these fields. To encourage interdisciplinary education at an early age, the last day and a half of ISAMA 2000 will feature K-12 teacher workshops. Complete details about the conference are available at <http://www.cs. washington.edu/isama2000/ >

Call for Papers

ISAMA 2000 offers an opportunity to present and publish selected and refereed papers in the Conference Proceeedings. For information about paper submission visit <http://www.cs. washington.edu/isama2000/ cfp.html>.

Affiliate Artists program

Deadline: January 1, 2000
Headlands Center for the Arts (HCFA) is jurying for new (Bay Area) Affiliates for their Affiliate Artists program. > If accepted, the artist is offered the opportunity to rent subsidized day studio space (now it's for up to 2 years) and may participate in all events created for and by the international HCFA community, including monthly dinners for the residents and affiliates, open studios and other presentations, a seasonal newsletter, etc. It's an opportunity to have a quiet space to create, away from home
and office, as well as to interact with other artists and with the beautiful protected environment of the Headlands. If you or a friend or colleague would like full information about requirements for submission, please call or write Holly Blake, director of the residency program at:
phone: 415-331-2787
address: 944 Fort Barry, Sausalito CA 94965
or visit the HCFA website at www. headlands.org

First Call for Abstracts / Papers

Shaping theNetwork Society
The Future of the Public Sphere in Cyberspace
DIAC-00
A Directions andImplications of Advanced Computing (DIAC) Symposium
Sponsored by Computer Professionals for Social Responsibility
May 20 - May 23, 2000., Seattle, Washington, USA

Through January 23, 2000
Museum of American Heritage
Robots!
A nostalgic look at robot toys and movies since 1925. Some working models, including research tools. Not open often:11 am–4 pm F-S-Sun.
Museum of American Heritage, 351 Homer St., Palo Alto, CA
94301;
650-321-1004

The Exploratorium's new art and performance series.
Second Wednesdays, 7 pm
Jan. 12, ***Table Series,*** a performance by Sam Mitchell, Sarah McLennan, and Steve Hunter.
Museum floor at Exploratorium, 3601 Lyon St., San Francisco, CA
415-561-0362; calendar available online: www.exploratorium.edu

Through January 2, 2000
Palo Alto Art Center
Televisors and Early Motion Picture Technologies
by Steve Gompf, a rapacious collector of televisors,which, according tohim, are rare, often quaint mechanical televisions produced between 1884 and 1928. The artists uses these televisors to display "digitally manipulated re-animation" of Victorian photographer Eadward Muybridge.
Palo Alto Art Center, 1313 Newell Rd., Palo Alto, CA
94303;
650-329-2366 xxxxxx

(From Members' News page 2)

These sales have raised a significant amount of money for the library and the event is a good tie to the community.

Leonardo Electronic Almanac formally launches its Pioneers and Pathbreakers project with _LEA_ Volume 7, Number 9. The exhibition "Electronic Rituals" - a 2-D and multimedia exhibition in the Minnesota-based Intermedia Arts Cafe Gallery - is curated by artist **Joan Truckenbrod**, and will include work by Dan Sandin, Muriel Magenta, Rebecca Allen, **Joan Truckenbrod**, **Ken Knowlton**, Herbert Franke, and **Barbara Nessim**. "Electronic Rituals" explores the artworks in a context that encourages the exploration of the time period in which the work was created, and recognizes the influences that the works and the artists have on each other.

Speaking of **Barbara Nessim**, the U.S. Postal Stamp she designed (.40¢ for a .33¢ stamp, with the extra to go to breast cancer research), has sold 67 million, raising $5,200,000 for research into this disease.

This fall, **Yoshiyuki Abe** displayed 45 prints at gallery Fleur, Kyoto Seika University in Kyoto. In December, he will show six recent works at gallery Chika in Tokyo. A computer artist, Yoshiyuki does math-based algorithmic images.

At Zeum, the art and technology center for children at San Francisco's Yerba Buena Center, **Rhoda Grossman** shows the kids how to scan images and transform them with the computer in the Cyber Studio there.

A sculpture by **Bruce Beasley** has been installed at the Mathematical Sciences Research Institute in Berkeley. His bronzes, which look like geometric crystals doing ballet, were also seen at Kouros Gallery in New York during September.

Canessa Gallery, host of three Ylem shows in recent years, still lives! **Zach Stewart** maintains this informal gallery in San Francisco as part of his architectural office. It is a non-profit in a particularly historic building beside the TransAmerica Pyramid. Unfortunately, it is so old that it required extensive seismic retrofitting which may double the rent. "I'll hold on as long as I can!," says Zach.

Cliff Pickover just published a new book on the fourth dimension. It covers topics ranging from string theory to the religous implications of higher dimensions. The book title is Surfing Through Hyperspace: Understanding Higher Universes in Six Easy Lessons (Oxford University Press).xxxxx

(From Forum and Meeting page 2)

Art as Activism, an aspect of Art and Ecology by **Theo Ferguson**. Theo Ferguson will address the issue of what constitutes ecological art in the new millenium through the works of contemporary artists such as Agnes Denes and her own work with "Still Standing."

Theo Ferguson is an artist and educator teaching Teachers Stewardship, Sustainability and Value Formation in Young People. She has been involved for years in promoting sustainability. She once ran a company linking makers of windmills with communities in need of wind-powered water pumps in several Asian countries.

The Fat of the Land, a video by Sarah Lewison and Niki Cousino that features a goofy trip across these United States in a car fueled by deep fry fat from truck stops and fast food joints—a not so goofy recycling idea for creating a petroleum substitute. xxxxxx

1.Introduction.

From a simple life as a tropical insect two million years ago, the monarch has evolved one of the most wonderful of nature's phenomena: the monarch migration. We may recount the story of this wonder briefly by following a colony for one year, beginning in the spring, after the winter rest in a special clump of trees high on a mountaintop in Mexico. (Figure 1.)

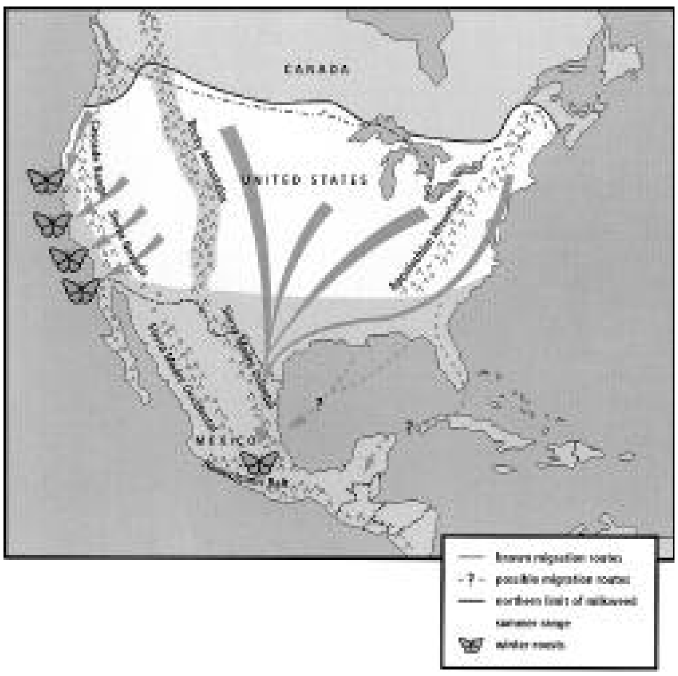


Figure 1. Paths of fall migrations. Western colonies (west of the Rocky Mountains) fly west to the California coast. Eastern colonies fly a longer route to Mexico. From (Grace, 1997, p. 48). Source (Brower, 1995, p. 322). See also (Brower 1996, p. 95).

Step 1. Awake, it is spring in Mexico.
Step 2. Fly 2500 miles north to a favorite summer spot, rich with milkweed fields, in southern Canada.
Step 3. Summer spectacular, sex and reproduction among the milkweeds.
Step 4. All change, it is fall in Canada.
Step 5. Fly south back to the same grove in Mexico.

We might think of this as a day in the life of a monarch colony: wake-up in the morning, go out to play hard all day long, back to bed in the evening when it gets cold. However, it is a year, and many miracles, long. We will focus now on just one of these miracles: Between the monarch that wakes up in the Spring and the one that goes to sleep in the Fall are several generations! Where do they store the road map back to the bedroom?

2. The microcosmic model.

Proceeding further with the day-in-the-life analogy, imagine that I awake one morning, fly to Canada, spend the day picking milkweeds, then fly home in the evening. The return journey is a replay of the morning flight in reverse, and my memory of landmarks along the way guide me home. Tired after a 12-hour journey, I go to sleep. Nothing unusual. However, if I am a monarch colony speeded-up by a factor of 360, then with each hour or two of daylight I have died and been replaced by a child.

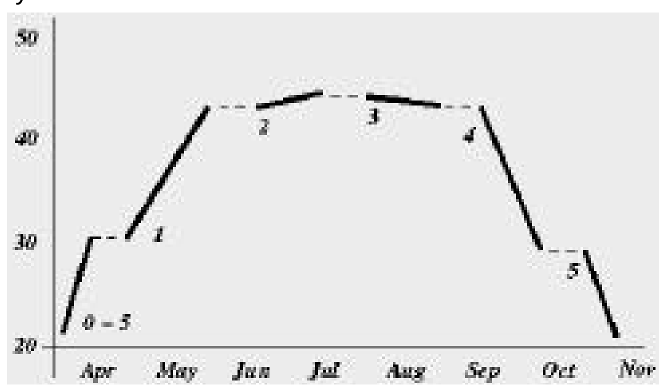


Figure 2. A histomap showing 8 months in the life of an eastern colony of monarch butterflies. Dashed lines indicate the caterpillar phase, and solid lines the butterfly stage, of each generation. Numbers count the generations. When butterfly 5 goes to sleep in Mexico in mid-November, it is the same butterfly, now counted as 0, which awakes in mid-March.

Latitude is indicated on the vertical axis, from 20 degrees North (Mexico City, bottom) to 50 degrees North (Southern Canada, top). Time runs along the horizontal axis to the right, for 8 months, beginning in mid-March.

Details taken from ((Cockrell, 1993), for example, arrival north of 41 degree. in mid-June, average travel speed of 24 km/day, typically 5 generations per season, etc. Also, there is an alternate route below (south of) that shown here, with typically 7 generations of monarchs per season.

Furthermore, during my early life I am a caterpillar, and later a butterfly, and in between I have a total meltdown. (Figure 2. page 8 right)

During all of these life bifurcations, where is my memory of the way home? Sheldrake proposes a morphic field as the storage medium for this knowledge. We might further propose a mathematical model for this field based on chaos theory, that is, a complex dynamical model for a morphic field that functions as a mental field with memory for a colony. In fact, we have already written about such a model in another context, that of the prehistory and history of the human colony on planet Earth, in the book, ***Chaos, Gaia, Eros***.

3. The macrocosmic model.

Now we consider the monarch summer journey as a model not of a day in my life, but of an epoch of human history. The wake-up in the Spring is the creation, told in so many ways in the creation myths of tribes of all times and places. The journey North is the development phase of culture, including stone industries, calendrical and astronomical math, languages, and so on, up until the development of agriculture. The summer among the milkweeds is the Garden of Eden, before the present realization that the environment is finite. And now we must find our way home. But after all these bifurcations, where is our map? Perhaps we have lost our connection to our own morphic fields, and must follow the butterflies. Unfortunately, they are facing extinction.

4. Mathematical foundations of morphum mechanics.

Yes, this section title is a paraphrase of the great classic, ***Mathematical Foundations of Quantum Mechanics***, by John von Neumann (Princeton University, 1955). When this book first came out, it was chosen as a text by one of my professors at the University of Michigan, Erich Rothe. This wonderful book and memorable professor played a pivotal role in my love affair with mathematics and early career. Focusing on the mathematical model for the quantum field, one is not distracted by the formidable question: just what is a quantum field? Proceeding in this fashion with the morphic field, with Peter Broadwell, I created a global-analytic model for the morphic field connecting a dog and her owner, and again for a flock of birds.

Global analysis is a branch of mathematics which emerged during the first half of this century. Its project was to rewrite about half of mathematics as a special case of dynamical systems theory, or chaos theory. In particular, the functions of mathematical physics, such as the fields or states of quantum mechanics, were regarded as infinite-dimensional vectors, and the partial differential equations of mathematical physics--such as the wave equation of d'Alembert, the heat equation of Fourier, the Maxwell equations for the electromagnetic field, and the Schroedinger equation of quantum theory--were considered vectorfields (dynamical systems) on the infinite-dimensional state spaces. This ambitious project resulted in a global unification of mathematics and mathematical physics, without clarifying in any way the real natures of the fields, forces, and mechanics of physical nature.

When the fields and equations of physics are transformed into chaos theory, and then prepared as computer programs for computational studies, the infinite dimensional systems are approximated by finite (but high) dimensional systems of the sort known to the theories of chaos, bifurcations, and complexity as cellular dynamical systems. And this is the approach taken by Peter Broadwell and myself in modeling the morphic field of a fish school or bird flock. In fact, we chose the wave equation as the mathematical foundation for our morphic field models, and thus the models tended to vibrate wildly. We taught our model birds to modulate and demodulate this vibrating field to communicate with each other. And this is the sort of model I am now proposing for a colony of monarch butterflies.

We may think of the ensemble of monarchs as having little motors maintaining a state of continuous vibration in their collective field. When one dies and another is born--these are bifurcations--the field is only slightly affected. (Figure 3.)

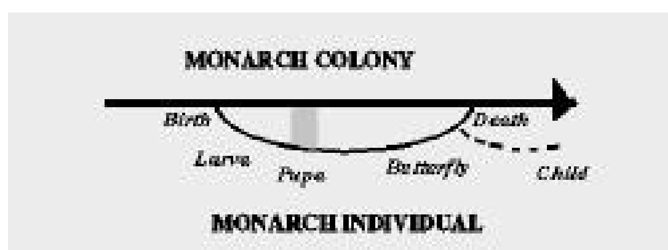


Figure 3. Bifurcation diagram showing attractors of the morphic field as a function of time. The hanging loop denotes life cycles of an individual butterfly of the colony.

(Continued on page 13.)

The Art is in the Defect

A. Grant Elliot

Computers are the epitome of perfection. If they are not assembled perfectly using perfect components, they do not work. The chips that make up these perfect components require the utmost in precision manufacturing, reproducing to perfection circuitry designed on a microscale. The crystals from which the chips are made must be free from all flaws at levels of detection and observation that most people find incomprehensible. Enormous sums of money are spent trying to achieve ever-more defect-free crystals to enhance the speed and operating characteristics of the devices. Scientists continually experiment with procedures in the hope of developing methods that grow perfect crystals every time. For many years I was one of those scientists. As I worked, I became more and more intrigued by the defects themselves.

When the objective of a perfect crystal has been met, the resulting material is featureless, flat, free from any irregularities and about as artistically inspiring as a monotone orchestral suite. However, when defects are present, they often create highly interesting, visually appealing geometric patterns. I have captured many of these defect patterns on film at magnifications of 100X to 250X using differential interference contrast illumination. This illumination technique uses the interference between polarized light incident on and reflected from the surface to enhance the observation of very small changes in surface topography. The system allows the photographer to capture the image in many different color combinations.

The defects that I photographed occurred during the growth of gallium arsenide (GaAs), gallium phosphide (GaP) and gallium arsenide phosphide (GaAsP) single crystals -- materials important to the semiconductor industry. These materials are used principally to make light emitting diodes (LEDs) and laser diodes. GaAs also is used to make very high speed integrated circuits and other related devices.

To give you a better feeling for the nature of the defects that occur, I need to tell you a little about crystals, defects and about crystal growing. First let's talk about crystals. The term crystal, as used colloquially, is really a generic term. It is used to refer to lots of different things -- some real crystals that occur in nature, such as amethyst, quartz, diamond, etc., and some fake crystals such as cut glass and polished plastic. Technically the term is quite specific. It refers to those things that closely approach a perfect single crystal. Now what does that mean? A perfect crystal can be imagined as made up of the repetition in three dimensions of the fundamental building block of a material. Imagine a very tiny cube in space with atoms at each of the corners. Stack billions of these cubes in all three directions and you can build a perfect cube about the size of a grain of salt where all the atoms line up in relationship to one another in straight lines, planes and layers. This is a perfect single crystal.

Now suppose that during the stacking process you got careless and left half a layer of atoms out here and there, or maybe you included a few partial layers at random during the stacking process. You have created defects in the crystal. If you look along a layer you might see a small jog where the extra or missing partial layer occurs. While this jog is only a few atoms thick it runs the entire width of the crystal in the direction perpendicular to which you are viewing. This is a line defect called a dislocation. Even with billions of these defects per cubic centimeter the crystal is still perfect enough to be considered a single crystal. However, an error rate as little as ten parts per cubic centimeter can cause problems with the operation of some devices.

Take some single crystal grains, rough up their edges, lop off some of their corners, and gouge some of their faces, making them irregular in shape. When we squeeze these grains together they do not stack up very nicely. They are misaligned with respect to one another and there are spaces between them. If we fill up the spaces with the material we sloughed off and let it take the alignment of one or the other of the grains, we find that we have created a solid "crystal," but with the individual grains unaligned. Grain alignment changes at well-defined boundaries. The boundaries are called -- you guessed it -- grain boundaries, and the crystal is called a polycrystal (made up of many crystals). Grain boundaries are considered defects in the world of single crystals. However the crystal may still be considered a single crystal if the alignment varies a degree or less..

Many examples of natural single crystals exist. I mentioned some of them earlier but most natural single crystals are too flawed for use in electronic devices, especially in today's world of very high speed operation. A flawless single crystal has the best electronic properties. Therefore, the goal is to synthesize flawless crystals. Now, Mother Nature really does not like perfect material -- reflect on the paucity of single crystals found in the world compared to all other matter. She makes it very difficult for us to create them. We are fighting the second law of thermodynamics when we try to make it happen -- bringing order out of chaos, so to speak. Consequently we must expend significant amounts of energy (and therefore money) to create single crystals. How do we do this? A variety of methods have been devised throughout the years to "grow" single crystals.

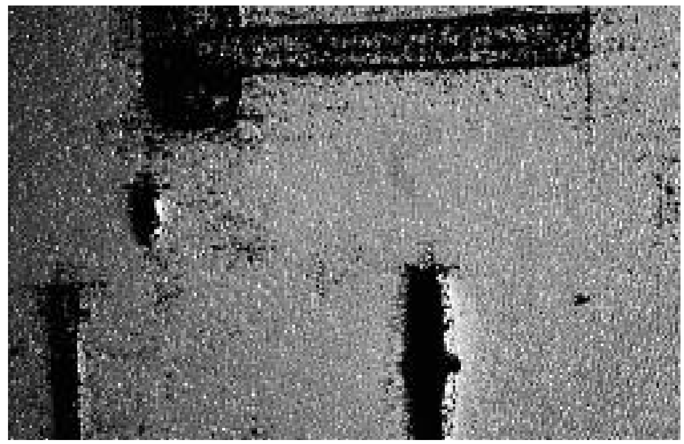
The most widely used method for growing large single crystal material is the Czochralski technique, developed in 1916 and named for the inventor of the basic process. A variant of this process is used to grow GaAs and GaP single crystals as well. Basically the process works by melting the desired material in a suitable pot and adjusting the temperature so that it is very near, but just above, its melting point. Then a seed crystal is gently dropped into the melt from the top, and slowly pulled up while the temperature is lowered just enough to cause molten material to crystallize onto the seed. Single crystals as large as 400 mm in diameter and weighing 100 kg, or more, have been grown this way. However, the growth process is imperfect. It introduces defects during each of its various stages. It is the job of the crystal grower to eliminate the most undesirable defects.

You can see some of the defects that have occurred while growing bulk GaAs and GaP single crystals. ***Breakdown*** shows growth striations, irregular light and dark bands across the center of a grown crystal.

A. Grant Elliot. ***Breakdown.*** 1995. Photomicrograph: Ilfochrome print. 19“X13.”

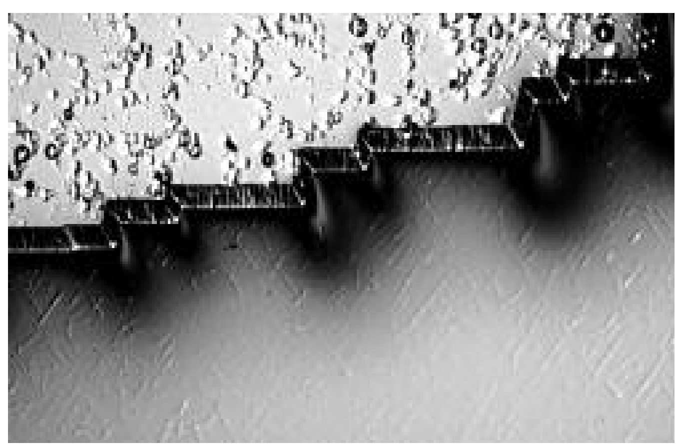
The growth striations are revealed by a process called selective etching wherein chemicals etch certain areas more rapidly than they etch others. Striation lines mark the shape of the solid-liquid interface at different times during the solidification process. This image shows that changes have occurred in the growth process leading to instability resulting in "interface breakdown" that gives rise to rapid polycrystalline growth.

Force reveals dislocations that are perpendicular to the plane of the image and a second phase inclusion, the lenticular black spot. This is a grain of material that has a different composition than the matrix and is usually caused by contamination in the melt.



A. Grant Elliot. ***Force***. 1995. Photomicrograph: Ilfochrome print. 13“X19.”

City Lights shows a grain boundary running across the image. The crystal from which it came was a polycrystal. The grains on either side of the boundary are unaligned and etch at different rates. The features within each grain may be dislocations.



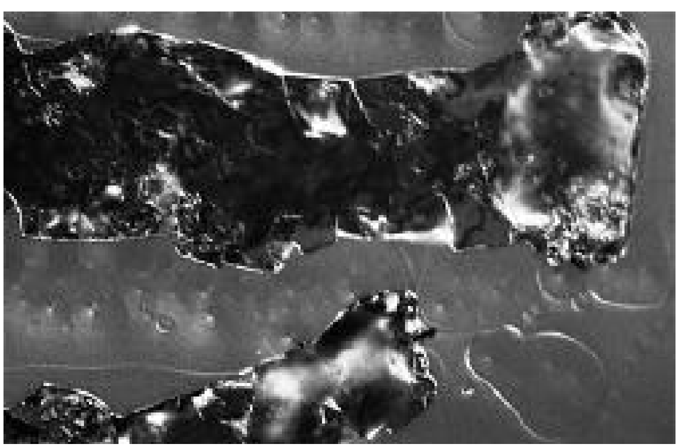
A. Grant Elliot. ***City Lights***. 1995. Photomicrograph: Ilfochrome print. 13“X19.”

A. Grant Elliot. ***Massif***. 1995. Photomicrograph: Ilfochrome print. 19“X13.”

Massif shows several different grains, and is a polycrystal.

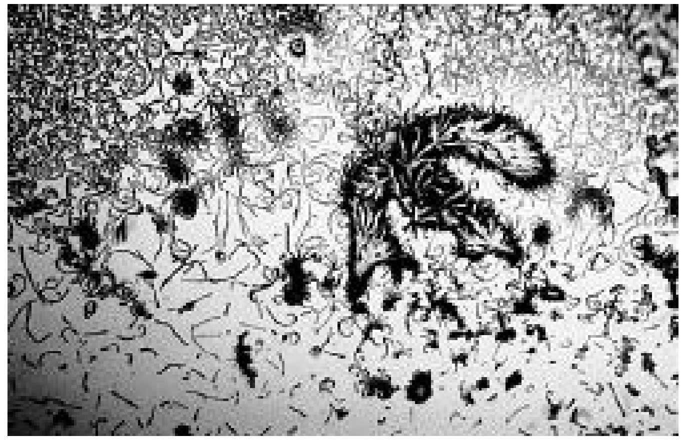
Another approach to growing single crystals, and one that is used routinely during the making of devices, is to grow them as thin film layers on top of a single crystal substrate. These substrates are typically made from a wafer cut from a large single crystal. Crystal quality is improved in this way. However, the slightest imperfection on the surface of the substrate will lead to defects in the growing film. Therefore, substrate surfaces must be highly polished and free from damage and any contamination. Otherwise the grown film can have a wide variety of defects. Images of contaminated polished wafers are shown here.

Creatures resulted from dust particles on the surface of a polished wafer, while



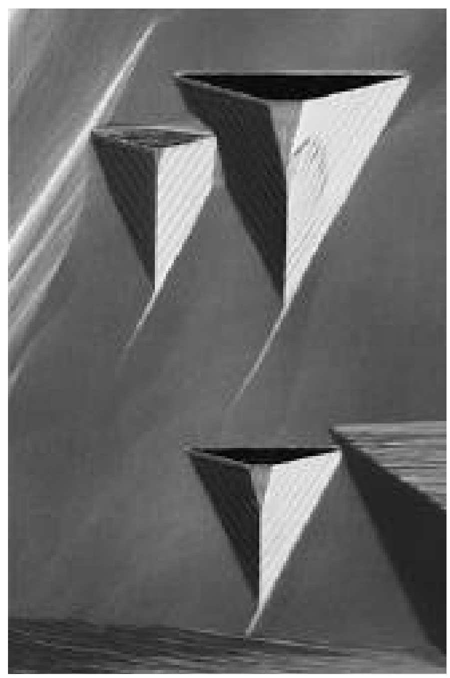
A. Grant Elliot. ***Creatures***. 1995. Photomicrograph: Ilfochrome print. 13“X19.”

Jungle Bird (top right) are the result of solvent residue left behind during the cleaning of a polished wafer.



A. Grant Elliot. ***Jungle Bird***. 1995. Photomicrograph: Ilfochrome print. 13“X19.”

Floating Pyramids (below) and ***Star Burst*** (cover) are images of defects that have occurred during the growth of thin films. Structures such as these usually are the result of improper growth conditions. Sometimes, however, they may result from residual contamination on the surface of the polished wafer.



A. Grant Elliot. ***Floating Pyramids.***1995. Photomicrography: Ilfochrome print. 19“X13.”

As one reflects on these images and their origin, one can only come to the conclusion that the art truly is in the defect.

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Biography of a monarch:
1. Egg: five days
2. Birth
3. Larva (caterpillar), 5 instars of 2-7 days: ca 3 weeks.
4. Making the pupa (chrysalis): 1 day
5. Metamorphosis: ca 1 week
6. Butterfly: 2-6 weeks in summer
7. Reproduction: anytime after the first few days
8. Death: shortly after mating
Note the overlap of a few days while the parent fails, and the egg grows.

The cognitive map of the colony (including the directions for finding the way home) is maintained in the collective field as a chaotic attractor.

5. Conclusion.

The phenomenon of the monarch migration is miraculous, and unexplained by modern science. For hundreds of thousands or even millions of years they have thrived, repeating their annual miracles, thanks to apparently paranormal powers. We must follow the monarchs into the morphic field, or into extinction. Chaos theory is just one strategy for reconnecting with morphic fields and the wisdom of nature. Adopting the monarch migration as a model for the entire trajectory of the human race, we are led to the idea that even though as individuals we know not where we are going nor from whence we came, we may nevertheless be en route, if we can maintain resonance with our collective morphic field. And mathematics may be a strategy for maintaining that resonance.

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YLEM

n., pronounced eye-lum, 1. a Greek word for the exploding mass from which the universe emerged.

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