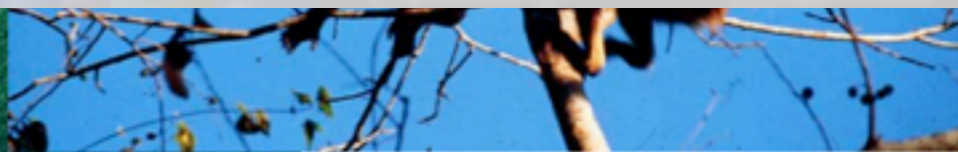
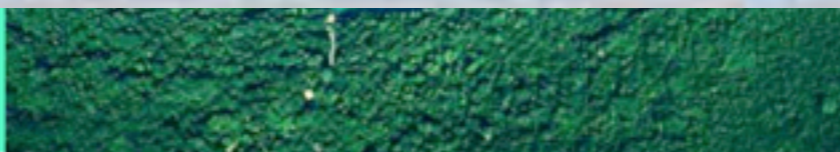
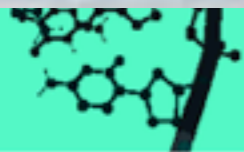




To boldly go where no
man has gone before

Clausura, Simposio Complejidad y Multi-disciplina,
UNAM, Mexico - 4-6/11/2013

Chris Stephens, C3 - Centro de Ciencias de la
Complejidad y Instituto de Ciencias Nucleares, UNAM



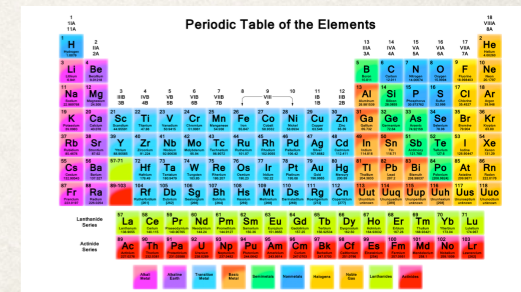


**Simposio Complejidad y
Multi-disciplina,
UNAM, Mexico - 4-6/11/2013**

**What did we learn?
What does the future hold?
Before looking to the future,
let's look at the past...**
(Levins, Gershenson,...)

How we do science in a nutshell...

- ❖ **The Scientific method:** Systematic observation, measurement, and experiment, and the formulation, testing, and modification of hypotheses
- ❖ **Phenomenology** - a body of knowledge that relates empirical observations of phenomena to each other, in a way that is *consistent* with fundamental theory, but is not directly derived from theory.
- ❖ **Taxonomy** - the practice and science of classification. A classification of things or concepts, as well as to the principles underlying such a classification.
 - ❖ Examples: Medicine, astronomy, chemistry, biology, physics,...
- ❖ **Scientific law** - when a particular phenomenon always occurs if certain conditions are present



Periodic Table of the Elements

The image shows a standard periodic table of elements, color-coded by groups. It includes the main groups (1-18), the lanthanide series (La-Lu), and the actinide series (Ac-Lr). The table is organized into rows and columns, with elements labeled by their chemical symbols and atomic numbers.

The worldview of the last 3 centuries:



NO EXCEPTIONS.

In fact...

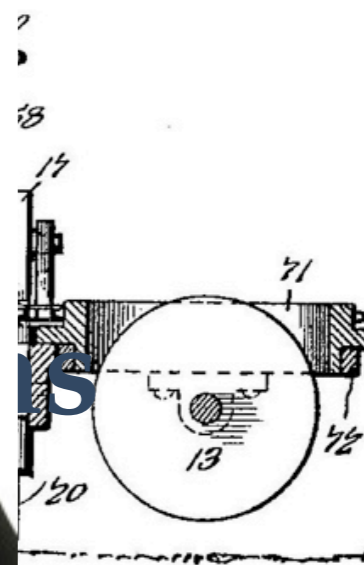
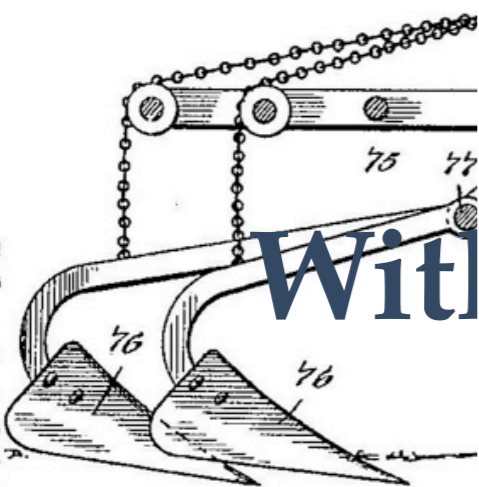
How

es?



With

Jacob L.H. Moravia Invention



we are slaves of the law

The

ne



Universality

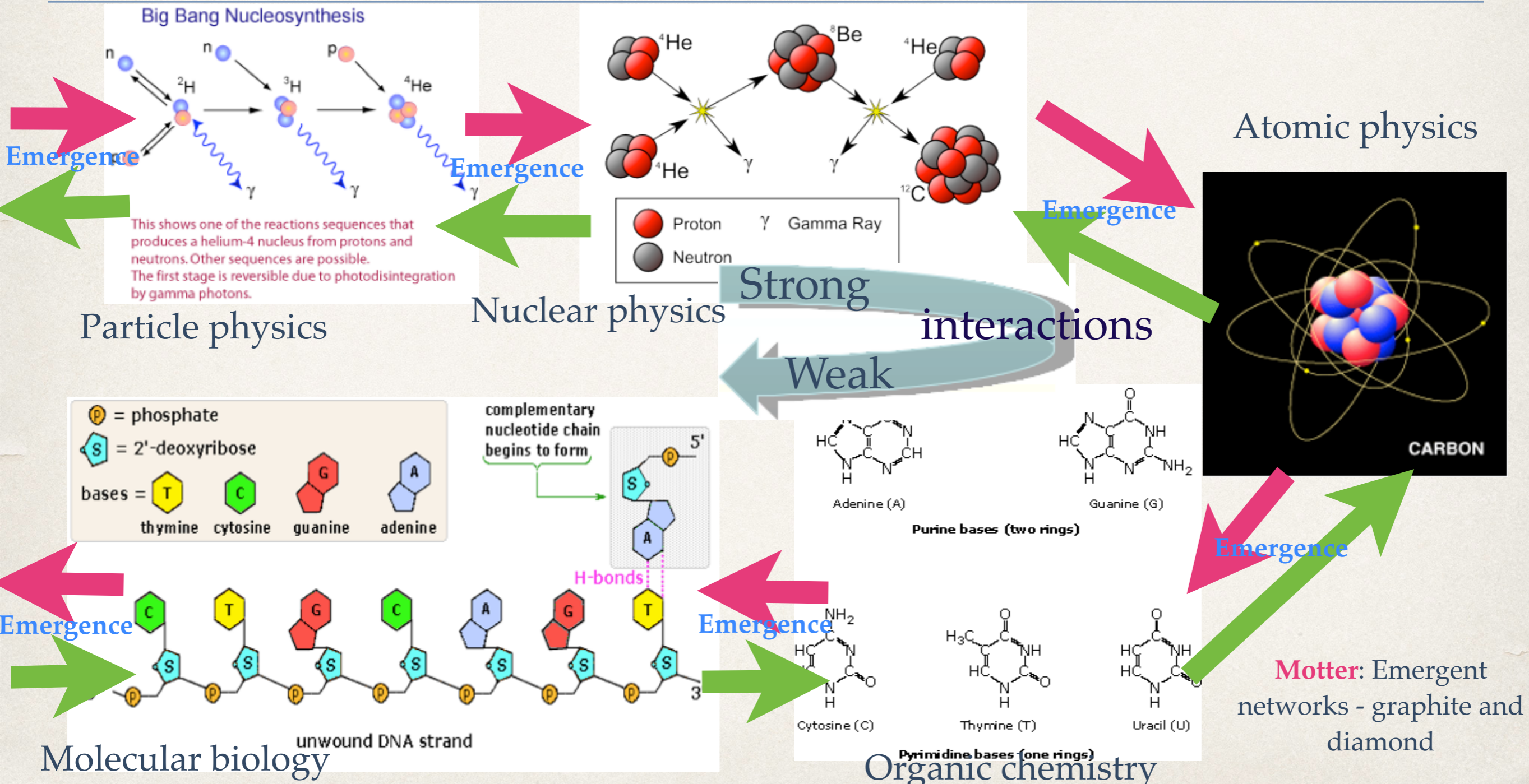
We're all equal under the law



But in physics and chemistry
once you've seen one perfect gas
there's really not a lot to say
In general, you don't need
At a minimum send them places
that much data

How the universe is built using "Building Blocks"

Emergence of structure and reductionism



Everything here is a slave to the law

So, what have we learned in the conference?

“Methodology”

Something missing

Levins, Gershenson

Networks

Bettencourt, Barrio, Motter,
Lugo, Alvarez-Buylla, Rasskin

Simulation

Motter, Bongard, Carbone

Using real data

Bettencourt, Barrio,
Motter, Nagy

Game theory

Santos

There was little to no mention of scientific law but there was of differential equations

There's a tacit agreement that we need new methodologies to study complexity

So, what have we learned in the conference?

Systems of interest

Animal behavior

Nagy

Disease

Martinez-Lavin,
Rohani,
Alvarez-Buylla

Cities

Bettencourt, Lugo

Climate change policy

Santos

Formation of opinions

Barrio

There was little to no mention of physical or chemical systems

There's a tacit agreement that complexity is linked to
biological and social systems

Complex Adaptive Systems

A Conclusion



you can
system



Imagine what you can
say about a city

versus

a crystal as big as a city!

Another conclusion

Any observable of a complex system depends
on a whole host of other factors

$$P(A, B, C, D, \dots; t \mid a, b, c, d, \dots; t')$$

Diabetes

Renal failure

Obesity

Father had diabetes

Angina

Leukaemia

SNP Rs7903146 45 mins exercise

per week

Many effects

Many causes

From the “micro” to the “macro”

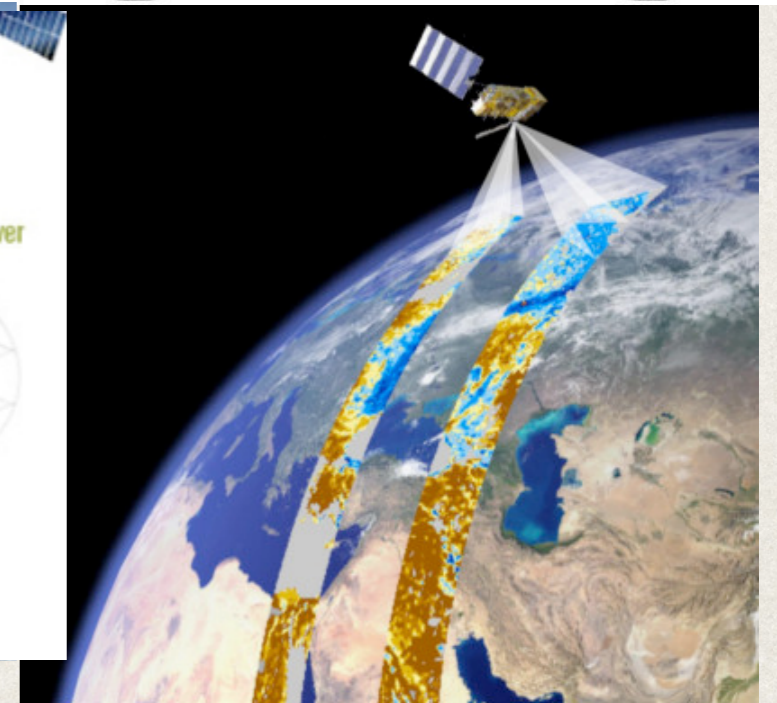
Many disciplines



Fortunately...
You need a lot of data to
we are in the middle of a
describe complexity
revolution

A revolution in data gathering...

Nagy, Barrio, Bettencourt, Lugo, ...

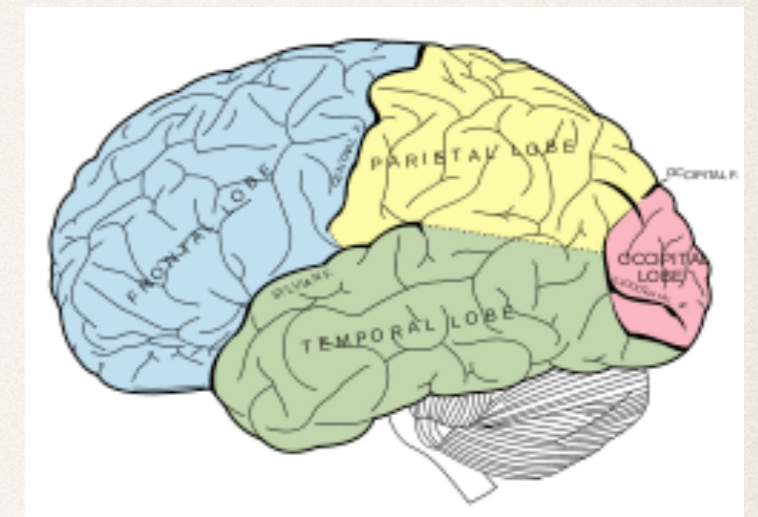
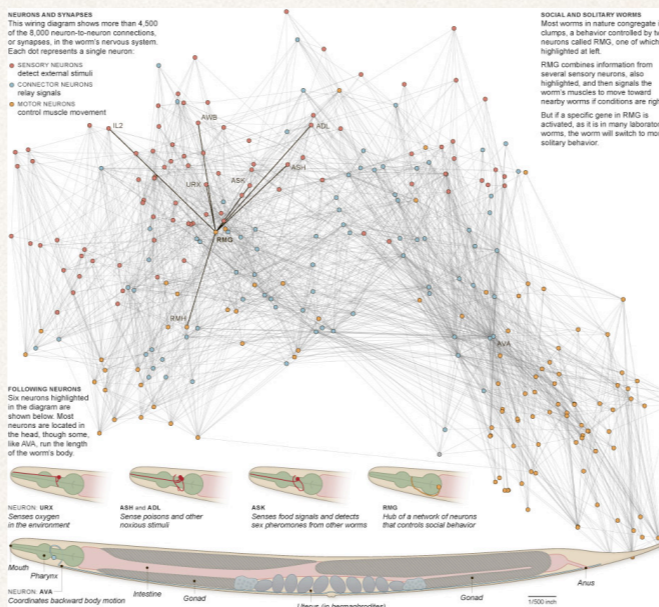
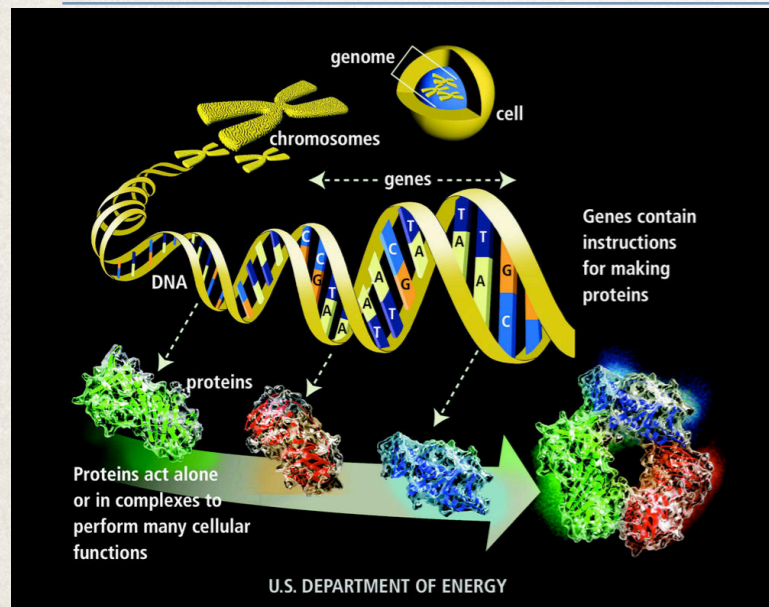


A revolution in data storage...

Nagy, Barrio, Bettencourt, Lugo, ..

Human brain

10-100 Terrabytes



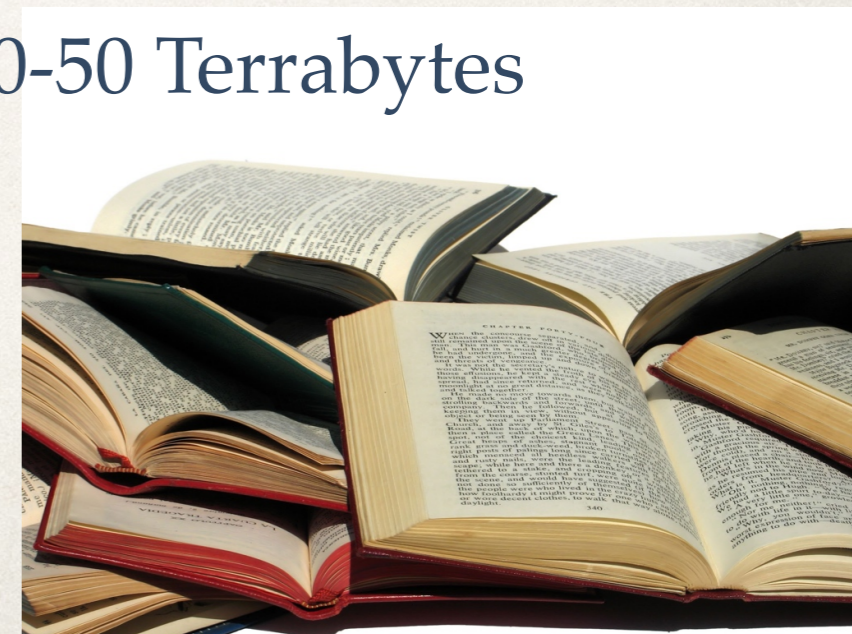
Genomes 1kB - 1.5 GB

Worm neural network 0.3MB

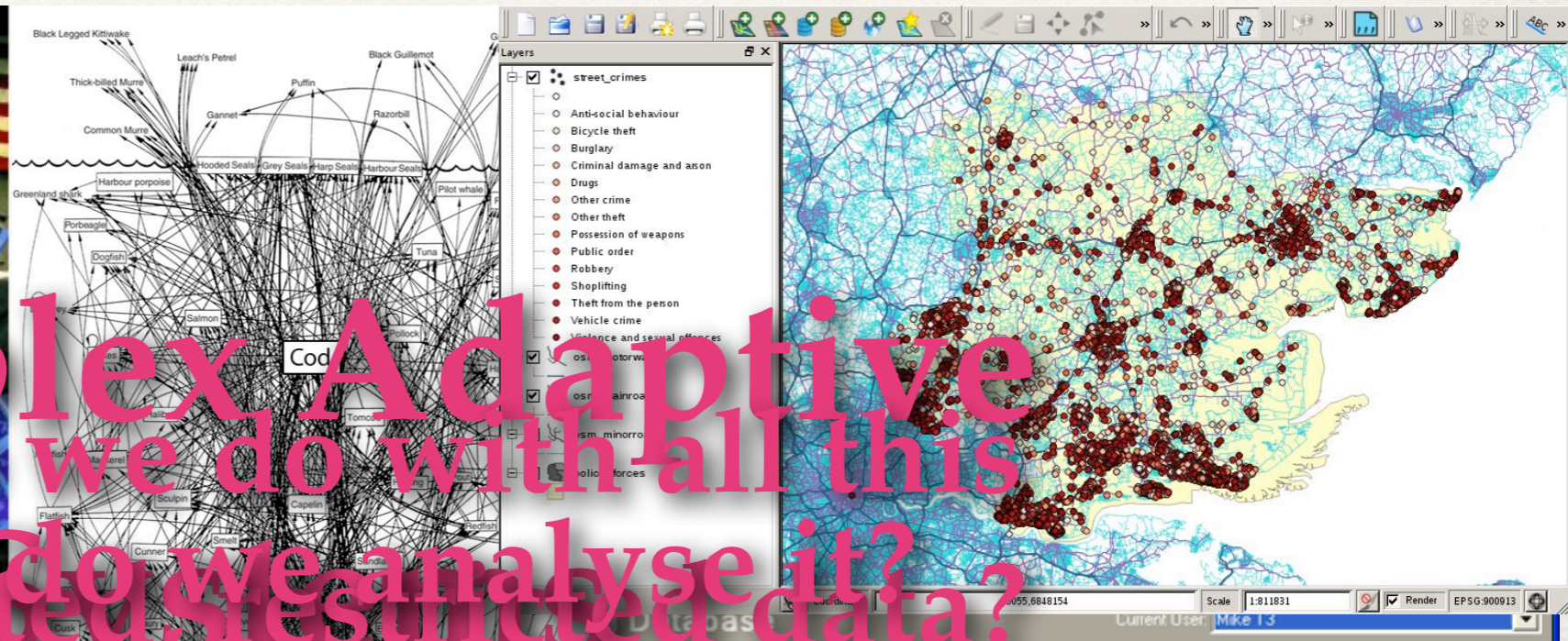
In electronic form 1 zettabyte

All the books in the world
30-50 Terrabytes

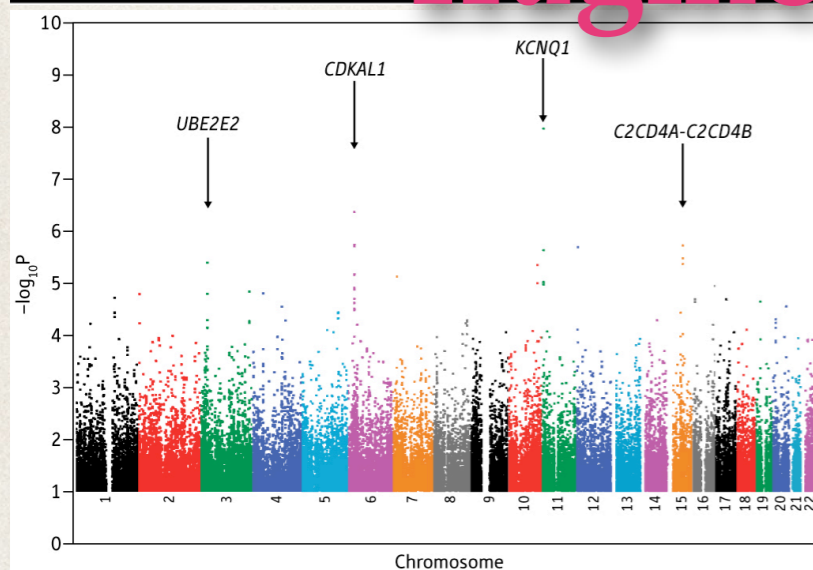
Raw data is processed and stored



What does all the data from the data revolution represent?



Complex Adaptive
What do we do with all this
fragmented, structured data?
How do we analyse it?



| Food Information | |
|------------------|----------------------------|
| Name: | Apricot-orange juice [1 c] |
| Carbohydrates: | 30.3 g |
| Fiber: | 1 g |
| Sugars: | 27.8 g |
| Protein: | 1.2 g |
| Fat: | 0.3 g |
| Saturated Fat: | 0 g |
| Calories: | 122.5 cal |
| Cal from Fat: | 2.7 cal |
| Sodium: | 7.5 mg |
| Cholesterol: | 0 mg |



Another conclusion

This data revolution is revolutionising our ability to study the immensely rich phenomenology of complex systems and construct more appropriate taxonomies



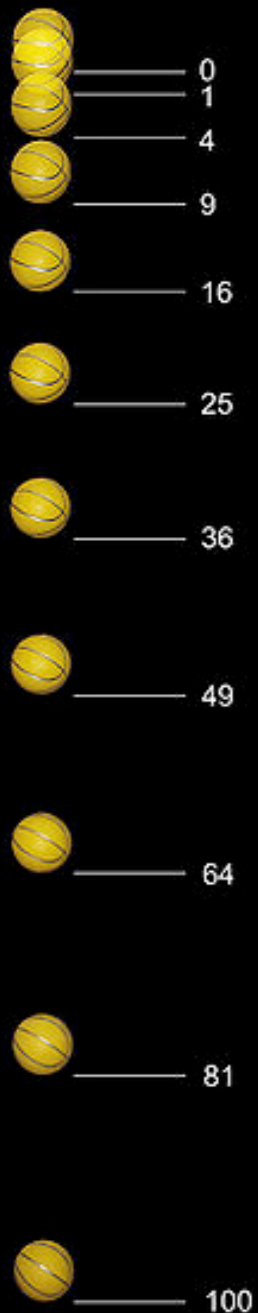
Another conclusion

Mechanistic

Adaptive

The *evolution* of function is the difference between complex and simple systems is the difference between systems that do the same thing in the same way and systems that do the same thing in different ways. But it's not a matter of doing them of physics as it pays.

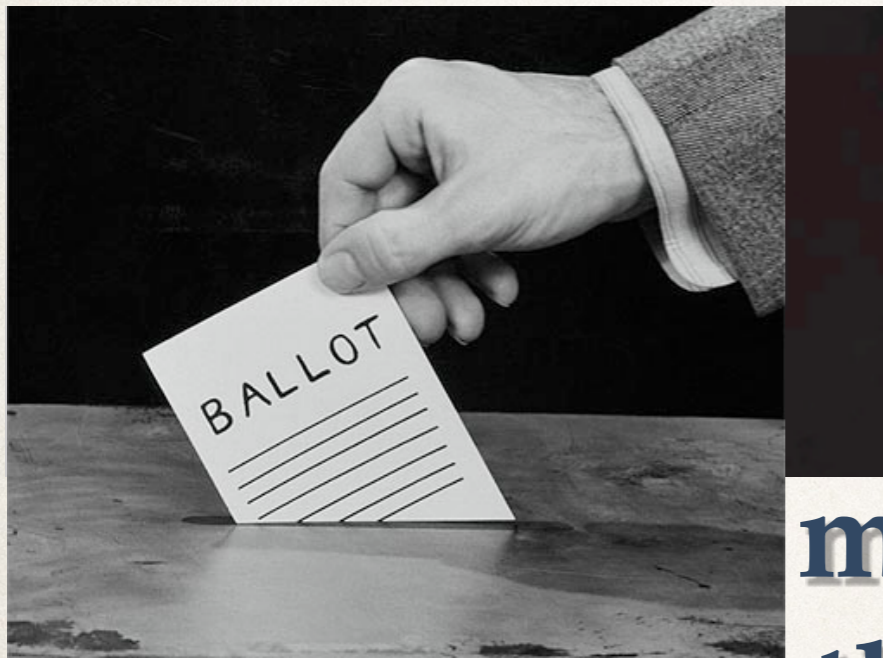
Complexity is a consequence of that revolution.





Another conclusion

Nagy, Bettencourt, Barrio, Bongard, Santos, Olive, ...



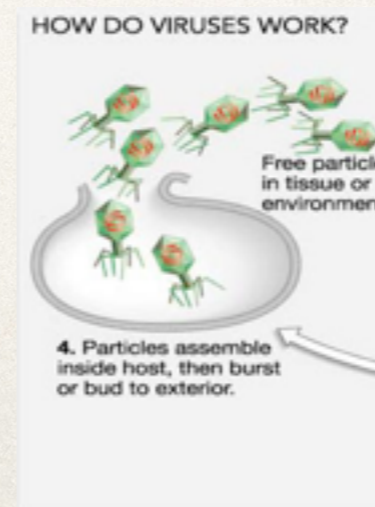
m
both



ste
s"
lual



a collective level



A 5x5 grid of 25 images of a tabby cat. The top row shows the cat walking on a wooden branch, a 'good' decision. The remaining 24 images show the cat in various awkward, upside-down, or contorted poses, representing 'bad' decisions. The text 'There are good decisions and there are bad decisions' is overlaid in the center.

**There are good decisions
and there are bad decisions**



Another conclusion

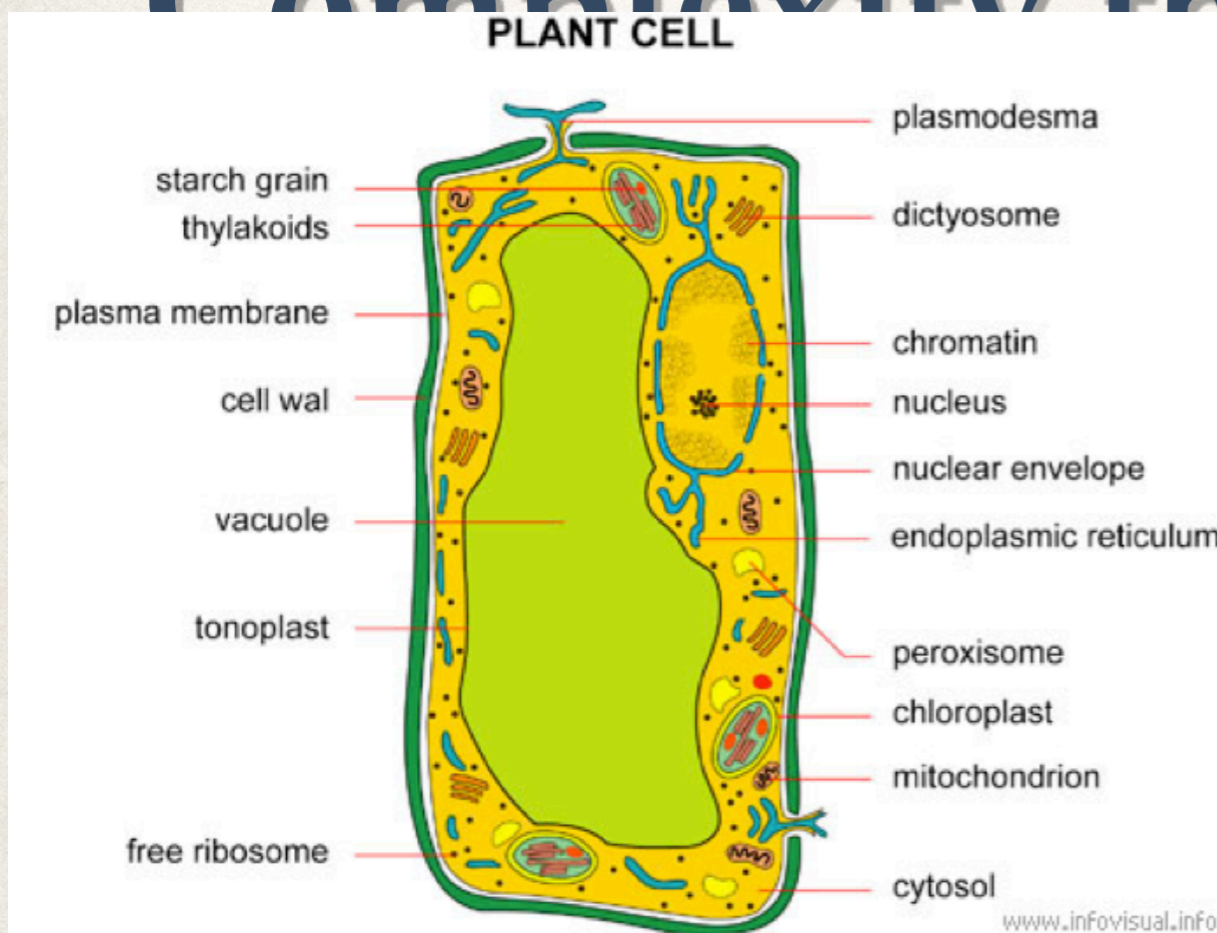
Bongard, Bettencourt, Nagy, Motter, Alvarez-Buylla,...

The advantages of specialisation

and the disadvantages

Complexity through evolution

out by
n of





Modeling complexity

**To make a mathematical
model of a dynamical
system...**

**we need a space of states
and update rules that tell us how
to get from one state to another**



Modeling complexity

**From the simple to the
complex and from the
complex to the simple**



This isn't describing complexity

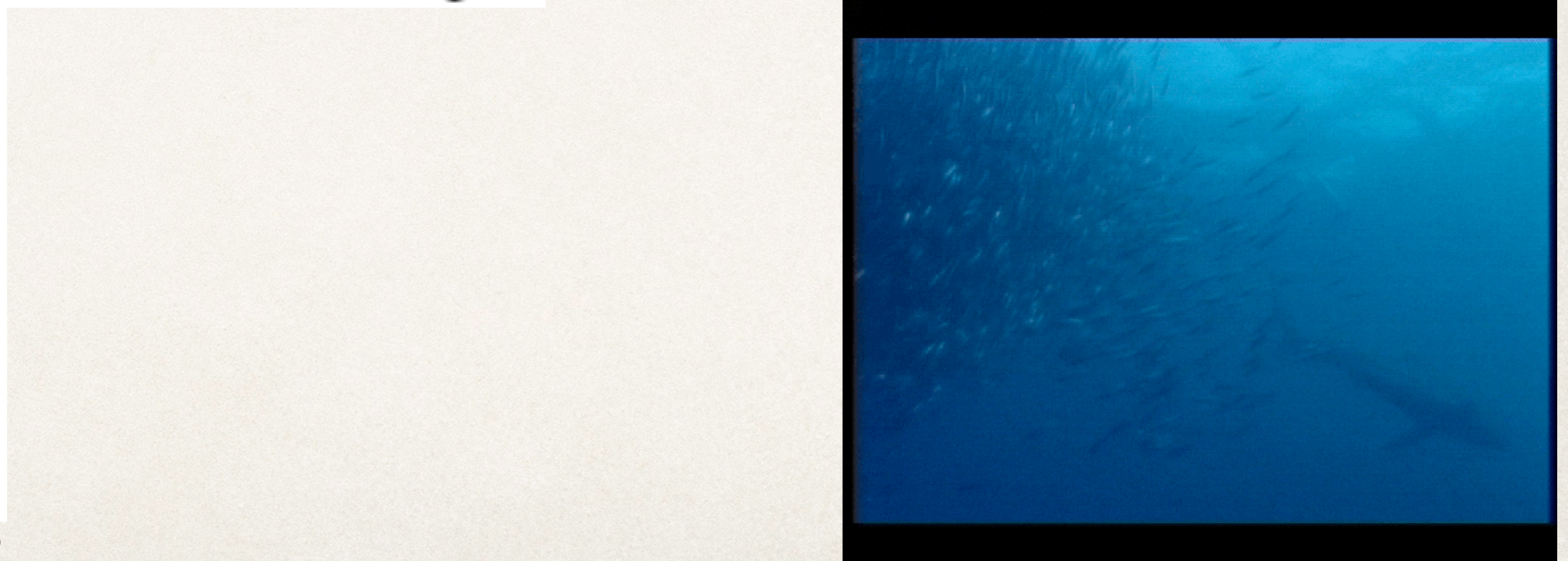
$$\mathbf{d}_i(t + \Delta t) = \sum_{j \neq i} \frac{\mathbf{c}_j(t) - \mathbf{c}_i(t)}{|\mathbf{c}_j(t) - \mathbf{c}_i(t)|} + \sum_{j=1} \frac{\mathbf{v}_j(t)}{|\mathbf{v}_j(t)|}$$

Competition between short-range repulsion and longer range attraction between “particles”

$$\hat{\mathbf{d}}_i(t + \Delta t) = \mathbf{d}_i(t + \Delta t) / |\mathbf{d}_i(t + \Delta t)|$$

$$\mathbf{d}_i'(t + \Delta t) = \frac{\hat{\mathbf{d}}_i(t + \Delta t) + \omega \mathbf{g}_i}{|\hat{\mathbf{d}}_i(t + \Delta t) + \omega \mathbf{g}_i|}$$

Equation for “charged” particles following an external force \mathbf{g}_i



Couzin, I.D. , Krause, J.,
Franks, N.R. & Levin, S.A.
(2005) Nature, 433 , 513-516.

Evolved Virtual Creatures

Here we see the
We begin with “building blocks”
and we end up with creatures
emerged from government
by the laws of physics (mechanics)

Examples from
work in progress

Misión del C3

- ❖ Realizar **investigación científica transdisciplinaria** de frontera en las ciencias de la complejidad, **creando un espacio** en donde expertos de muy diversas áreas puedan interactuar y contribuir a la **solución de problemas trascendentes y de importancia nacional**
- ❖ Es también misión del Centro formar científicos entrenados en el trabajo transdisciplinario en **equipo** y en el fortalecimiento de los métodos modernos asociados a la **ciencia computacional**





We have neither an agreed conceptual
framework, nor an adequate
But we are getting data...
Of a great revolution!
Complex Adaptive Systems

Some homework problems...

How do we model adaptation?

How do we classify complex systems?

How do we obtain and integrate data?

How do we model the emergence of function?

How do we model the emergence of multi-tasking and specialisation?

How do we mathematically model macro-evolution?

How do we mathematically model meta-evolution?

A Call to Arms!

- * Leon Olive: “podemos tomar medidas y promover acciones que pueden tener impacto en la sociedad y en el planeta”

We experience and manage complexity every day,...

unconsciously

“Consciously”, we look always to single, simple causes...

capitalism, communism, rich, poor, PRI, PRD,
junk food, soft drinks, colonialism,...

Why?

How do we all contribute to making this complex adaptive world of ours a better place to live?

Evolution has created a world of organisms that are not only more complex and adaptive than any other world, but also more just and fair. Natural selection also enslaves organisms to the laws of physics.

Thank you / Gracias

Gracias a los organizadores