### COMPLEX DYNAMICAL SYSTEMS

A SERIES OF TEN LECTURES TO THE ROSS INSTITUTE, 2011-2012 BY RALPH ABRAHAM

### SERIES OUTLINE

- 1. Introduction
- 2. Grades K, 1, 2
- 3. Grades 3, 4, 5
- 4. Grades 6, 7, 8
- 5. Grades 9, 10,11

6-10. Grade 12, NetLogo Programming

### LEC. 1: INTRODUCTION

\* A. My epiphany of the miracle year, 1972.

\*\* B. WHAT: Systems thinking, General systems theory, cybernetics, system dynamics, and complex dynamical systems (CDS).

C. WHY: The Spiral and World Cultural History as systems, systems thinking to understand the future.

D. HOW: Foregrounding the systems of each grade with NetLogo (needs participation).

### A. MY EPIPHANY OF 1972

#### EPIPHANY BACKGROUND

#1500, Nodal lines, Leonardo, dust, table, drum #1680, Nodal lines, R. Hooke, flour, glass, bow #1738, Glasspiel or verillon, 18 beer glasses #1762, Armonica of Ben Franklin #1787, Ernst Chladni book published #1791, Chladni euphonium #1831, Faraday crispations

#### EPIPHANY OF 1972

- #1960, Jenny, Kymatik = Cymatics
- #1967, Jenny, first book published
- #1969, visit brother Fred at UCLA, brains
- #1972, I saw Jenny's book in Thom's office, went to meet Jenny in Dornach, saw his movies
- Go to Jenny movies (10 minutes)

#1974, my lab in Santa Cruz, two publications

#### MACROSCOPE System



6. INTRODUCTION TO MACRODYNAMICS

FIGURE 6.1. Schematic view of the four-inch macroscope of the University of California, Santa Cruz. (Diameter, 4 in.; F, 48 in.)

parameters-for example, physical dimensions and viscosity-upon the logos.

But what is the relationship between the colored image on the screen, the physical macron within the medium, and the mathematical attractor which describes it? Theoretically, the physical parameter represented on the screen is the horizontal gradient vector field of the index of refraction of the medium, expressed in polar coordinates of color and intensity. In practice, interpretation in macroscopy, as in radiology, is learned by experience. Two separate causes of coloring must be distinguished: deformation of the surface of the medium (lenticulation) and pressure waves within it (pressurization). Normally, two separate images are superimposed on the screen, the  $\lambda$ -image (due to

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### THE EPIPHANY

The biological organ as a system
Forms coupled by vibrations = function
Examples: liver, heart, brain, locomotion
My start in systems thinking

# B. WHAT IS SYSTEMS THINKING ?

#### SYSTEMS THINKING EXAMPLES

% Kekule, 1865; Poincare, 1890

Barbara McClintock (1902-1992) Cold Spring Harbor Lab, Cytogenetics

# Emily Fox Keller (b. 1936), MIT, Hist. Biol.

Stephen Jay Gould (1941-1992), Harvard

Dorothy Sayers (1893-1957), Peter Wimsey

First, and more general, McClintock does not follow the style of logical and sequential thinking often taken as a canonical mode of reasoning in science. She works by a kind of global, intuitive insight. If she is stuck on a problem, she will not set it out in rigorous order, write down the deduced consequences and work her way through step by step, but will take a long walk or sit down in the woods and try to think of something else, utterly confident that a solution will eventually come to her in extenso. This procedure makes scientists suspicious and has often led colleagues to label her as a "mystic" in the pejorative, not appreciative, sense. (Gould, 1987; p. 165)

And then it happened—the thing he had been half-consciously expecting. It happened suddenly, surely, as unmistakably, as sunrise. He remembered—not one thing, nor another thing, nor a logical succession of things, but everything-the whole thing, perfect, complete, in all its dimensions as it were and instantaneously; as if he stood outside the world and saw it suspended in an infinitely dimensional space. He no longer needed to reason about it, or even to think about it. He knew it. (Sayers, 1923; Gould, 1987; p. 166)

#### SYSTEMS CHRONOLOGY

Go to visual-chaos.org/complexity

\*\* 1950, Systems Dynamics (SD), Jay Forrester
\*\* 1966, Catastrophe Theory (CT), Rene Thom
\*\* 1980, Complex Dyn. Systems (CDS), RA

#### WHAT IS A CDS ???

Dynamical scheme = Node

Functions as an I/O box with control knobs

Directed links

Connect an output to a control

A network of linked nodes

# C. WHY DO WE NEED TO DEVELOP SYSTEMS THINKERS?

#### SYSTEMS THINKERS BECAUSE ...

World Cultural History is a system.

The Ross Spiral Curriculum is a system and comprises many subsystems.

The World in which we live is a system.

Our survival may depend on our systems thinkers.

# D. HOW MIGHT WE DEVELOP SYSTEMS THINKERS?

#### SYSTEMS EDUCATION AT ROSS

- \* Foregrounding the systems in each grade
- Demonstrating model systems in each grade
- Practicing participatory simulations using the NetLogo/Hubnet system

#### HOMEWORK

Read Forrester's autobiography

# Identify as many systems as you can in the curriculum for one grade. Email your results to me before the next lecture.

# Participate in Blackboard Discussion

## END OF LECTURE ONE OF TEN