Knowledge Presentation and Visualization

Franz J. Kurfess

Computer Science Department
California Polytechnic State University
San Luis Obispo, CA, U.S.A.

Acknowledgements

Some of the material in these slides was developed for a lecture series sponsored by the ***European Community*** *under the* ***BPD program*** *with* ***Vilnius University*** *as host institution*

CAL POLY

Use and Distribution of these Slides

These slides are primarily intended for the students in classes I teach. In some cases, I only make PDF versions publicly available. If you would like to get a copy of the originals (Apple KeyNote or Microsoft PowerPoint), please contact me via email at fkurfess@calpoly.edu. I hereby grant permission to use them in educational settings. If you do so, it would be nice to send me an email about it. If you're considering using them in a commercial environment, please contact me first.

Overview

Overview Knowledge Presentation and Visualization

- ❖Background and Context
- ❖Information Transmission Channels
- ❖Cognitive Aspects
- ❖Presentation and Visualization Methods
- ❖Assessment and Evaluation
- ❖Examples

Background

Background and Context

- emphasis on presentation and visualization of **knowledge**
  - concepts, relationships
- visualization is one way of presenting knowledge
  - possibly the most important, but not the only one
- only *explicit* knowledge can be presented
  - *tacit* knowledge must be circumscribed
  - many of the approaches presented are used in attempts to make tacit knowledge more explicit

Relevance of Knowledge Presentation

- better user experience
  - shorter time to locate, identify relevant knowledge
  - knowledge is easier to comprehend and utilize
- improved understanding
  - critical examination of existing bodies of knowledge
  - exploration and validation of relationships
  - suitable presentation of abstract concepts
- creation of new knowledge
  - integration of existing diverse bodies of knowledge
  - addition of relationships between knowledge items

Information Transmission Channels

- sensory equipment of humans and computers to send and receive information
  - knowledge has to be encoded in order to be transmitted
    - sender and receiver must have compatible encoding schemes

Main Human Information Channels

- visual
  - input via eyes; output via movement, gestures, manipulation of the environment
- auditory
  - input via ears; output via voice, gestures (clapping, stomping), manipulation of the environment
- tactile
  - input and output via touching (skin)
- olfactory and gustatory
  - smelling (nose), taste (mouth)

Main Computer Information Channels

- visual
  - almost exclusively for output (screen, printer)
  - some use for input (optical mouse, camera)
- tactile
  - mostly for input (keyboard, mouse)
- auditory
  - input (speech recognition) and output (alerts, messages)
- other channels for computer-computer communication
  - network, wireless, infrared

Evaluation Criteria

- capacity
  - amount of information that can be transferred
- selectivity
  - how difficult is it to concentrate on certain parts of the communication
    - focus, attention, noise
- dimensionality
  - how many dimensions can be perceived
- persistence
  - how long is the sensory signal available

Visual Communication

- heavily used
  - writing/reading, diagrams, images
- often relies on text (spoken language)
  - requires writing/reading skills
- some specialized functions
  - color, motion detection, resolution gradient
- limitations
  - range(distance, angle, frequency)
  - resolution (spatial, temporal)
  - sensitivity
  - fatigue

Evaluation Visual Communication

- capacity
  - high
- selectivity
  - good (close eyes, change direction, focus distance)
- dimensionality
  - 2+ (two dimensions, distance calculated)
- persistence
  - emphasis on changes (motion)
  - can be long-lived (writing, drawing, photos)

Auditory Communication

- heavily used
  - spoken language
- requires skills for knowledge presentation
  - speaking, understanding a language

Evaluation Auditory Communication

- capacity
  - medium (significantly lower than visual)
- selectivity
  - poor (closing ears difficult, changing direction requires head movements, focussing on specific auditory signals can be difficult)
- dimensionality
  - 1+ (all spatial information calculated)
- persistence
  - spoken language is transitory
  - can be long-lived (writing, drawing, photos)

Cognitive Aspects

- cognitive engineering
  - design principles for presentation techniques
  - based on cognitive processes in humans
    - information processing, attention, memory
  - main emphasis on the visual system
  - mental depiction can be as important as mental description

Perception

- interface between our mind and the world
- sensory information translates physical aspects of the world into neural encodings in our brain
  - visual and auditory systems are most relevant for knowledge-related perception
  - many lower-level processing steps are encoded in "wetware" and happen sub-consciously

[Kowalski 1997]

Presentation and Visualization Methods

Information Visualization

- utilizes the human visual system to indicate important aspects of data and information
  - absence/presence, quantity, features
- basis for writing, drawing, art
  - long-distance communication
  - long-term preservation of knowledge
- graphical displays offer a much richer visual experience than text-based terminals
  - flexibility, resolution, color

[Kowalski 1997]

Cognitive Aspects of Vision

- proximity
  - nearby items are grouped together
- similarity
  - similar items are grouped together
- continuity
  - smooth continuous patterns vs. separate items
- closure
  - automatic filling of gaps in a figure
- connectedness
  - interpretation of related items as single units

[Kowalski 1997]

Visualization Primitives

- built-in, low level functions of our visual system
- orientation of shapes
  - easy detection of groupings
- color
  - preference for primary colors
- depth
  - cues to size, distance of objects
- arrangement of objects
  - deviation from regular arrangements are easily detected
- spatial frequency

[Kowalski 1997]

Technology: Visual Computing

- computer presentation technology has some advantages over other media
  - modify representations of data and information
    - e.g. change color, scale
  - show changes in space and time through animation
  - use interaction with the user to optimize presentation
    - according to the user's preferences
  - show relationships between items
    - e.g. through hyperlinks

Visual Presentation Techniques

- text
  - mostly sequential
  - good for details, explanations
- diagrams
  - two-dimensional
  - good for structural aspects, relations between items, properties
- images
  - two-dimensional
  - (partial) reproduction of real-world objects

Visual Presentation Methods

- hierarchical structures (trees)
  - appropriate for items with relations such as
    - is-a, part-of, parent-child, dependencies, etc.
  - becomes difficult to use for large structures
- map
  - arranges items according to spatial proximity
    - useful for properties that map into space
  - with zooming, it can be used for large sets of items
- grid
  - visualization of tabular data
    - requires strong regularities in the overall information space

[Kowalski 1997]

Visual Presentation Methods cont.

- network (graph)
  - items are represented as nodes, and relationships as arcs
- clusters
  - related items are grouped together
- bar chart
  - indicates values of properties
- histogram
  - shows the distribution of items
- perspective wall

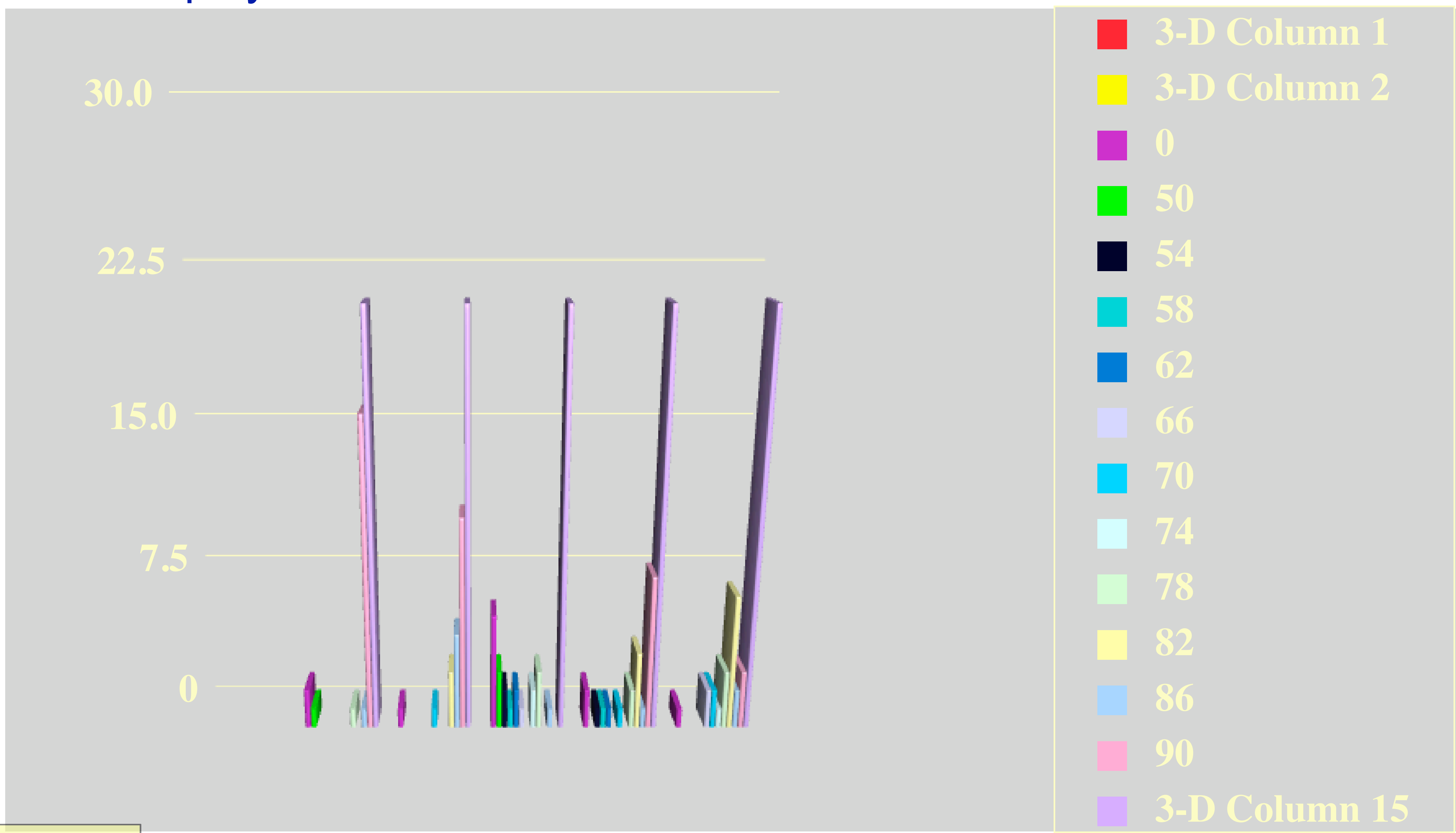
[Kowalski 1997]

Auditory Presentation Techniques

- language
  - sequential
  - similar to text
- sound
  - (partial) reproduction of real-world events
  - creation of new events
    - e.g. music

Data Visualization

- visual display of data values



Information Visualization

- display of relationships for structured data
  - e.g. entity-relationship diagrams
- document clustering
  - present the user with a visual representation of the document space constrained by the search criteria
  - group related documents together
    - requires a similarity measure
- search formulation analysis
  - display the relationships between various aspects of the search terms and the retrieved results
    - effects of expansion, relevance feedback, etc.

Knowledge Visualization

- link display
  - indicates relationships between items
  - color, patterns, thickness, arrows, labels, etc. can be used to differentiate types of relationships
- link analysis
  - correlates multiple documents that share certain aspects
  - helps with the identification of dependencies, trends, etc.

Alternatives to Visualization

- utilization of other senses for the presentation of knowledge
  - auditory
    - speech
    - signals
      - beeps
  - tactile
    - virtual reality
  - olfactory (smell)
  - gustatory (taste)

Sound

- speech
  - somewhat limited due to the sequential nature
  - helpful as alternative or additional method
- sounds
  - sometimes used for alerts, or to augment aspects of visual display
- music
  - primarily used for entertainment purposes
  - may be used to evoke emotional responses

Tactile Presentation

- Braille
  - as alternative to text input for visually impaired people
- virtual reality
  - mainly augmentation of visual input
- special-purpose devices
  - feedback mouse
    - special mouse/mouse pad combination that delivers some tactile feedback to the user
  - feedback joysticks, haptic gloves
    - force feedback
    - used for tele-manipulation, VR

Virtual Reality

- tries to provide a computer-based model of an environment
- relies mainly on 3D visual input
- feedback between user and system is critical
  - direct manipulation of virtual objects
- mostly used for modeling purposes, not so much for knowledge presentation

Immersion

- similar to VR, tele-presence
- the user has the impression of being in another environment

Assessment and Evaluation

- transmission capacity
  - more is not necessarily better
- effectiveness
  - does it enable the recipient to do something that wouldn't be possible otherwise
- efficiency
  - can a task be done with few resources
- user satisfaction
- expert evaluation
  - correct, complete, appropriate level of detail

Augmented Reality

- additional information is added to our perception of the real world
  - e.g. overlays with additional information on the windshield of a car or airplane
- requires matching of the real world with the virtual reality parts

Examples of Knowledge Presentation and Visualization

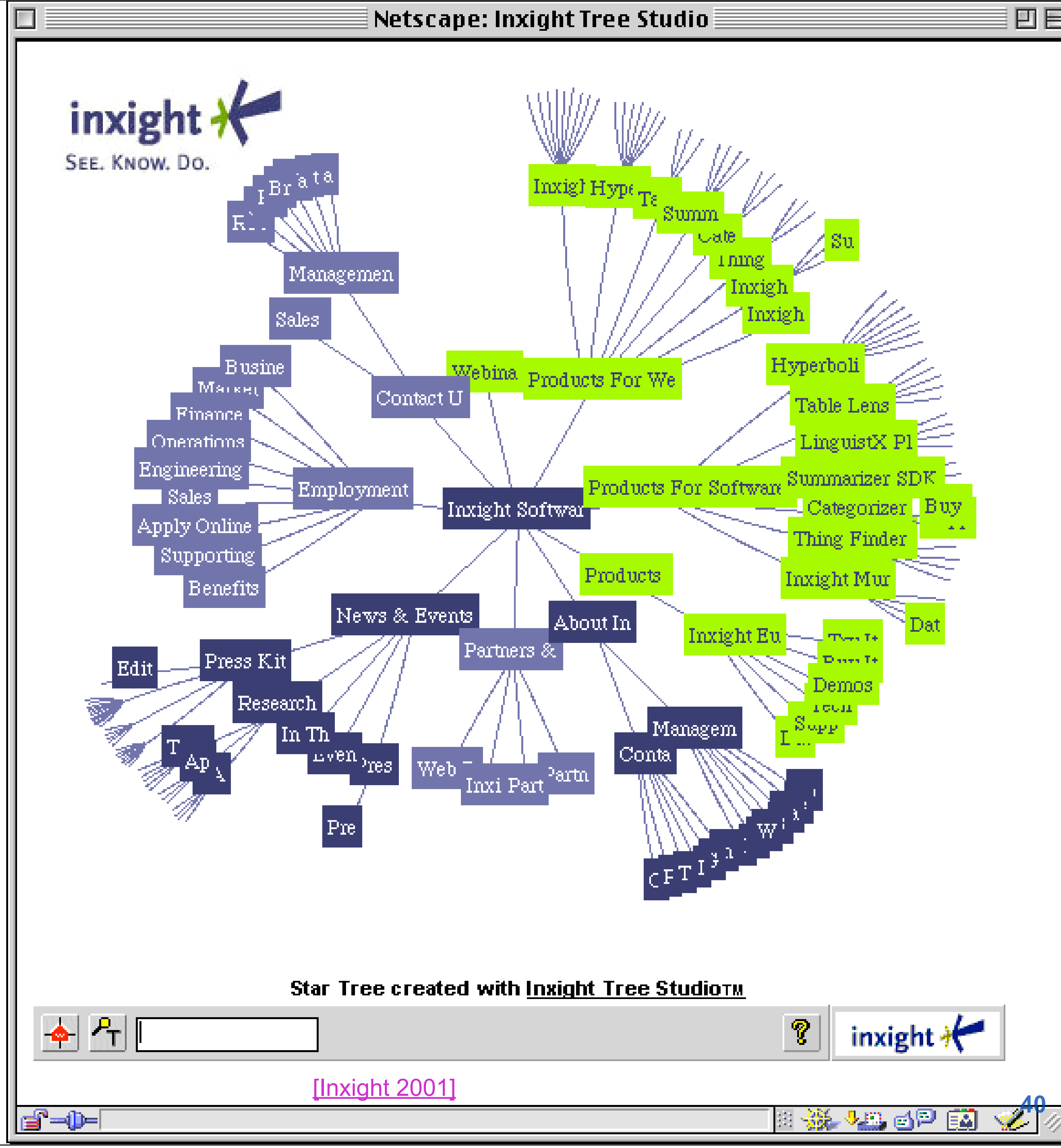
- hierarchical methods
  - trees
- graph-based methods
  - concept maps, mind maps, conceptual diagrams
- similes
  - the appearance of the proxy reflects the original
    - maps
- models
  - important functional properties are reproduced
- metaphors

Tree-Based Presentations

- hierarchical structure
- displayed visually, often as an upside-down tree
  - root node at the top, leaf nodes at the bottom
  - sometimes sideways
  - can also be arranged to optimize the utilization of available space

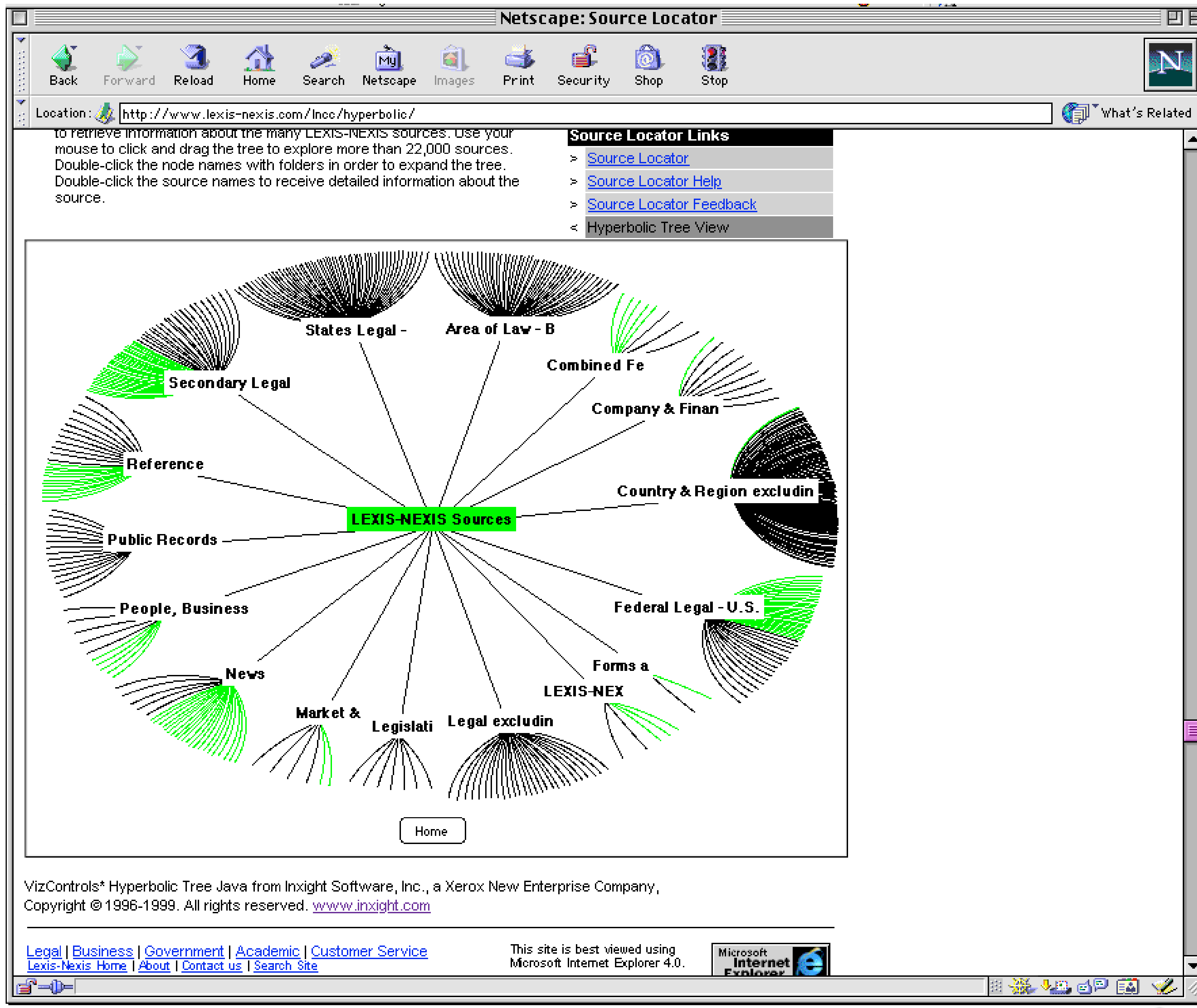
Inxight Tree

- tree displays the hierarchical structure of a Web site
- overview of available contents
- quick navigation
- no details



Lexis-Nexis Tree

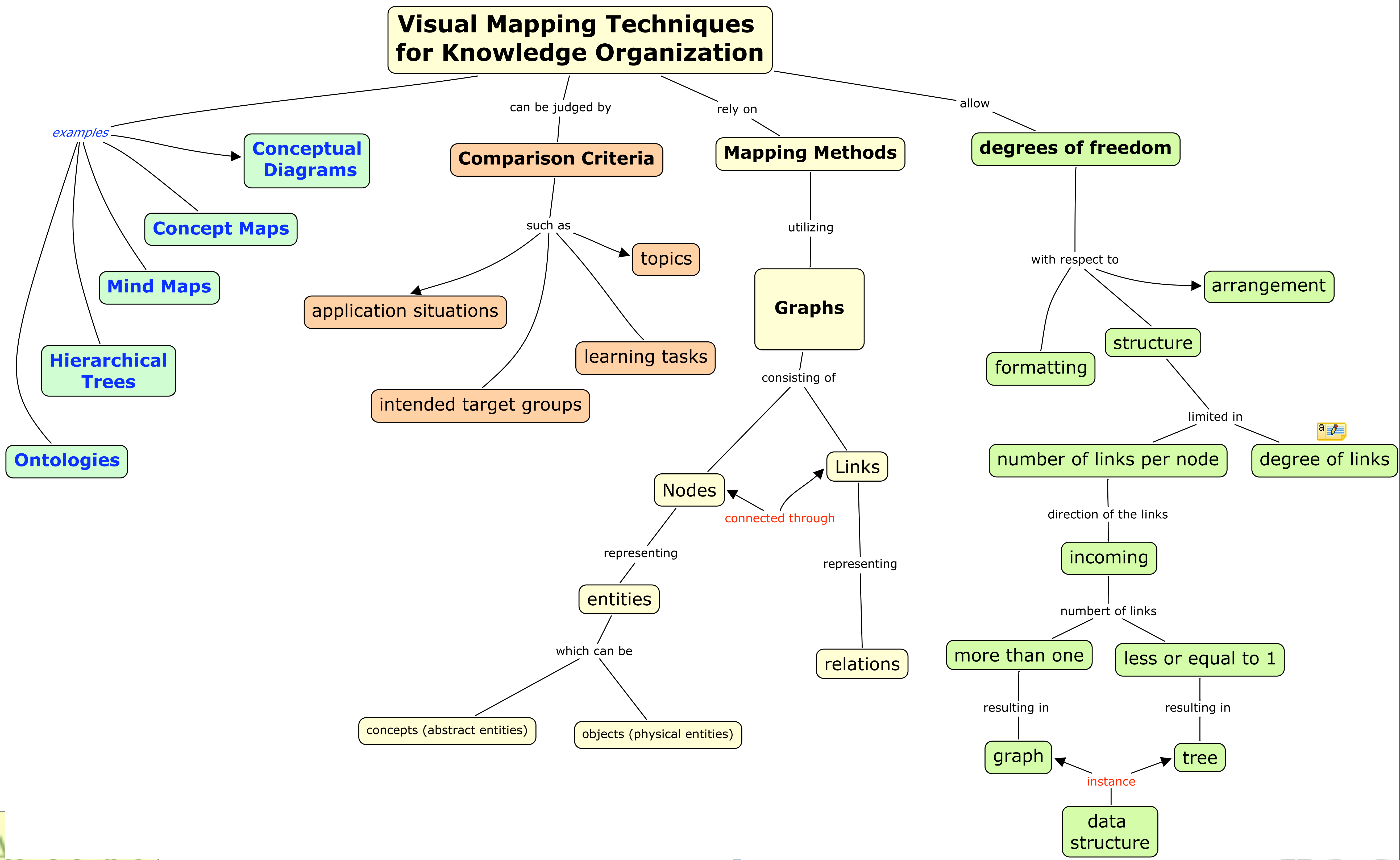
- built with Inxight Tree Studio



Graph-Based Presentations

- arbitrary links between nodes are allowed
- nodes often stand for concepts, links for relationships

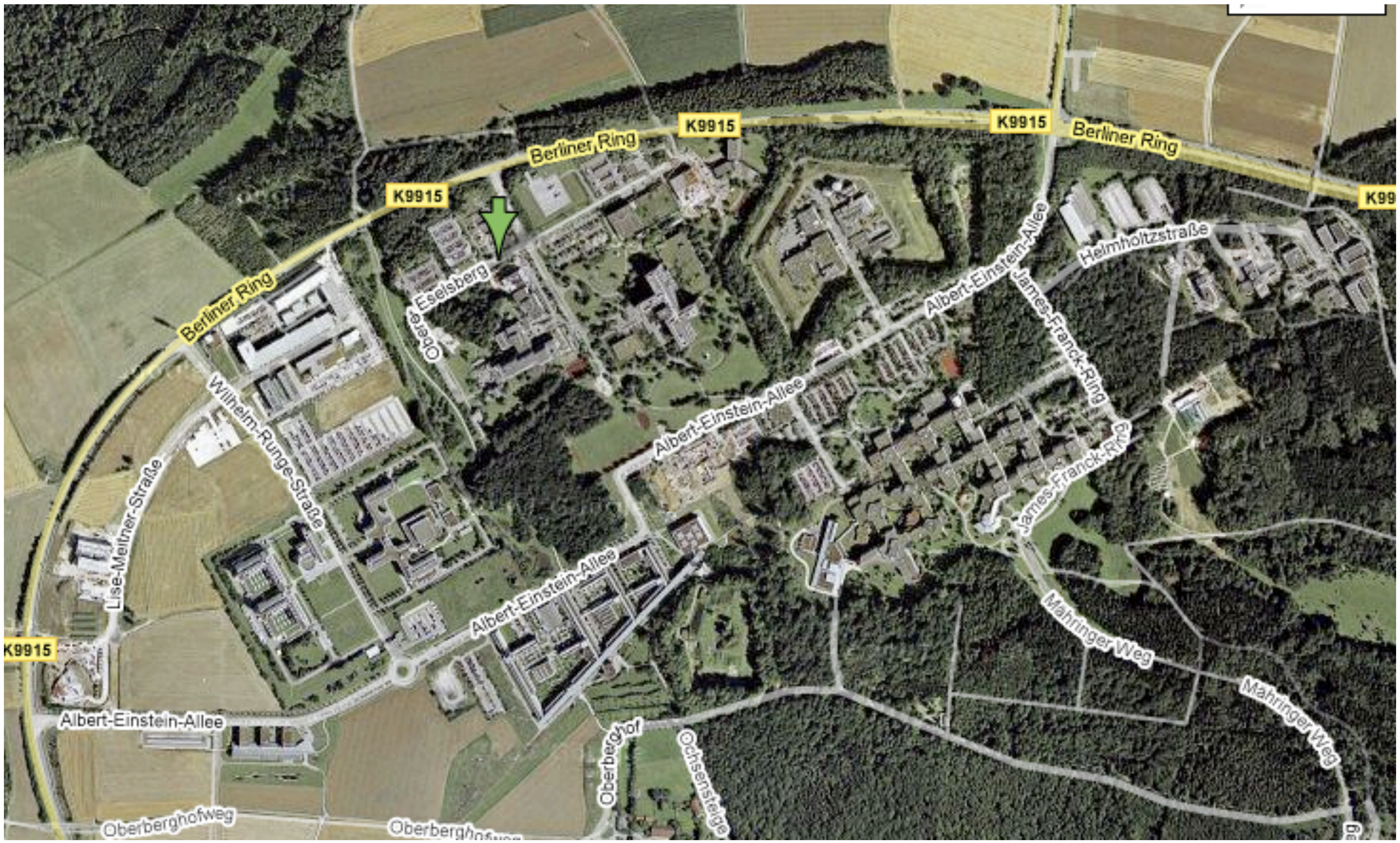
Example Concept Map



Similes

- representations that capture the appearance of the original
  - reproductions of sensory inputs using different technologies
    - paintings, photographs
    - audio recordings
  - often used to increase the persistence of sensory impressions

Example Simile



http://maps.google.com/maps?f=q&hl=en&geocode=&q=Universit%C3%A4t+Ulm,+Germany&sll=37.0625,-95.677068&sspn=44.339735,73.212891&ie=UTF8&ll=48.412853,9.94606&spn=0.036461,0.071497&t=h&z=14

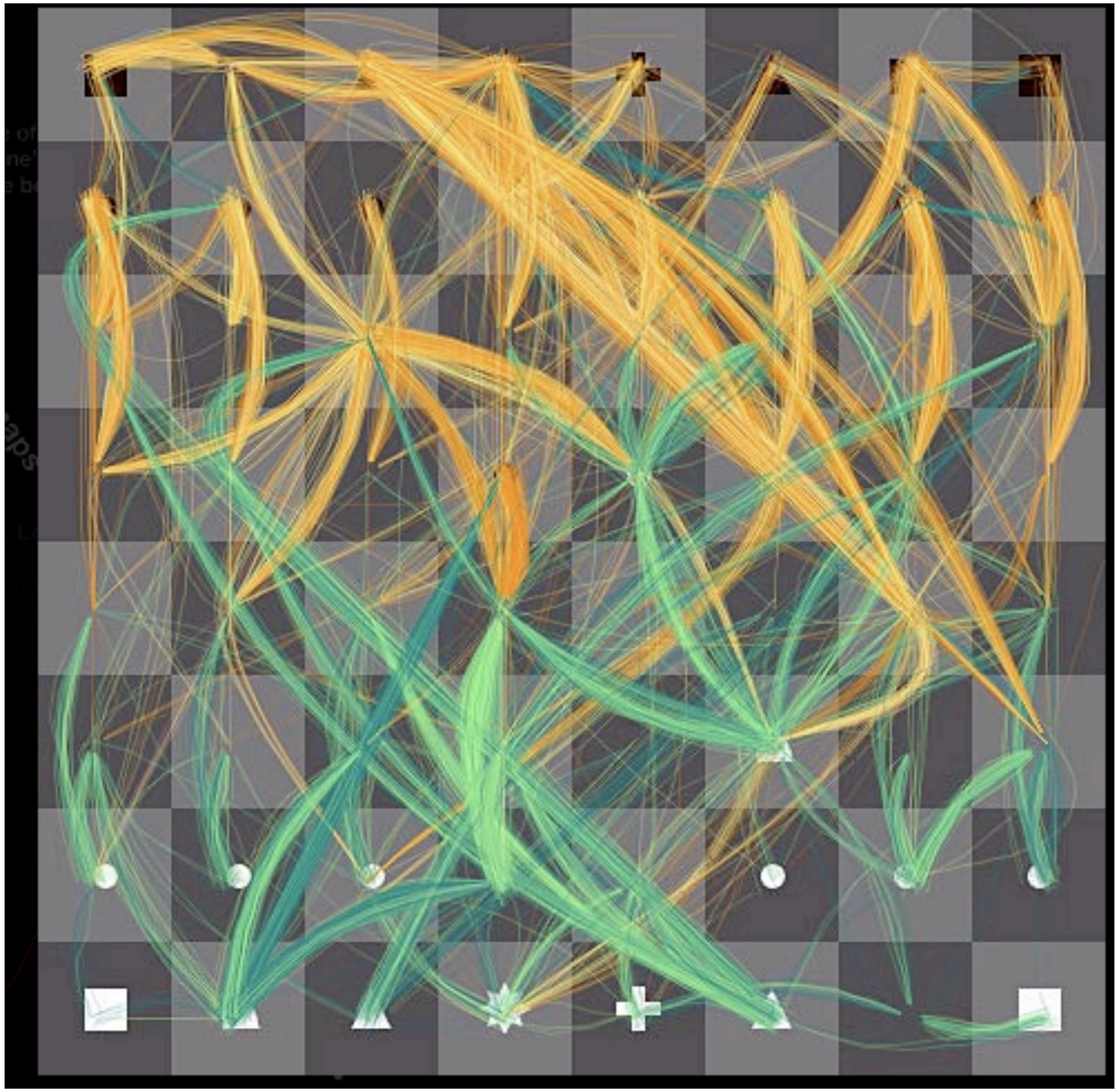
Simile or Graph?

Models

- capture important functional aspects
- conceptual models, theories, hypotheses
  - abstract descriptions, often in formal languages like mathematics, logic
- simulations
  - implementations of models in a different technology or scale
    - nowadays often computers, electronic devices
    - sometimes at a more practical scale

Modeling Chess

- visualization of the computer's possible moves as it plays
- makes the machine's evolving "thought process" visible
- play the game at http://www.turbulence.org/spotlight/thinking/chess.html

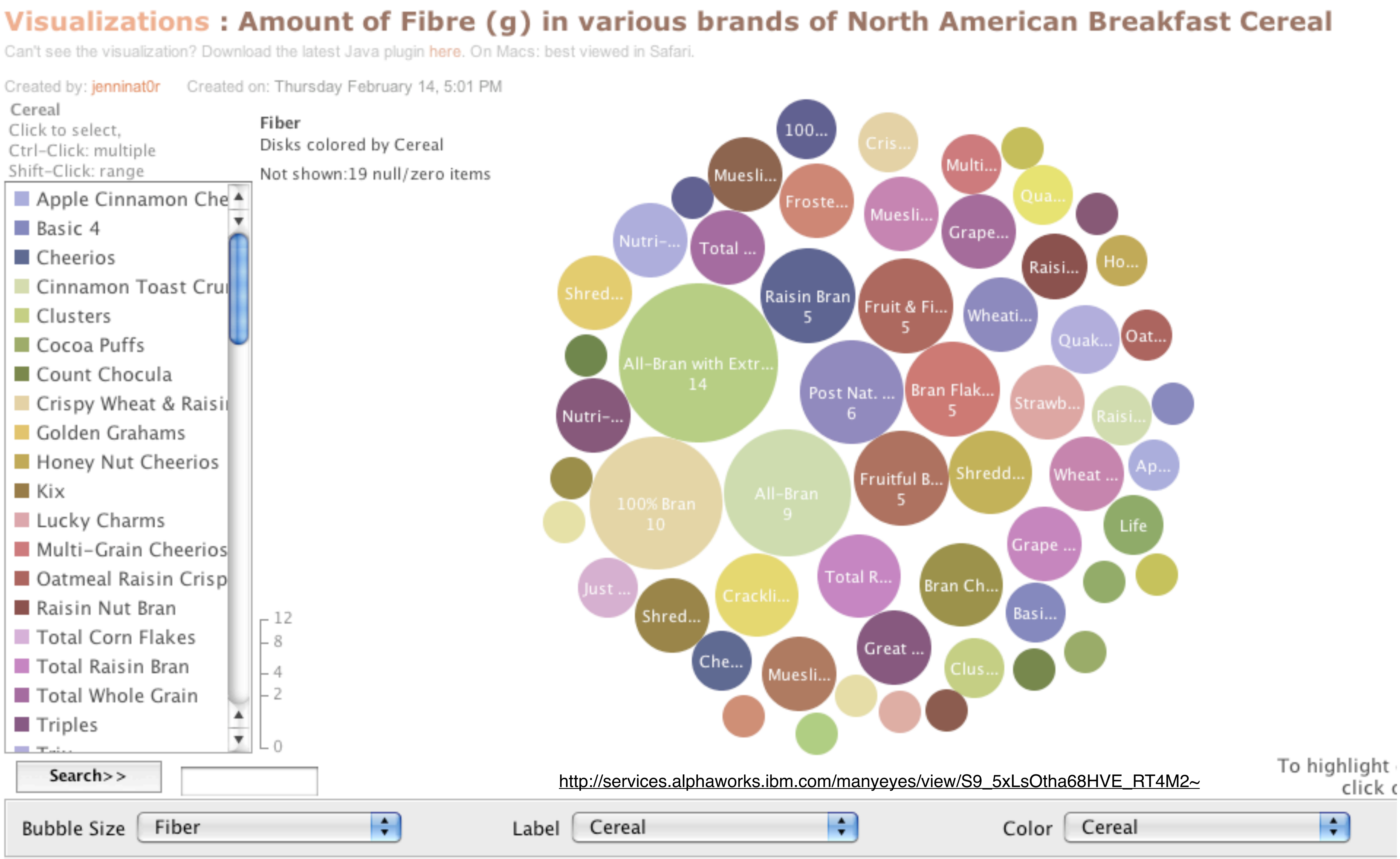


http://www.moma.org/exhibitions/2008/elasticmind/#/283/
http://www.turbulence.org/spotlight/thinking/index.html

Visualization for the Masses

- Web site as service for the general public to visualize data sets
  - http://www.many-eyes.com/
  - http://services.alphaworks.ibm.com/manyeyes/
  - not only for academics
- various types of frequently used visualizations
  - arranged by purpose
  - explanations with examples and guidelines for usage

ManyEyes Example Visualization



http://services.alphaworks.ibm.com/manyeyes/view/S9_5xLsOtha68HVE_RT4M2~

Hybrid Presentations

- combinations of several techniques are used

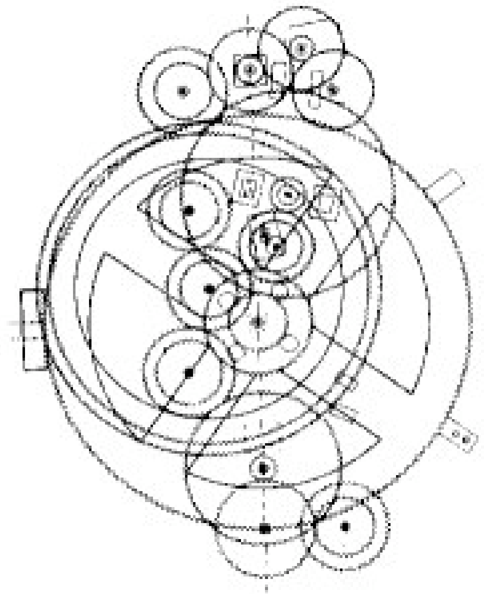
Embodiment of Knowledge

- creation of artifacts that represent important aspects of knowledge
  - replication of physical systems
  - demonstration of processes
  - simulation for experiments

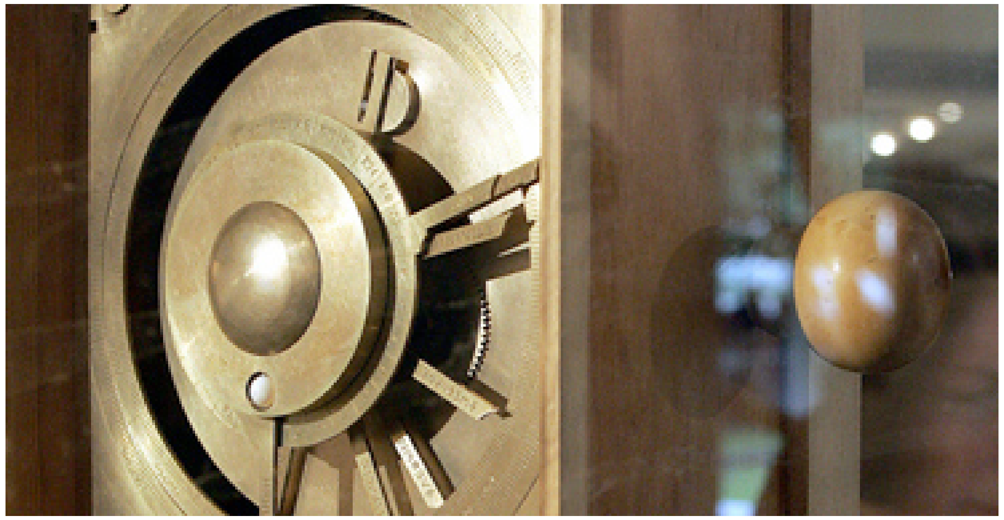
Knowledge Embodiment Examples

http://commons.wikimedia.org/wiki/Image:NAMA_Machine_d%27Anticyth%C3%A8re_1.jpg

- Antikythera Mechanism
  - astronomical calendar capable of tracking
    - position of the sun
    - several heavenly bodies
    - phases of the moon
  - earliest known mechanism to use gear wheels
    - not observed again until about 1600 years later



http://commons.wikimedia.org/wiki/Image:Meccanismo_di_Antikytera.jpg



A reconstruction of the Antikythera mechanism.
Photograph: Louisa Gouliamaki/AFP/Getty

http://www.guardian.co.uk/science/2006/nov/30/uknews

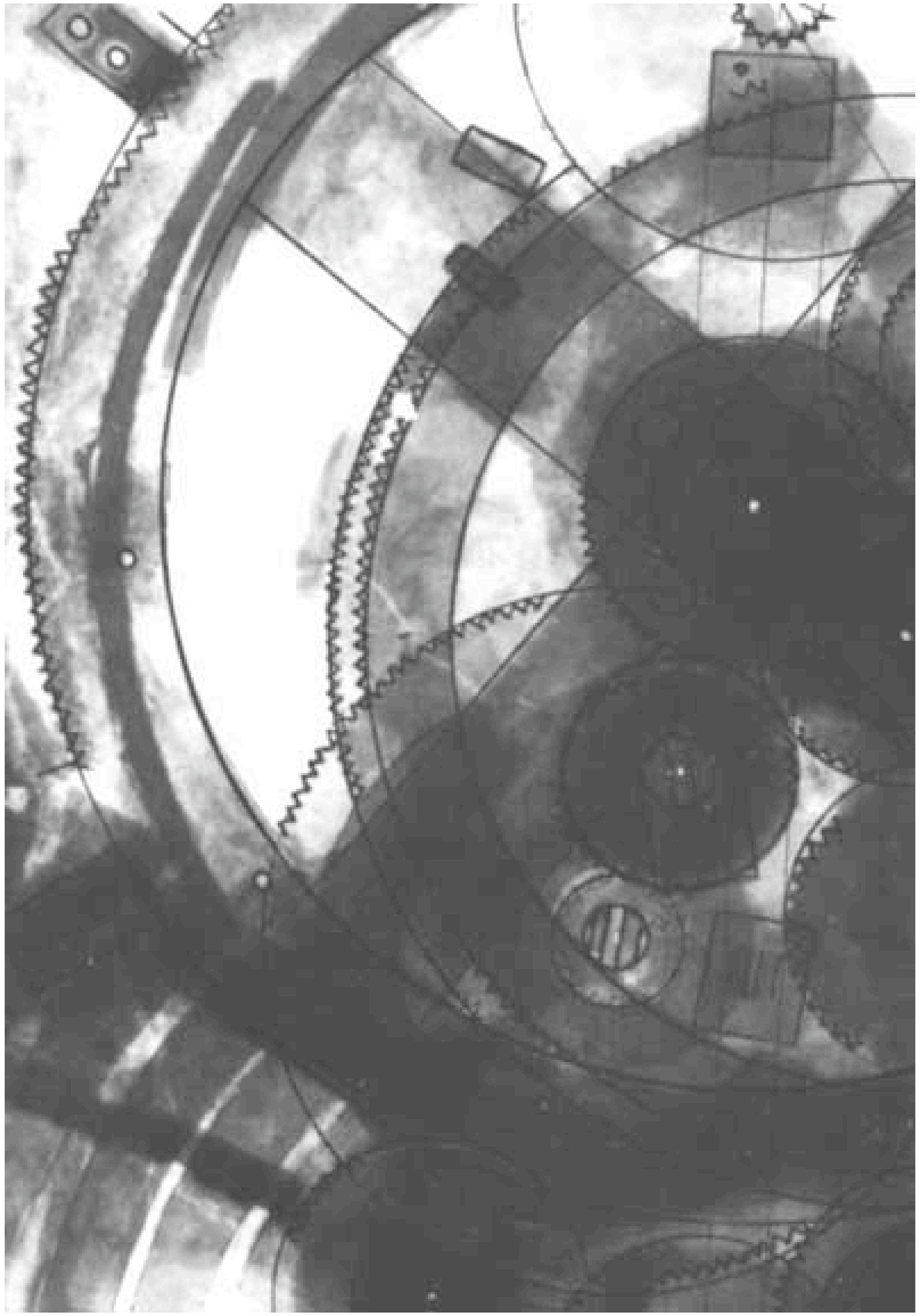
Antikythera Original

http://www.crystalinks.com/antikythera.jpg

http://news.bbc.co.uk/nol/shared/spl/hi/pop_ups/06/technology_enl_1164817474/img/1.jpg

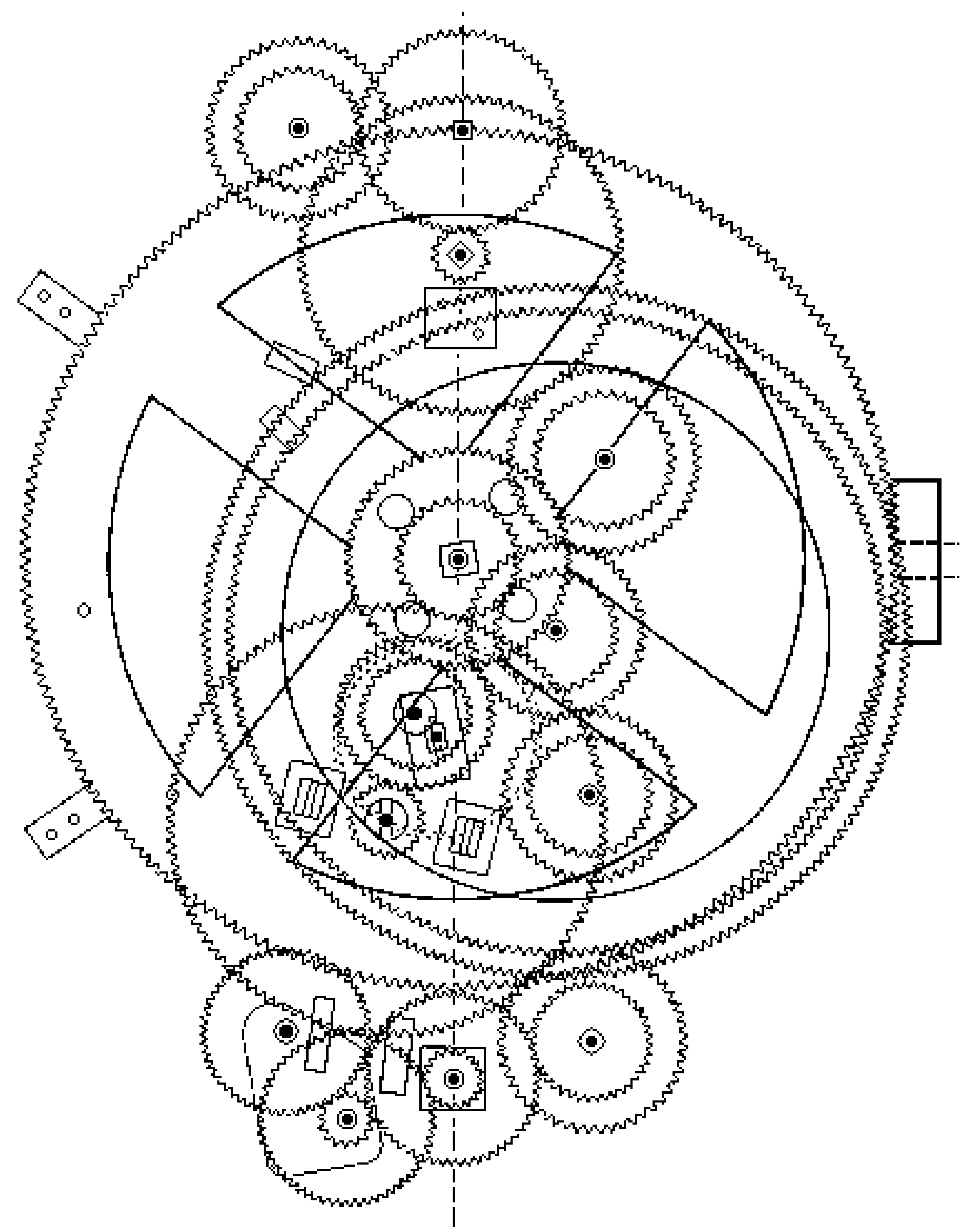
Antikythera Analysis

- ❖trying to decipher the purpose and function of the mechanism
  - ❖only partially preserved
  - ❖some faint inscriptions
  - ❖impractical to take apart



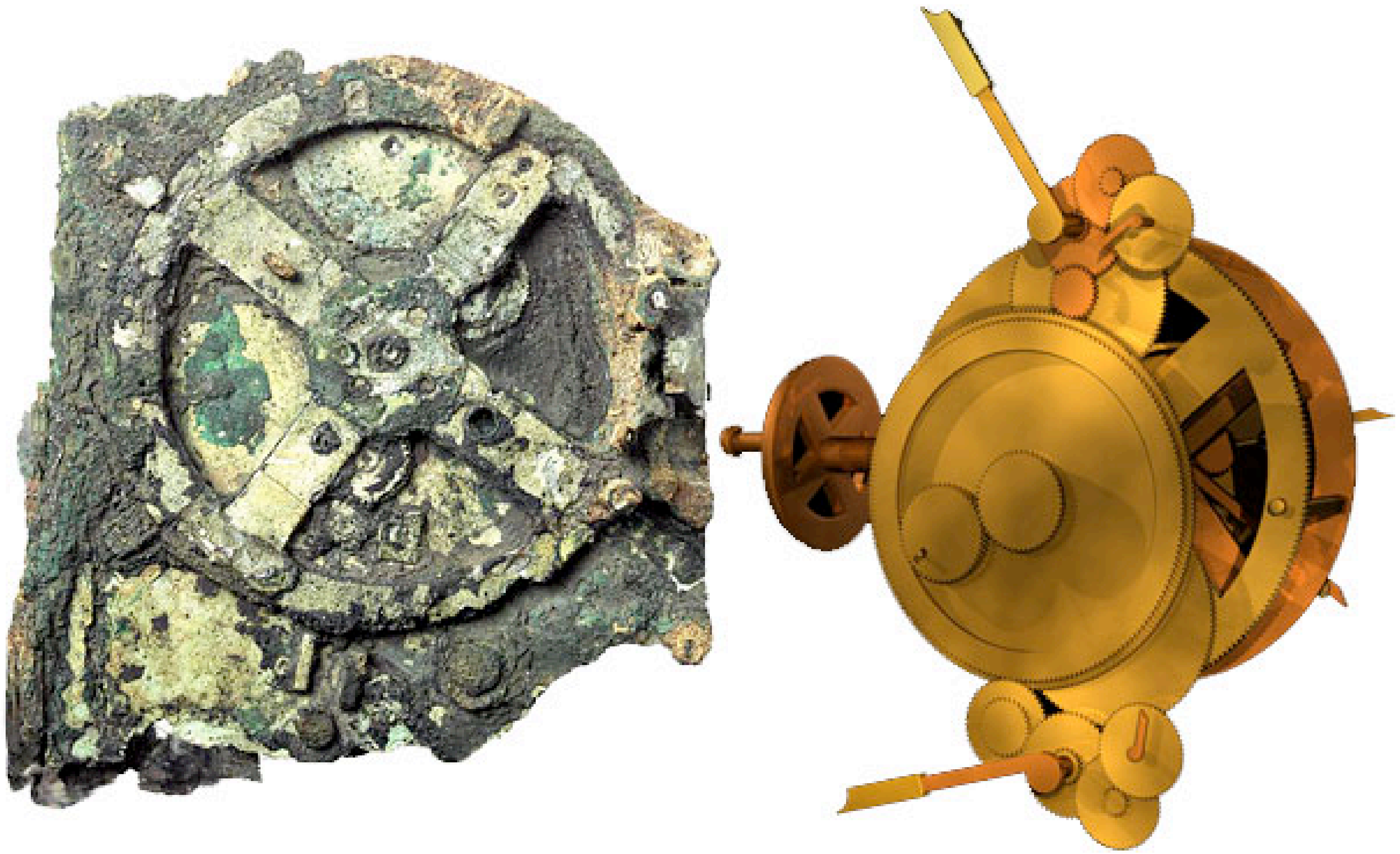
http://www.virtuescience.com/antikythera.jpg

Antikythera Schematics



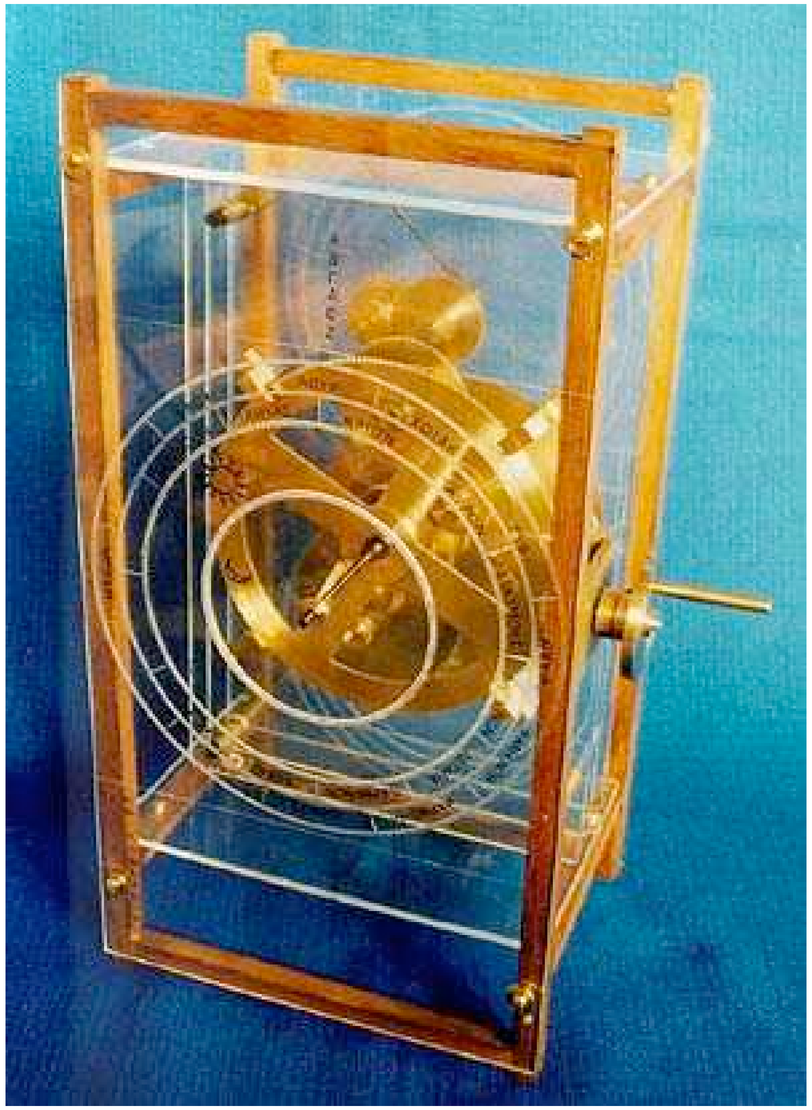
http://www.cs.uwaterloo.ca/~shallit/Courses/134/antik3.gif

Antikythera Virtual Model



http://asymptotia.com/wp-images/2006/11/29comput650.jpg

Antikythera Reconstruction



http://www.grand-illusions.com/images/antik1.jpg

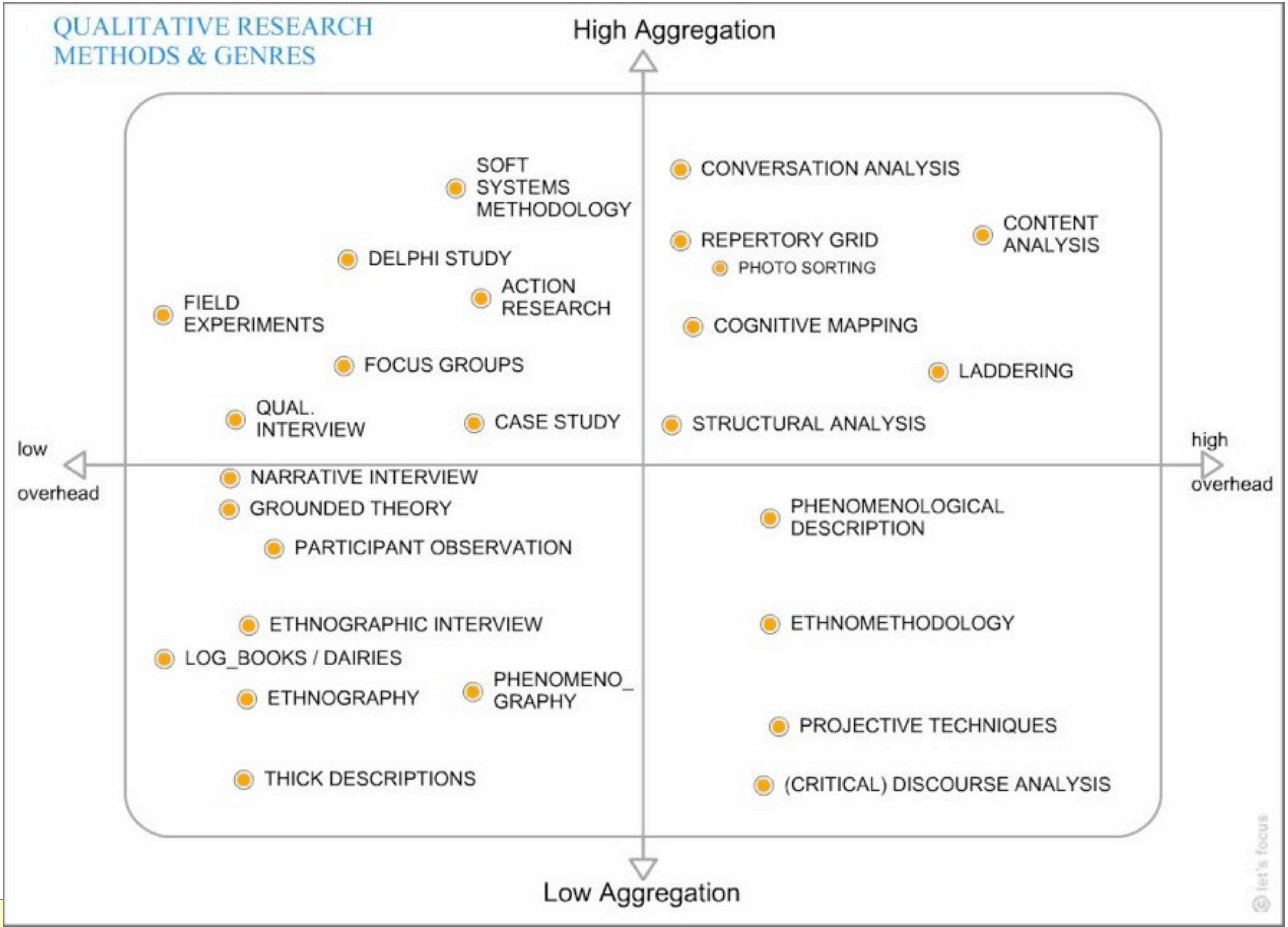
http://www.grand-illusions.com/images/antik2.jpg

Astrolabe

- later development
  - possibly influenced by the Antikythera mechanism

New York Metropolitan Museum of Art, April 2003.
en.wikipedia.org/wiki/Astrolabe, if you are interested in how they are used.
Photo by Charles Tilford, http://www.flickr.com/photos/charlestilford/189670488/
via http://iscience.wordpress.com/2006/11/29/the-antikythera-mechanism/

Qualitative Research Methods

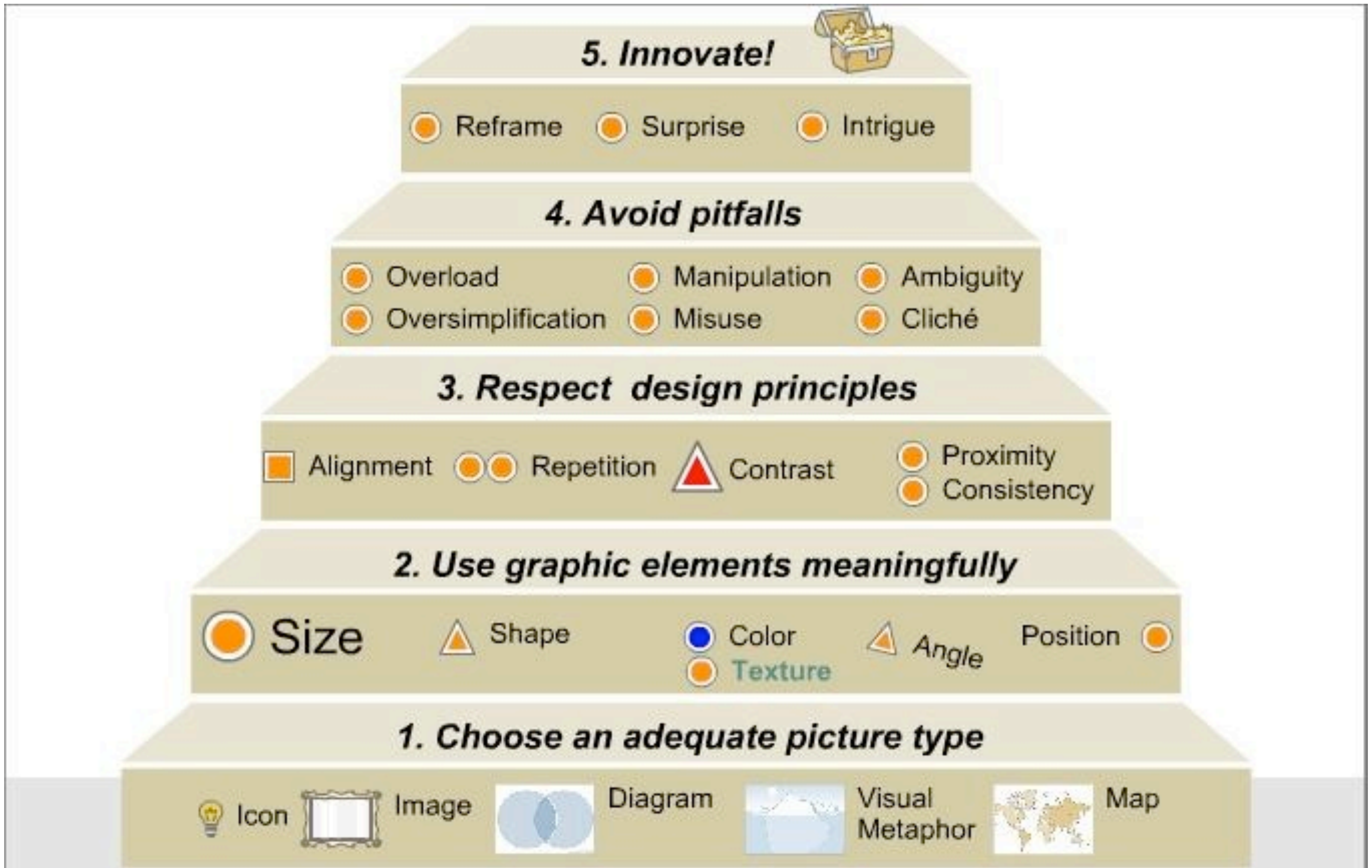


Martin Eppler, http://www.knowledge-communication.org/images/qualitative_methods_final.jpg

Knowledge Types

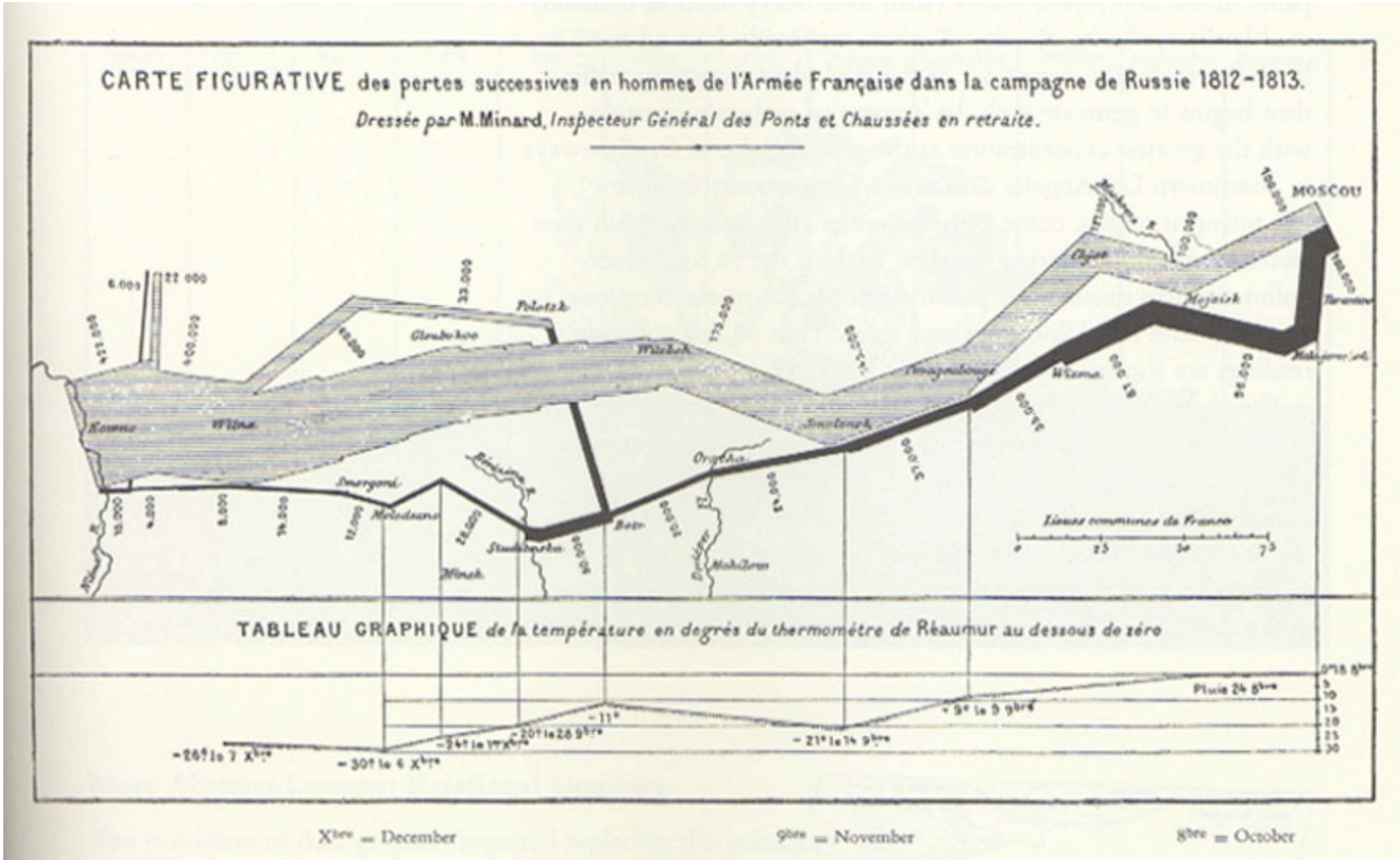
Martin Eppler: http://www.knowledge-communication.org/knowledge%20capucchino.BMP

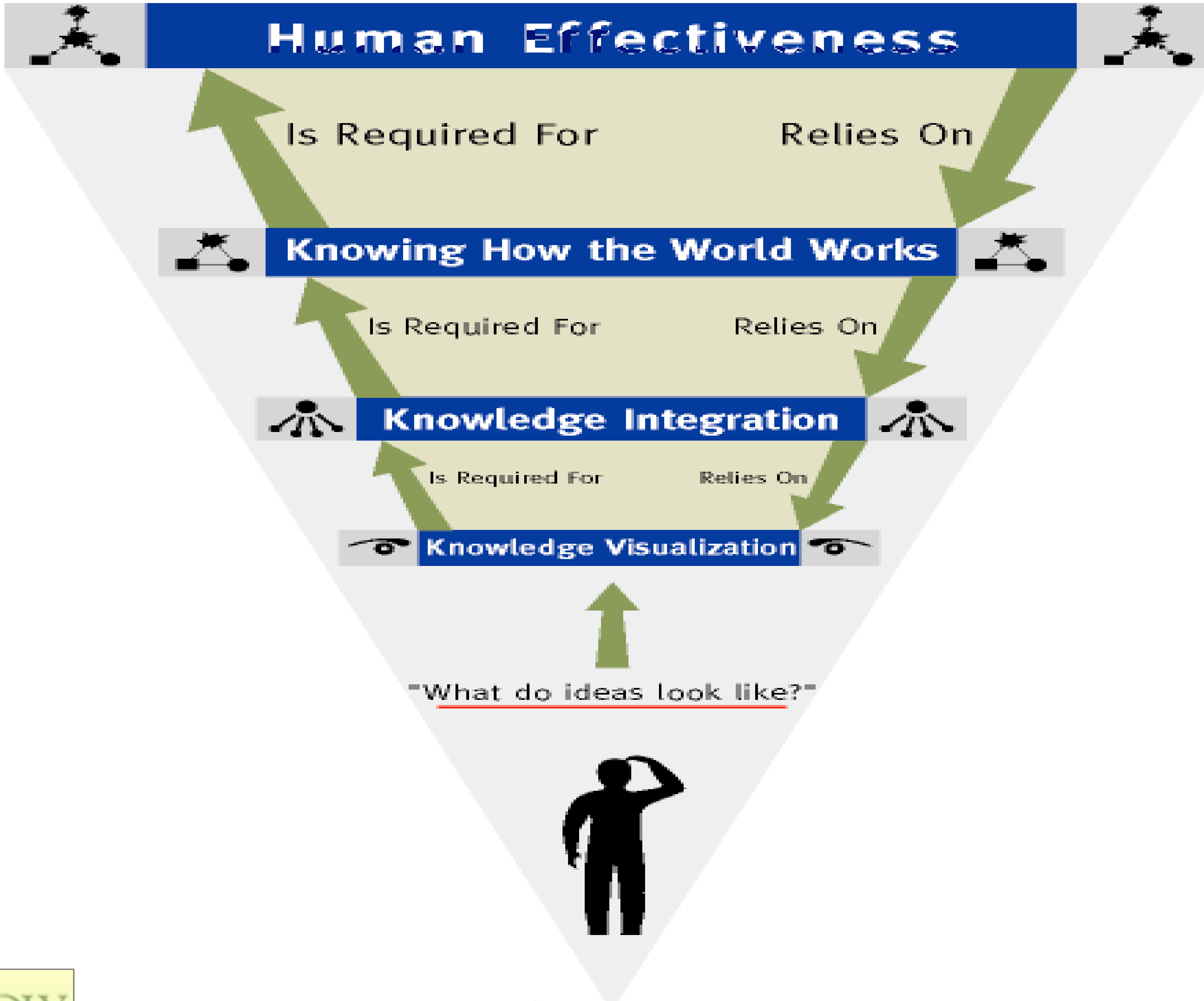
Stairs of Visualization



Martin Eppler, http://www.knowledge-communication.org/stairs.html
(contains annotations and images to illustrate the issues addressed)

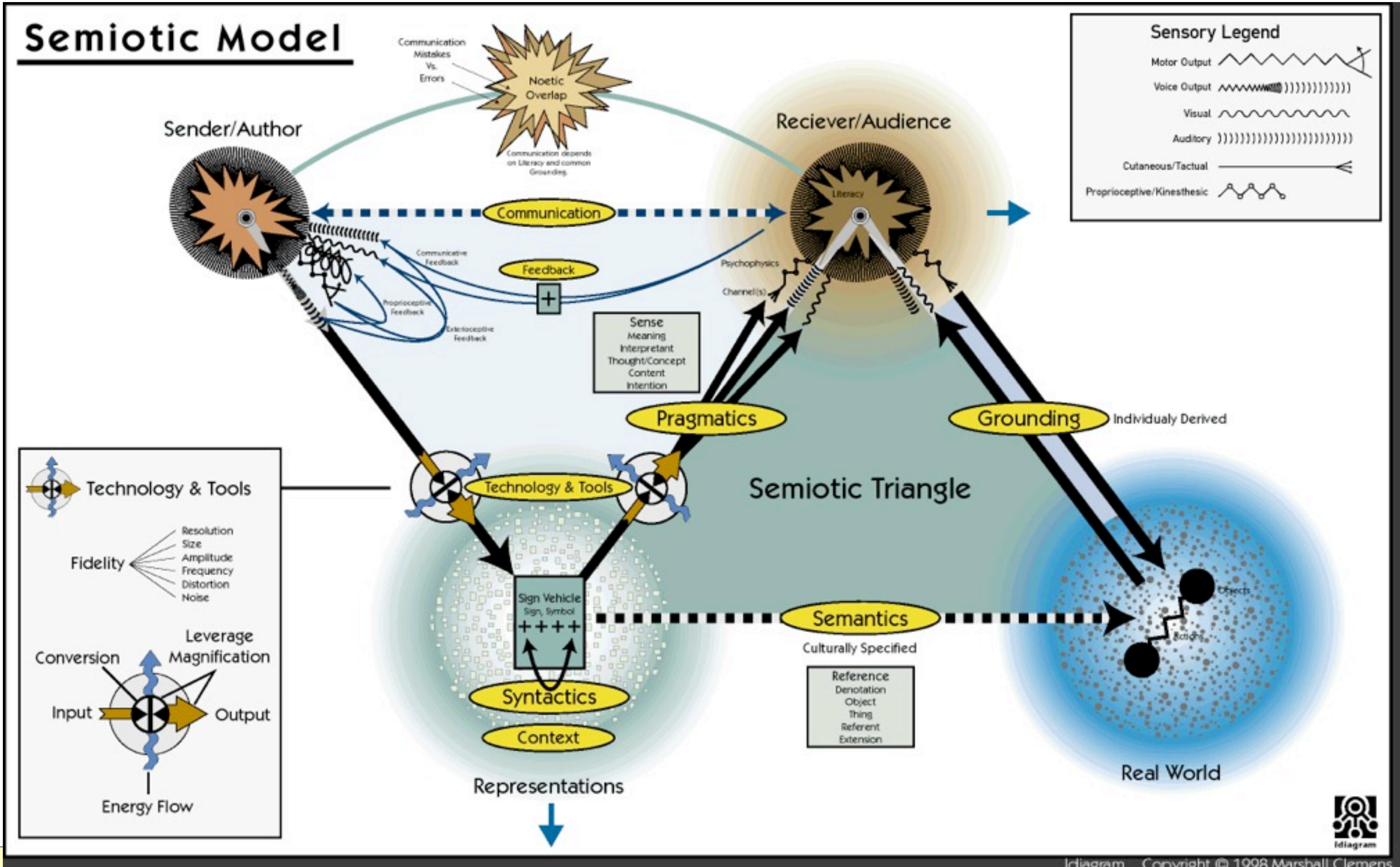
Minard: Napoleon’s Russia Campaign





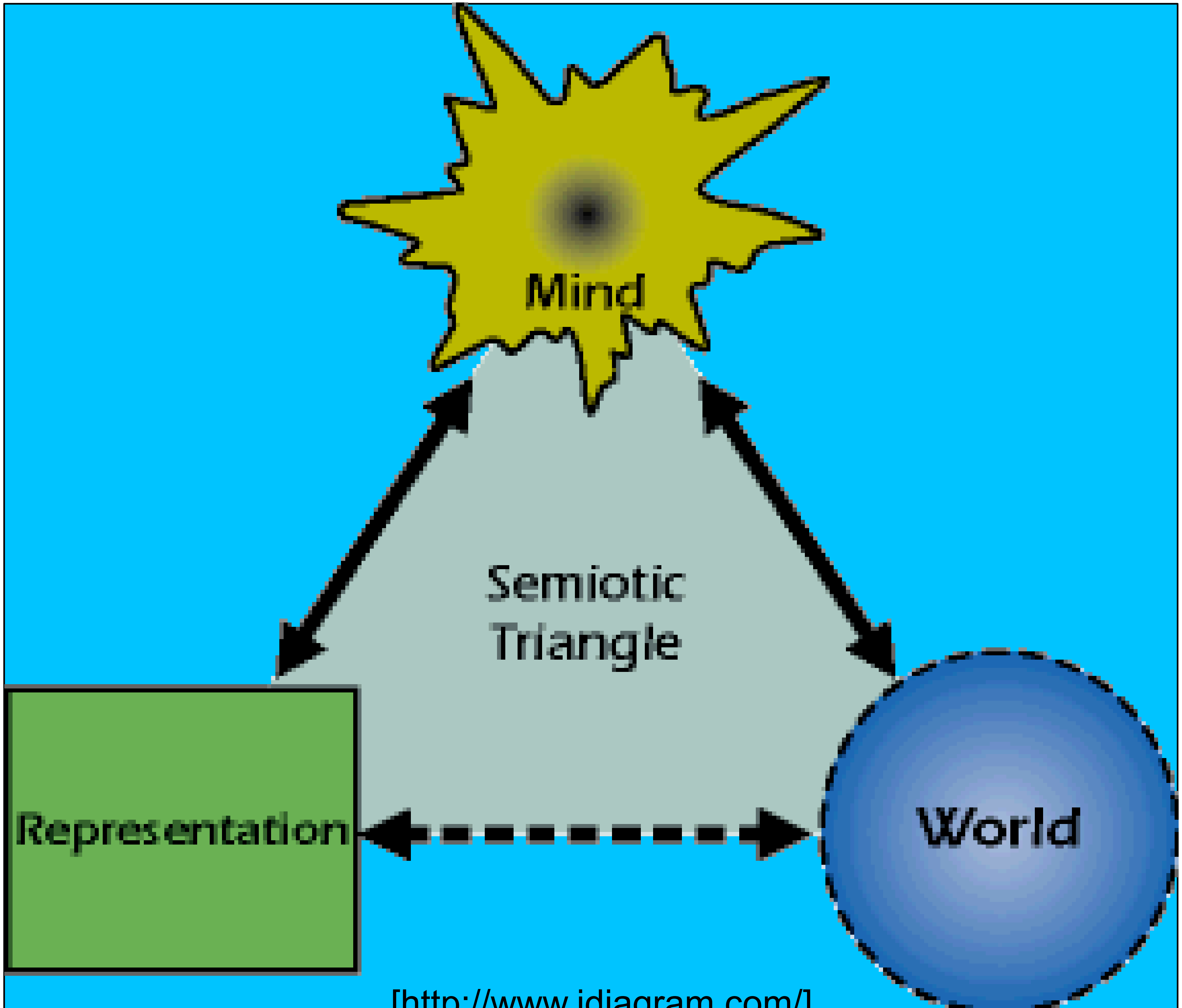
[http://www.idiagram.com/]

Semiotic Model

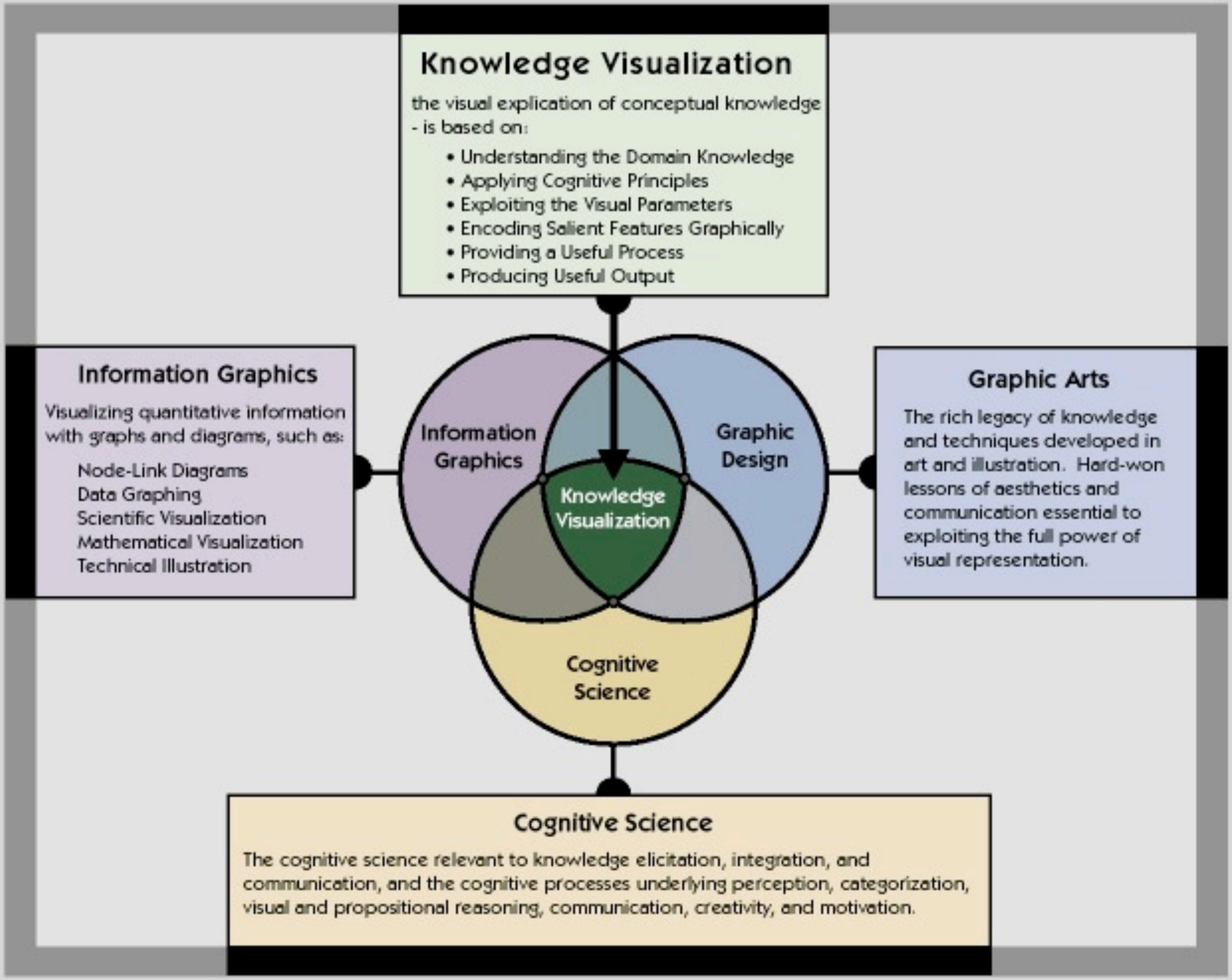


[http://www.idiagram.com/]

Semiotic Triangle

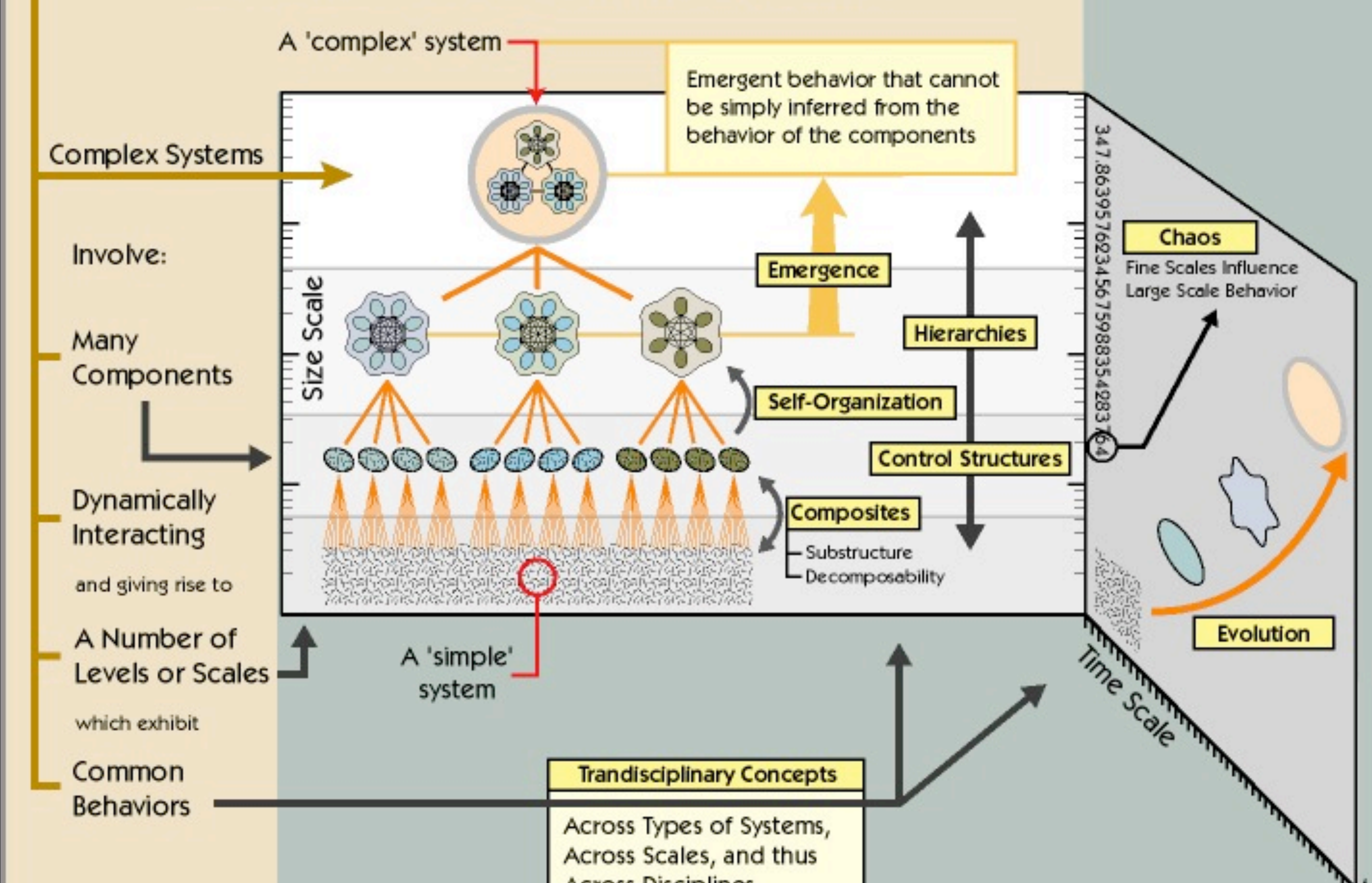


[http://www.idiagram.com/]

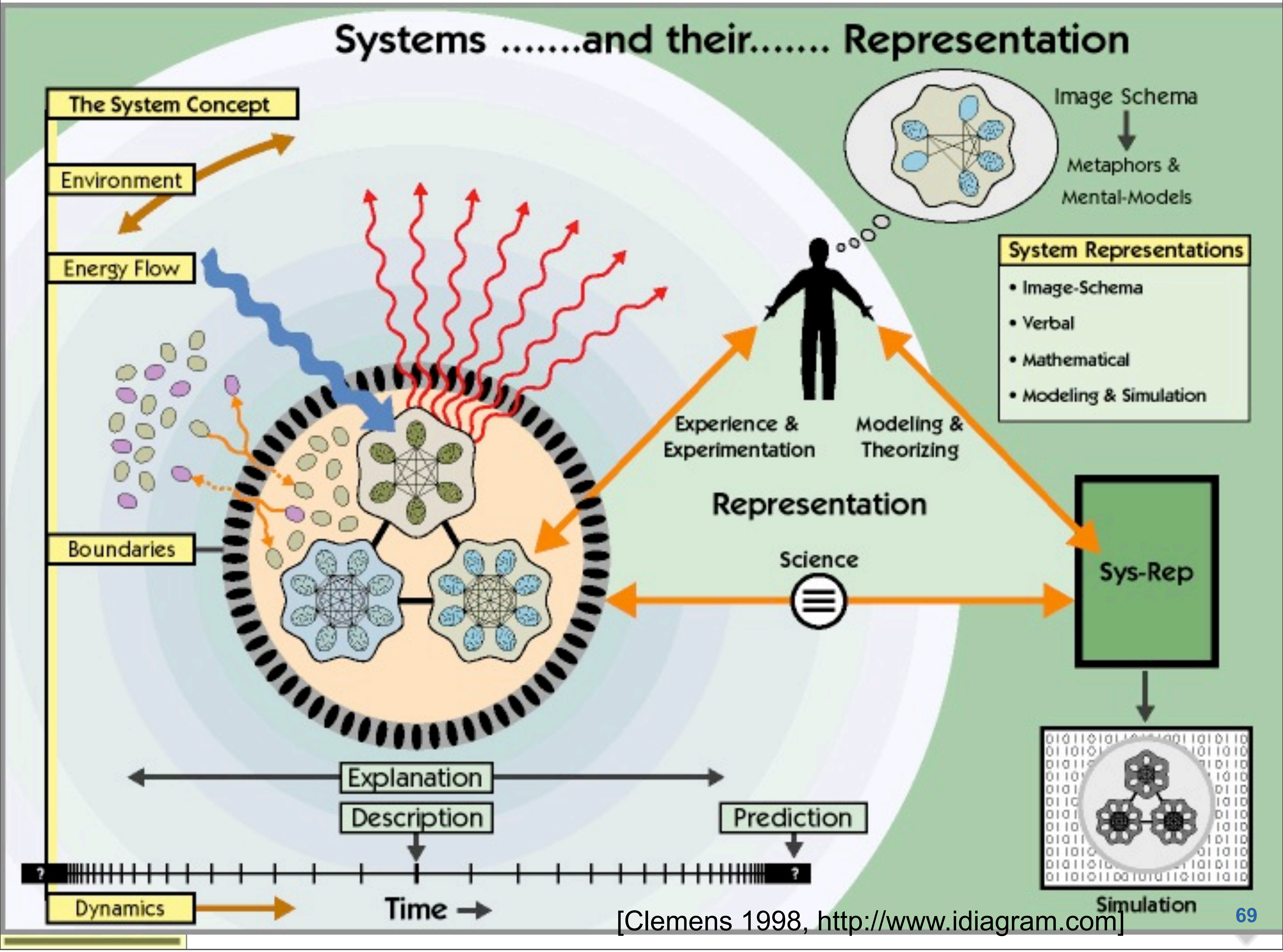


[Clemens 1998, http://www.idiagram.com/kv_venn.html]

Characteristics of Complex Systems

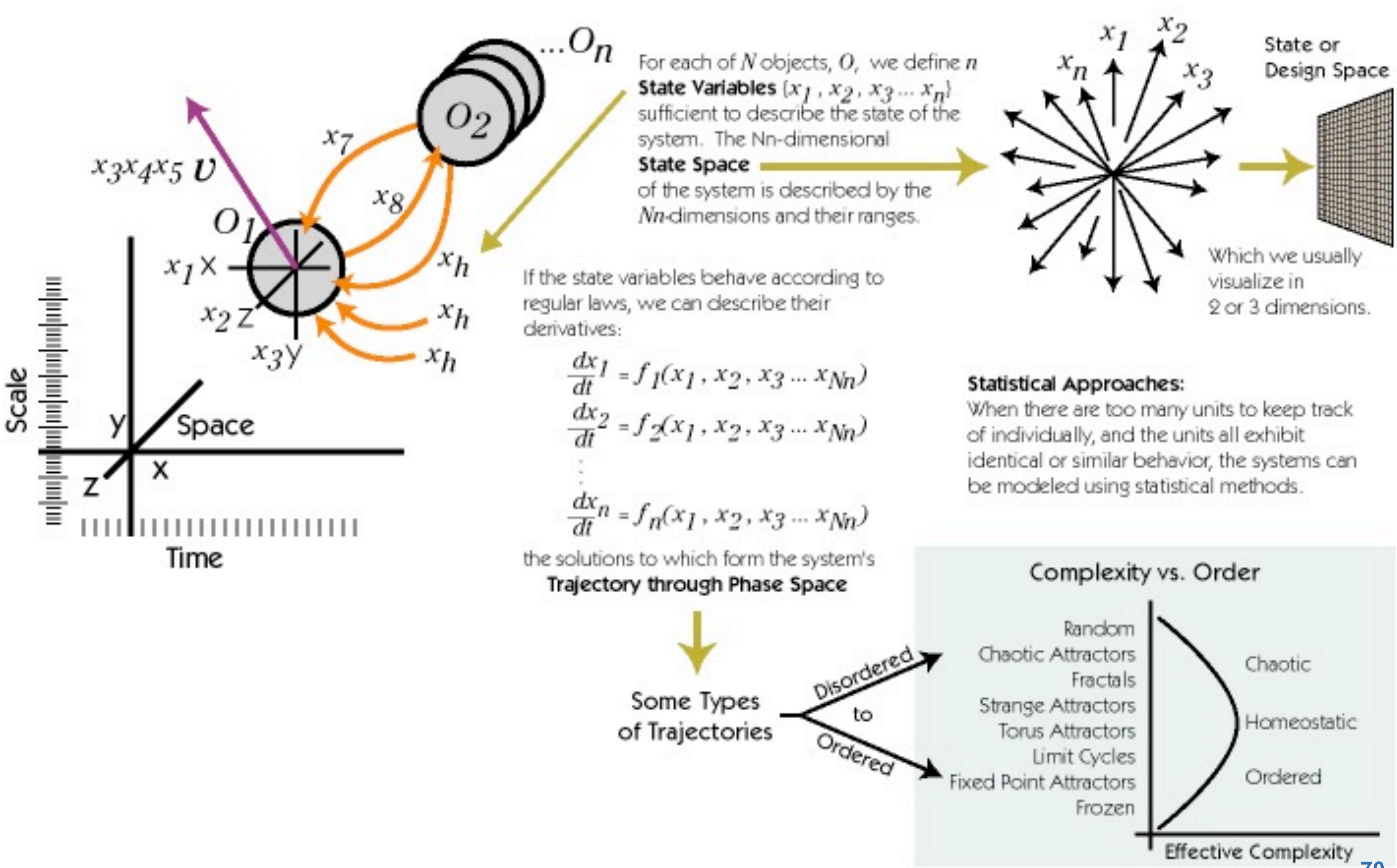


[Clemens 1998, http://www.idiagram.com]

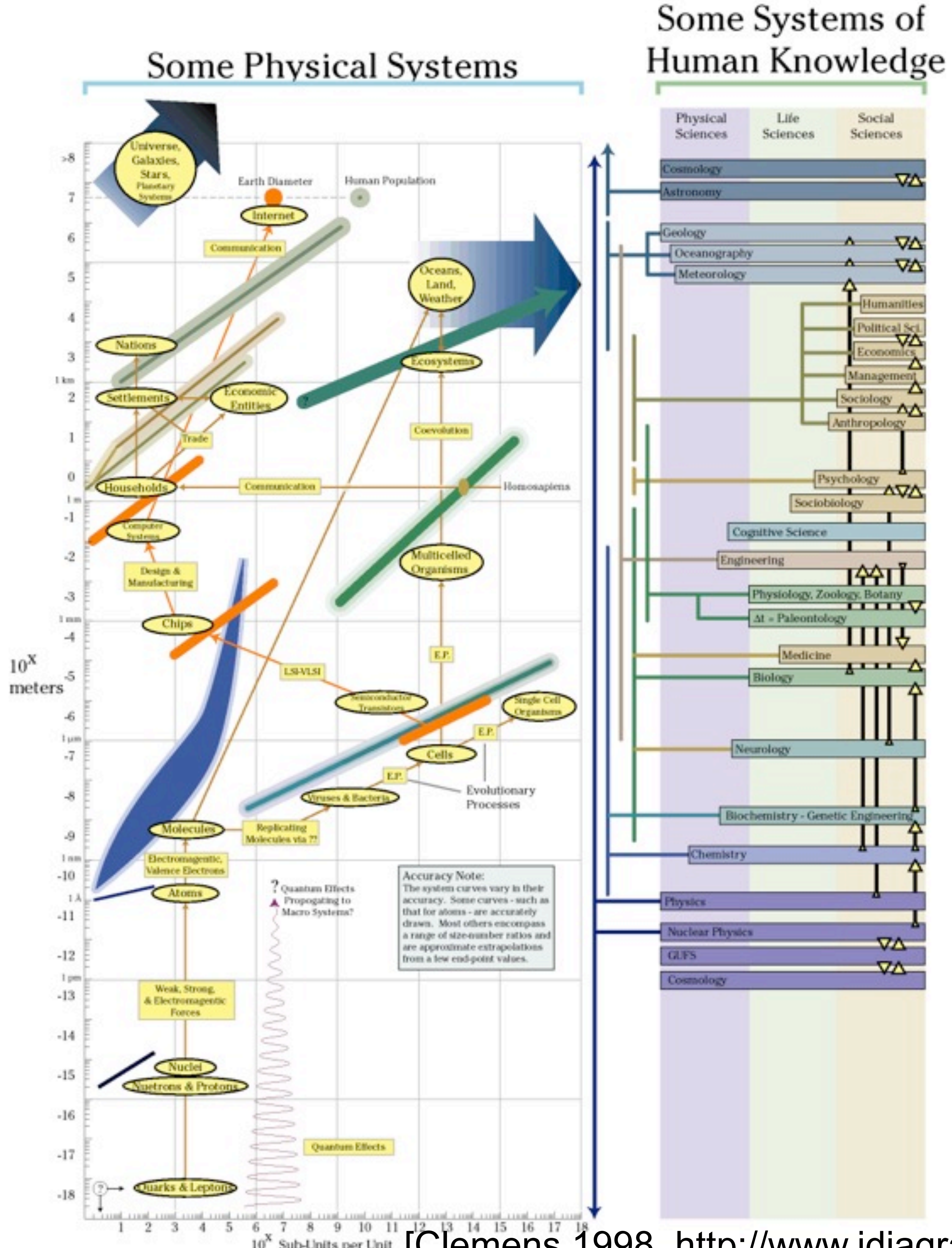


[Clemens 1998, http://www.idiagram.com]

System Dynamics: State & Phase Space

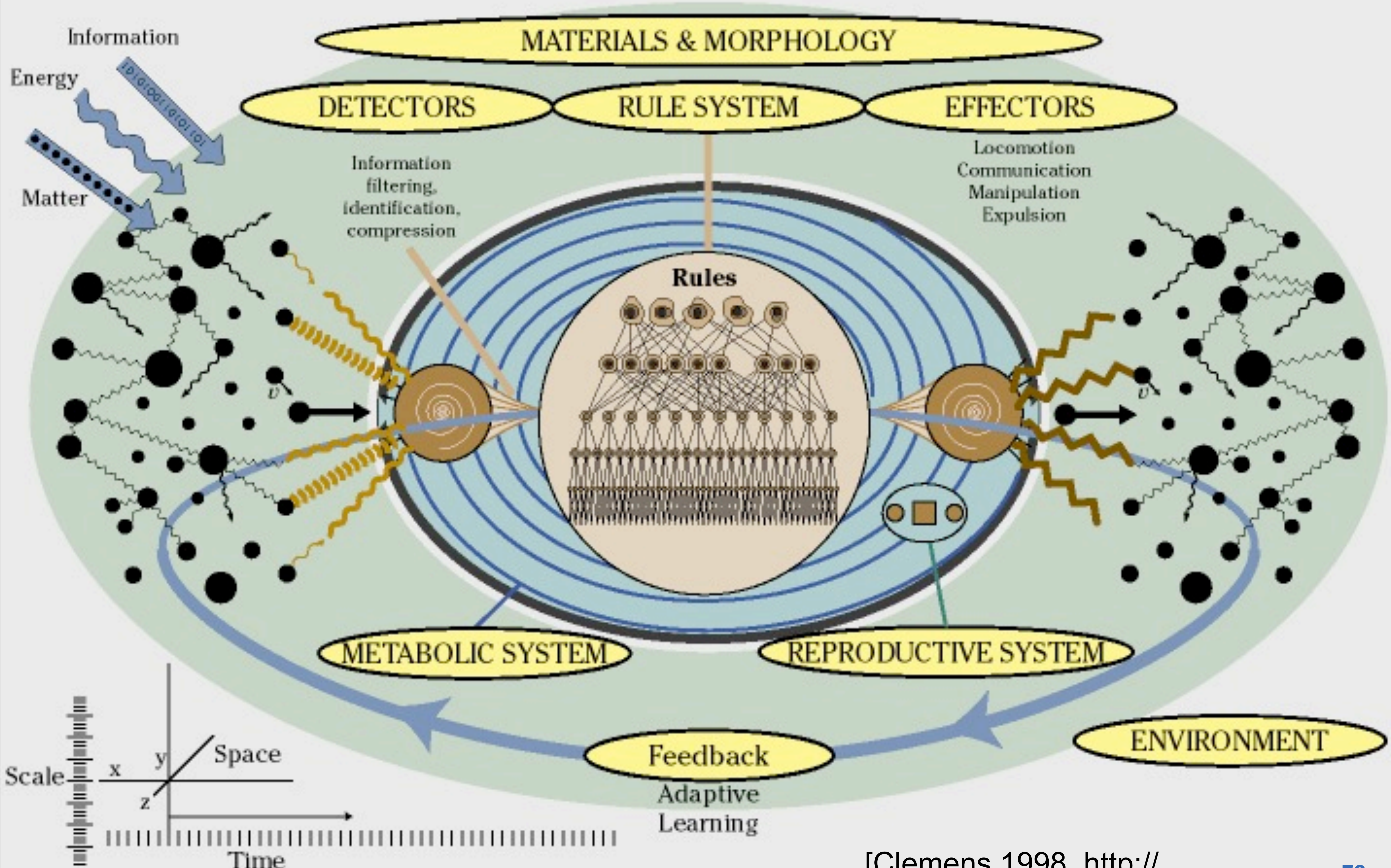


[Clemens 1998, http://www.idiagram.com]



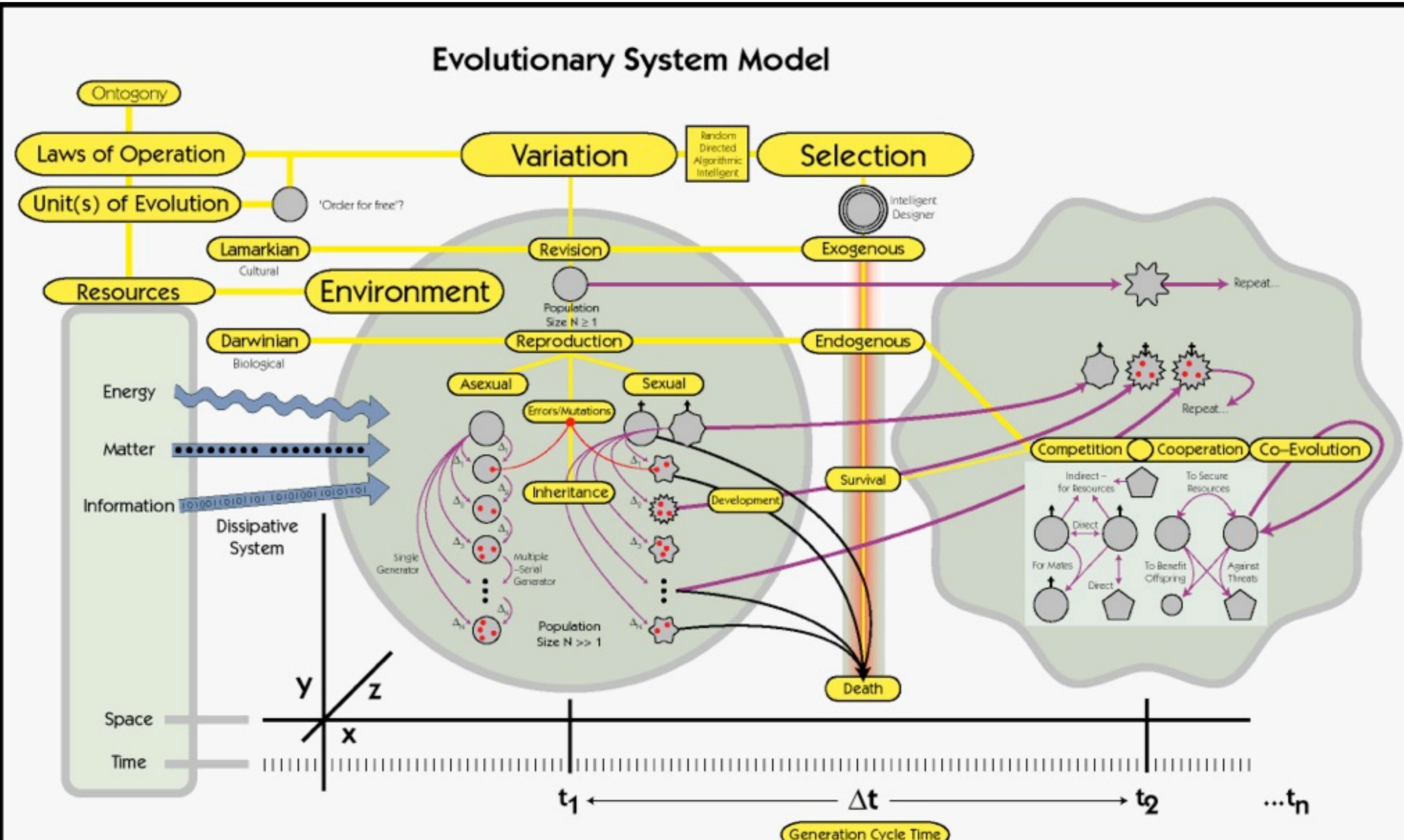
[Clemens 1998, http://www.idiagram.com]

Complex Adaptive System Model

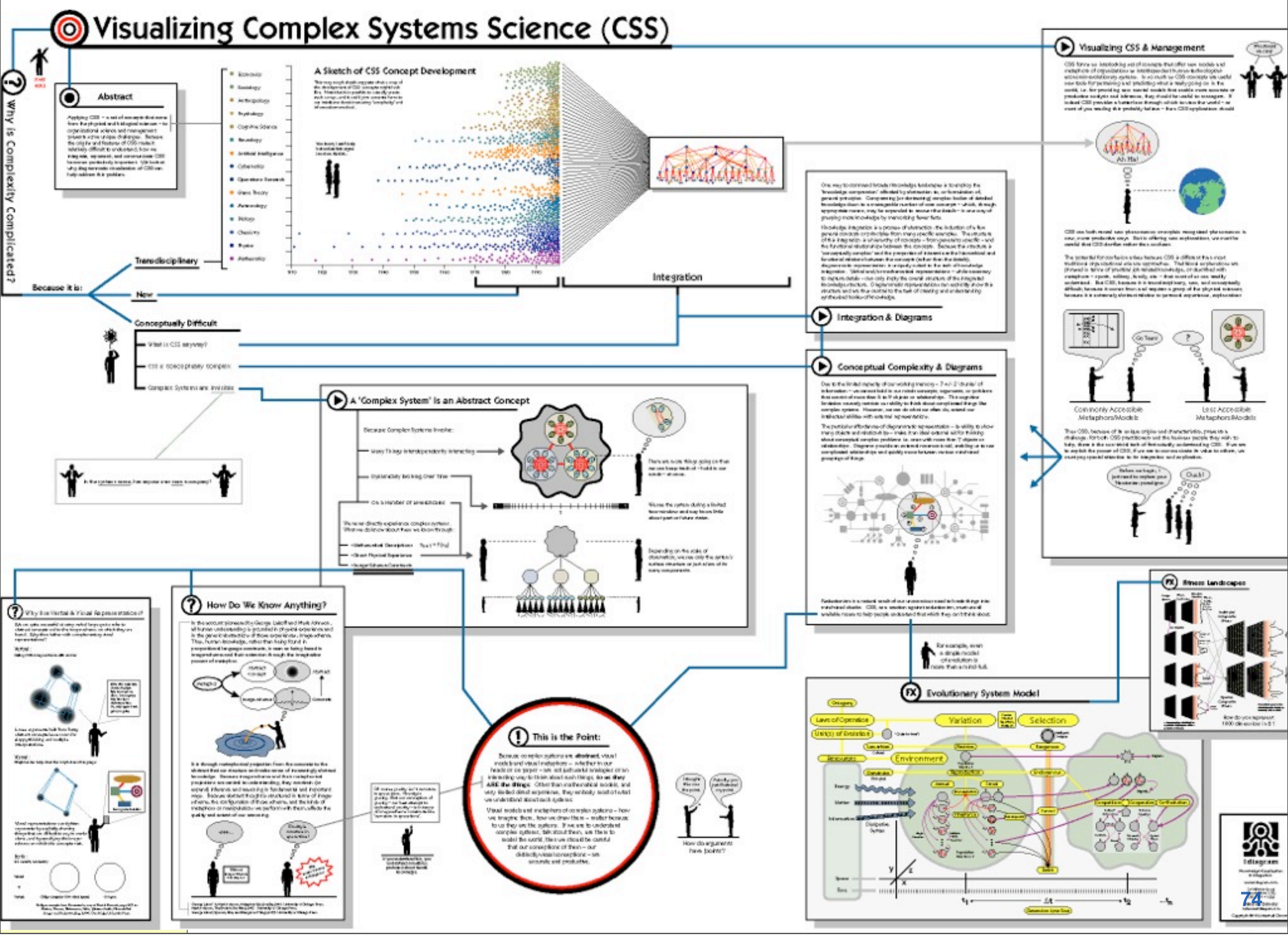


[Clemens 1998, http://www.idiagram.com]

Evolutionary System Model



[Clemens 1998, http://www.idiagram.com]


Visualizing Complex Systems Science (CSS)
Why is Complexity Complicated?
Abstract
A Sketch of CSS Concept Development
Transdisciplinary
Because it is:
New
Conceptually Difficult
Integration
Visualizing CSS & Management
Ah Ha!
Integration & Diagrams
Conceptual Complexity & Diagrams
Commonly Accessible Metaphors/Models
Less Accessible Metaphors/Models
Go Team!
Ouch!
A 'Complex System' is an Abstract Concept
How Do We Know Anything?
This is the Point:
How do arguments have points?
Evolutionary System Model
Laws of Operation
Unit(s) of Evolution
Variation
Selection
Environment
Fitness Landscapes
74

Brain Images

- visualizations of structures and activities in the brain
  - e.g. neurons, cerebellum, visual cortex,
  - functions such as connections (wires)
  - electrical and chemical activities

Ramón y Cahal’s Neuron Diagram

- drawing of a Purkinje cell
  - large neurons in the cerebellum
- based on tissue stained with silver nitrate
  - viewed through a microscope

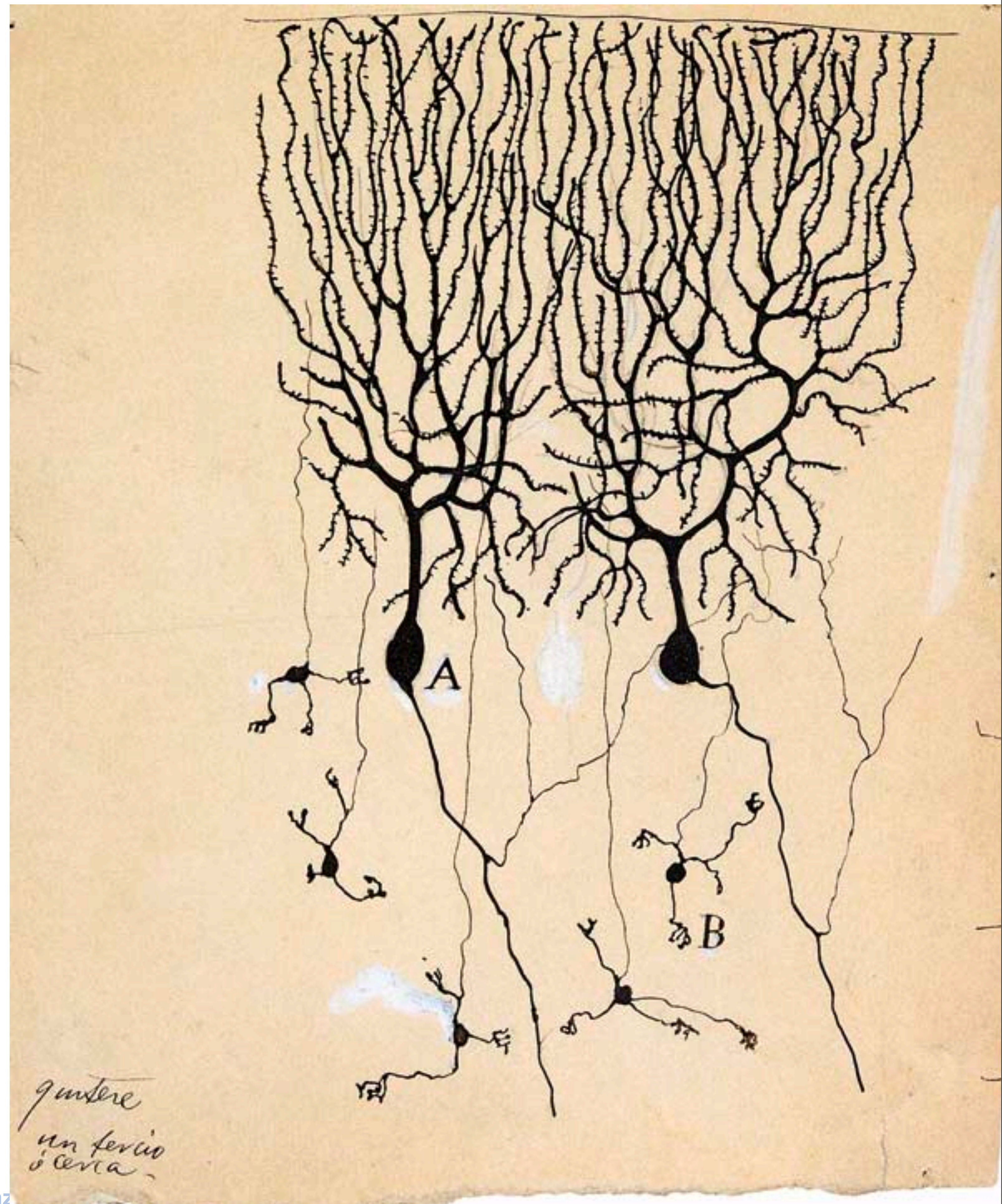


Photo Credit: Herederos de Santiago Ramón y Cajal,
via MIT Technology Review “Time Travel Through the Brain” http://www.technologyreview.com/biomedicine/23758/

Mouse Cerebellum

- two-photon microscopic image
- allows images of live tissue
- uses infrared light

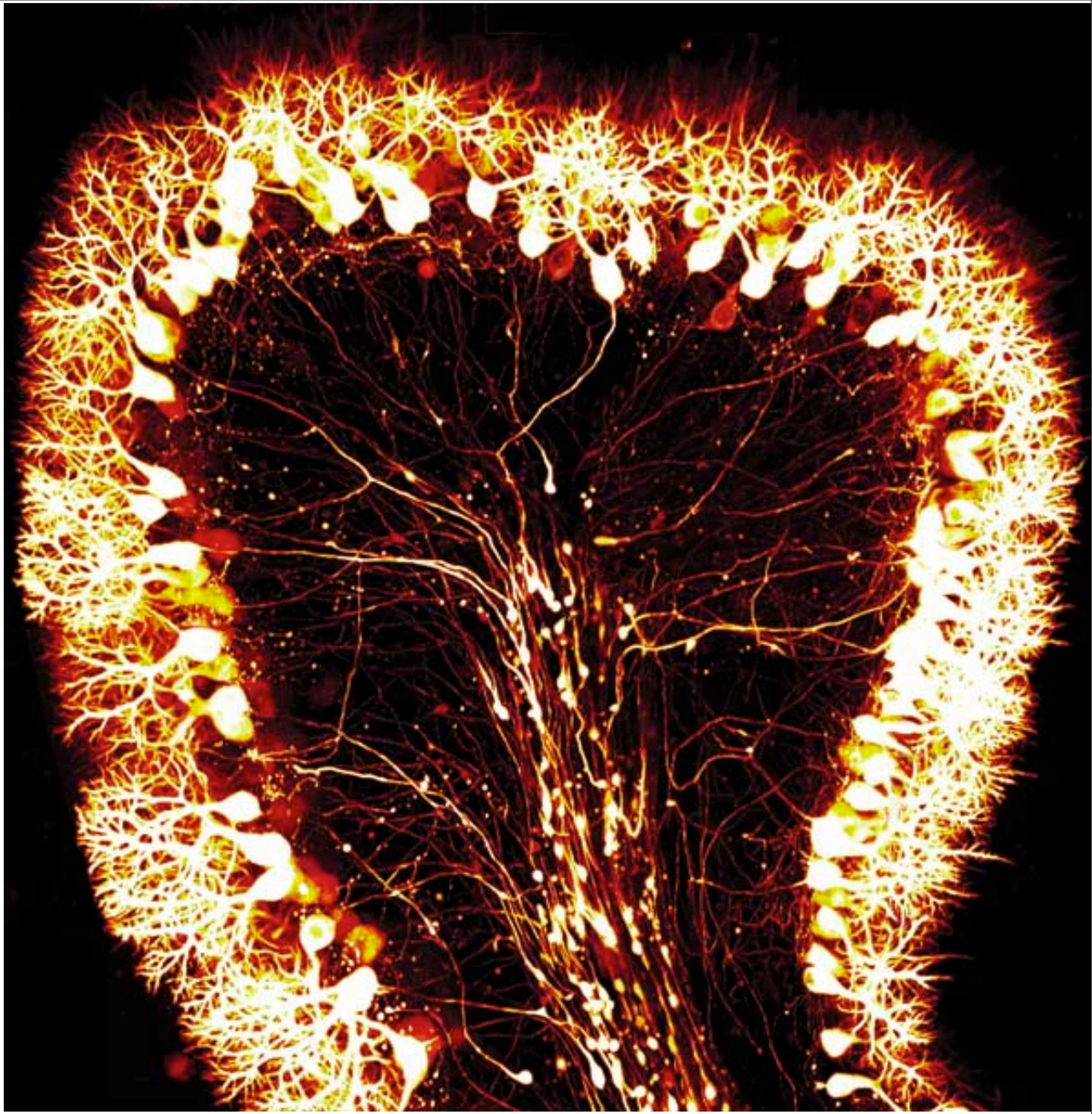
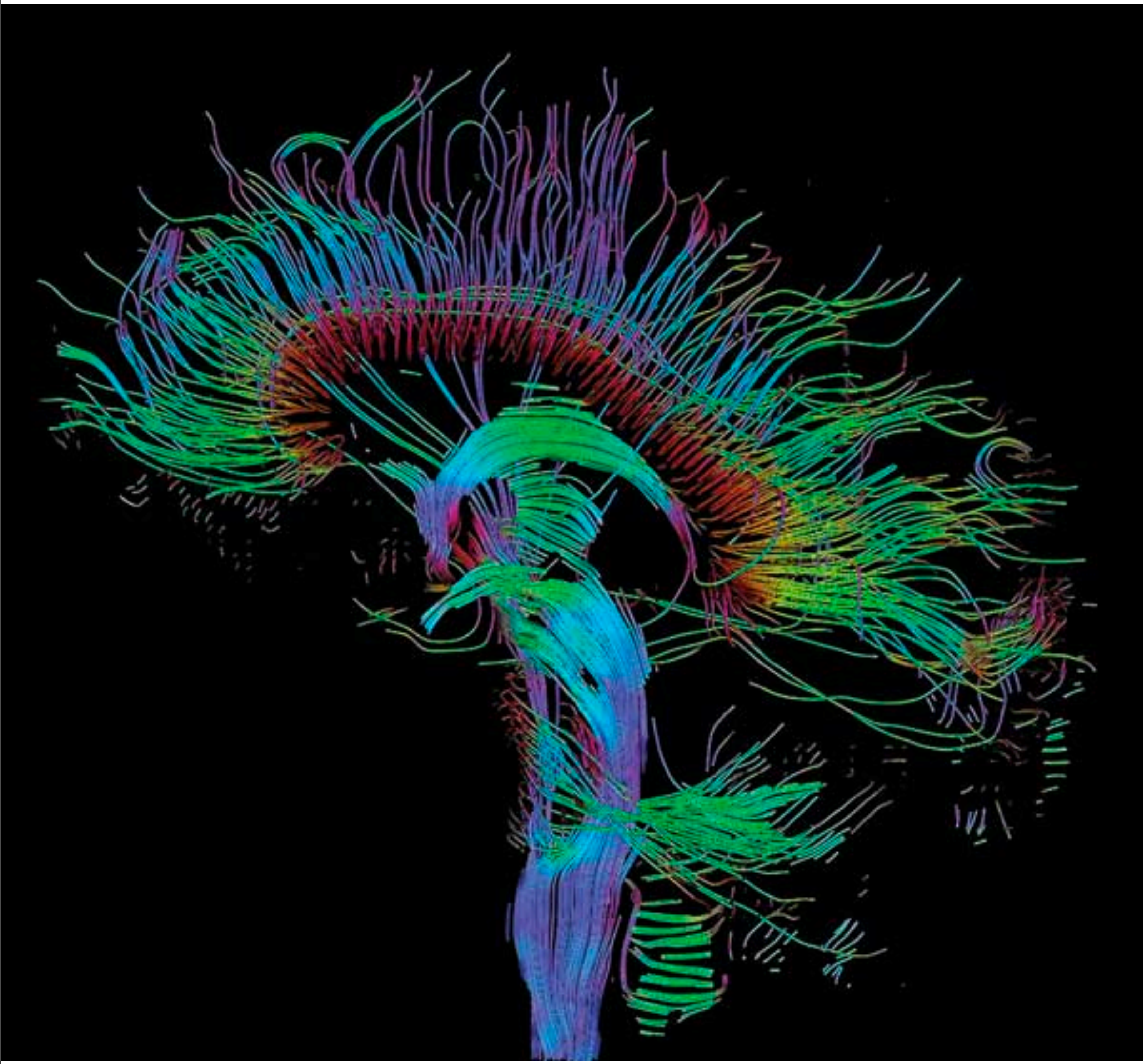


Photo Credit: Alanna Watt and Michael Häusser, UCL,
via MIT Technology Review “Time Travel Through the Brain” http://www.technologyreview.com/biomedicine/23758/

Human Thalamus



- fibers radiating from the thalamus in the human brain
- diffusion tensor image
  - variation of magnetic resonance imaging (MRI)

Photo Credit: Thomas Schultz/University of Chicago, via MIT Technology Review "Time Travel Through the Brain"
http://www.technologyreview.com/biomedicine/23758/

Fluorescent Purkinje Cells

- Purkinje cell (red)
- nerve fiber from another cell (green)
- injection of fluorescent dye into individual cells

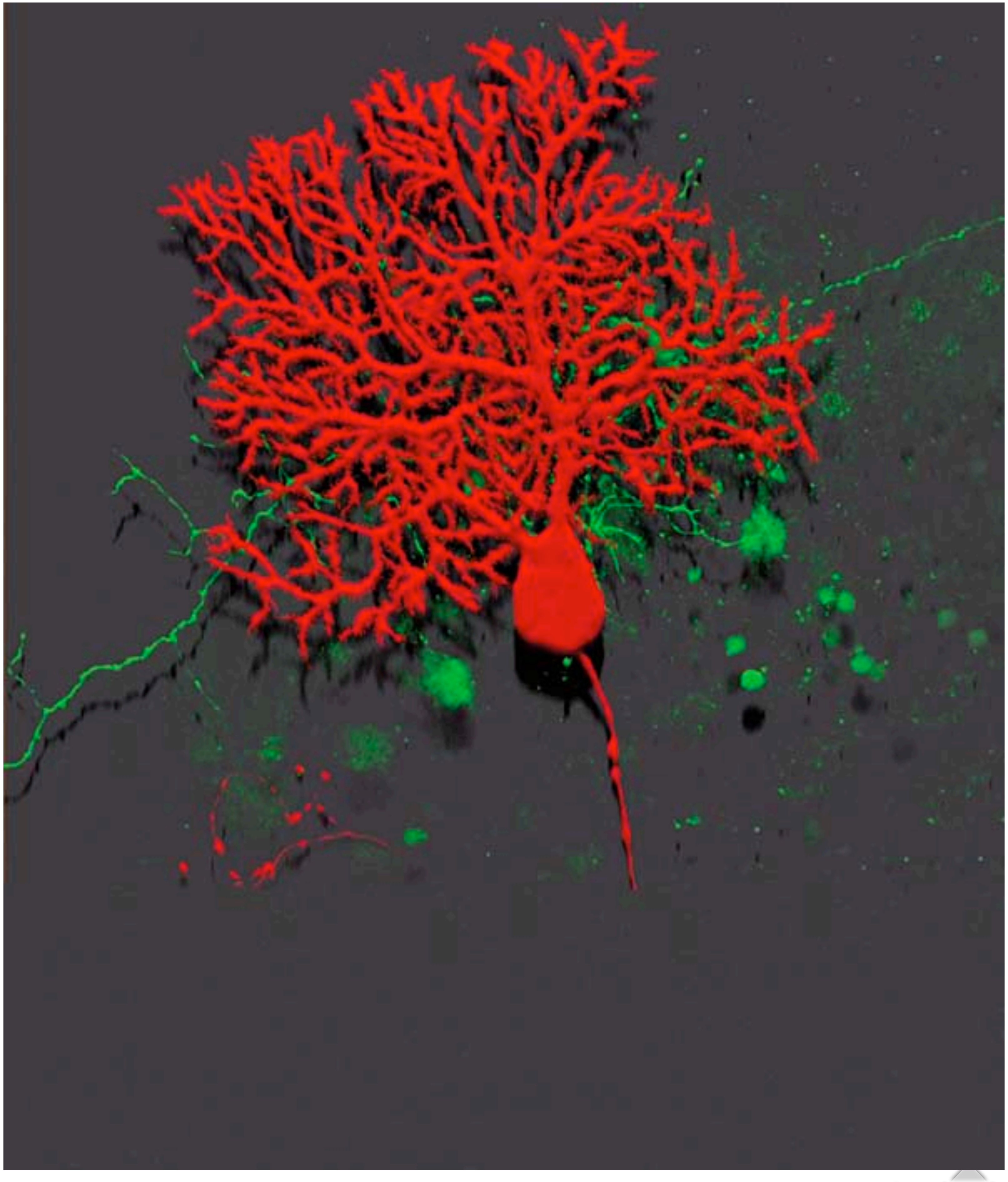
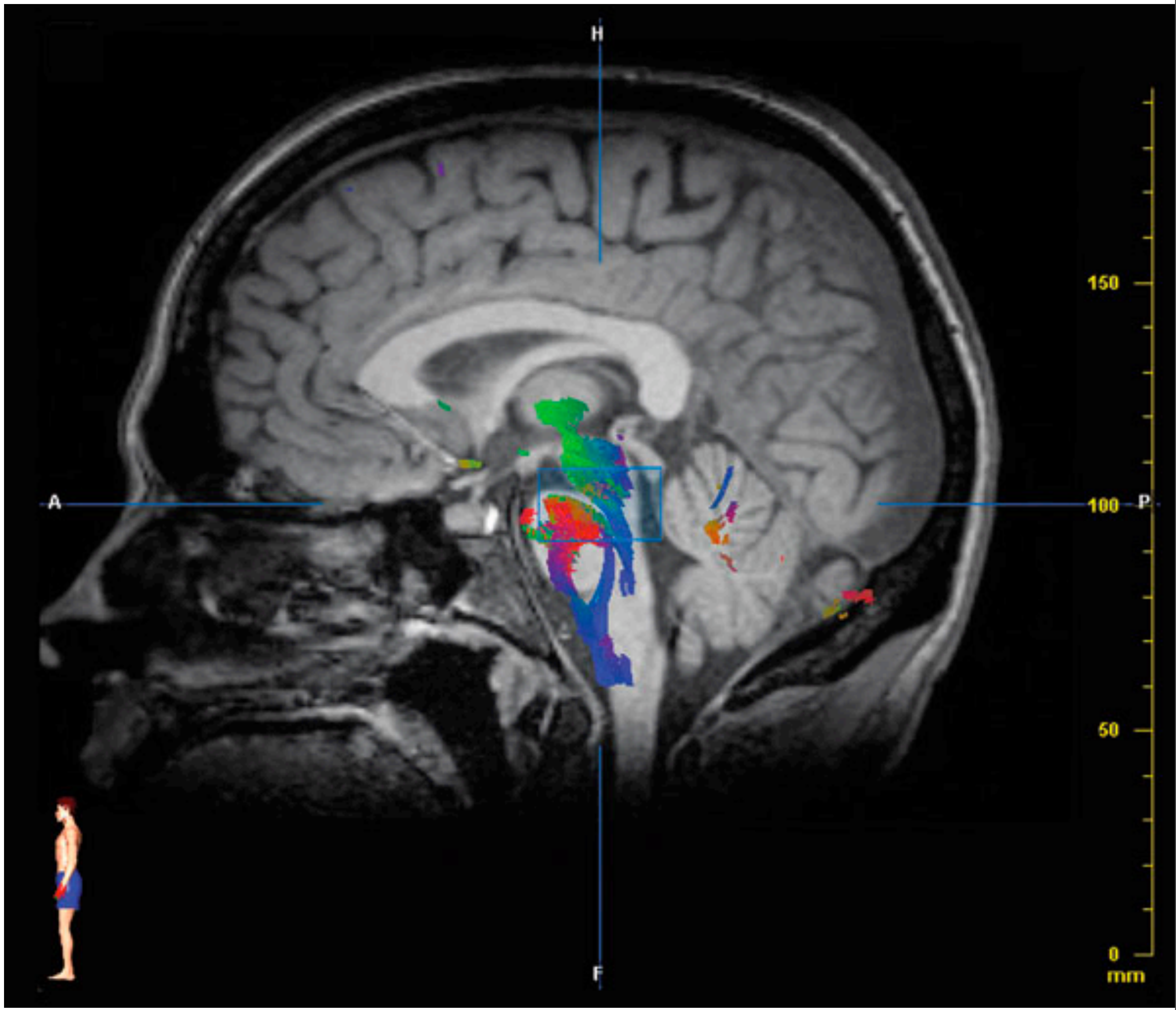


Photo Credit: Michael Häusser, University College London
via MIT Technology Review "Time Travel Through the Brain"
http://www.technologyreview.com/biomedicine/23758/

Neural Wiring Map 1

- created via BrainLab software from an MRI scan
- subsets of wires are highlighted
  - colors indicate the directions of the wires

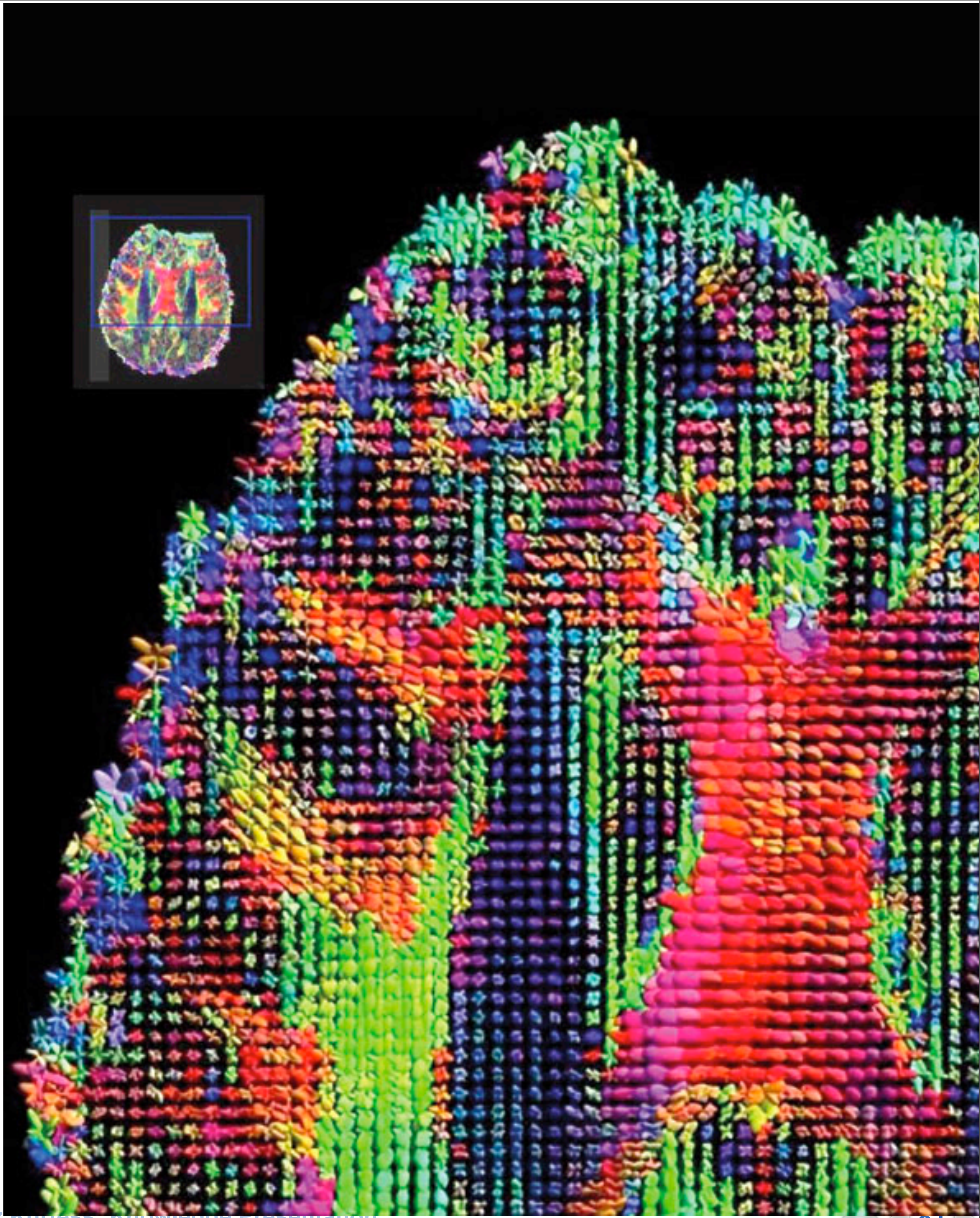


Intelligence Explained, MIT Technology Review, November/December 2009
http://www.technologyreview.com/biomedicine/23695/

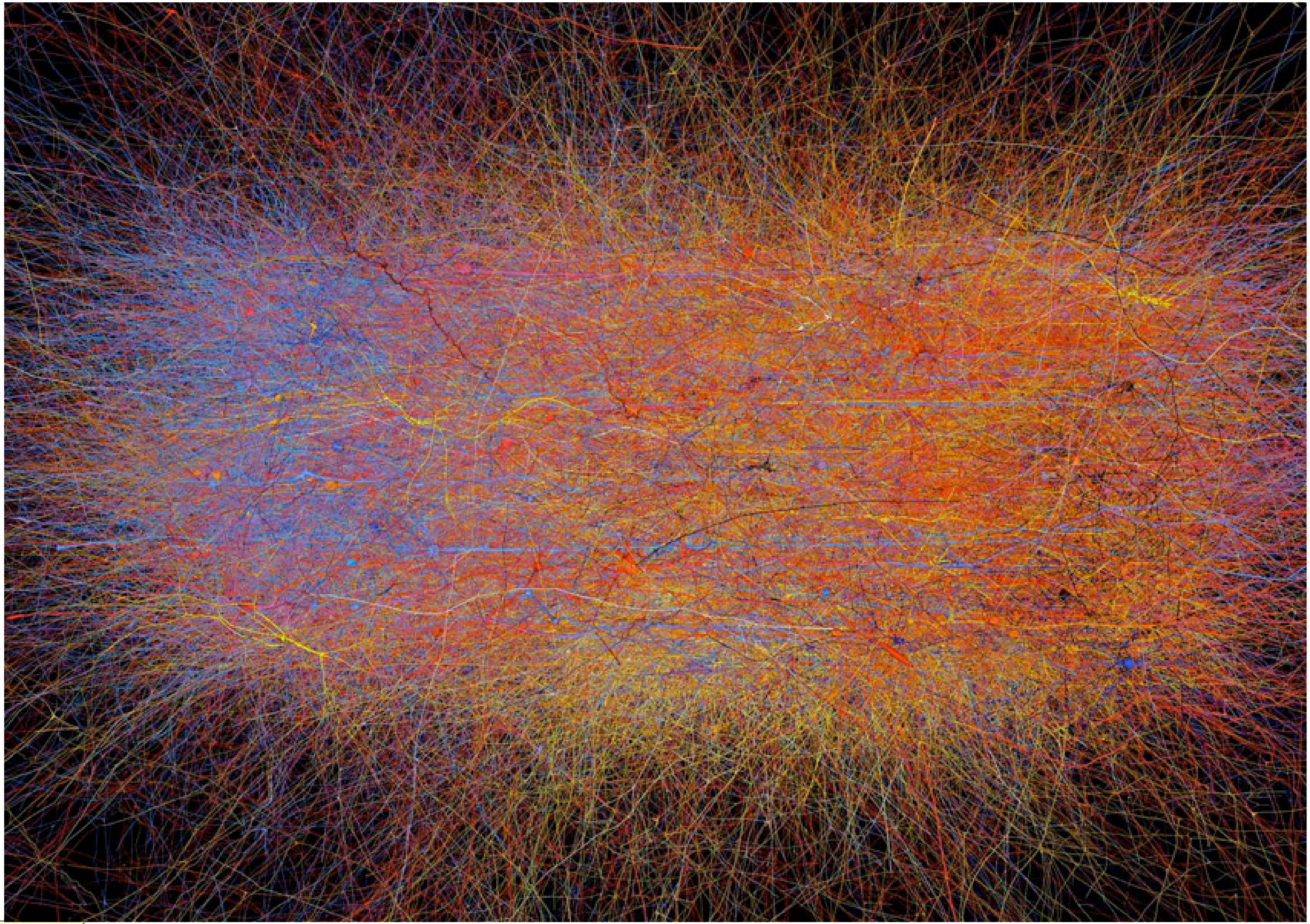
Neural Wiring Map 2

- circuit diagrams derived from the diffusion of water molecules in the brain
- software calculates the most likely paths of neural wires

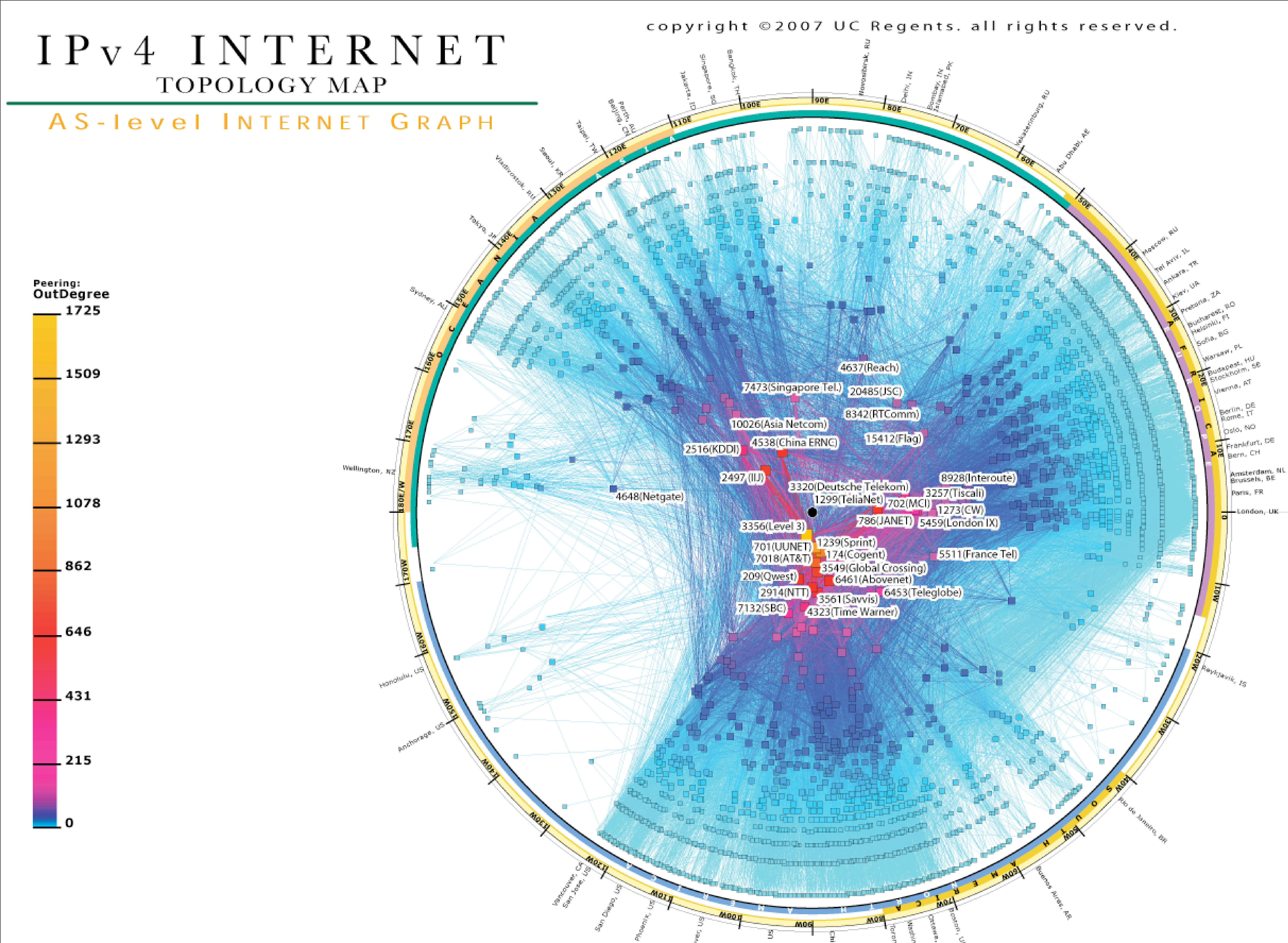
Intelligence Explained, MIT Technology Review, November/December 2009
http://www.technologyreview.com/biomedicine/23695/



Mammalian Neocortical Column

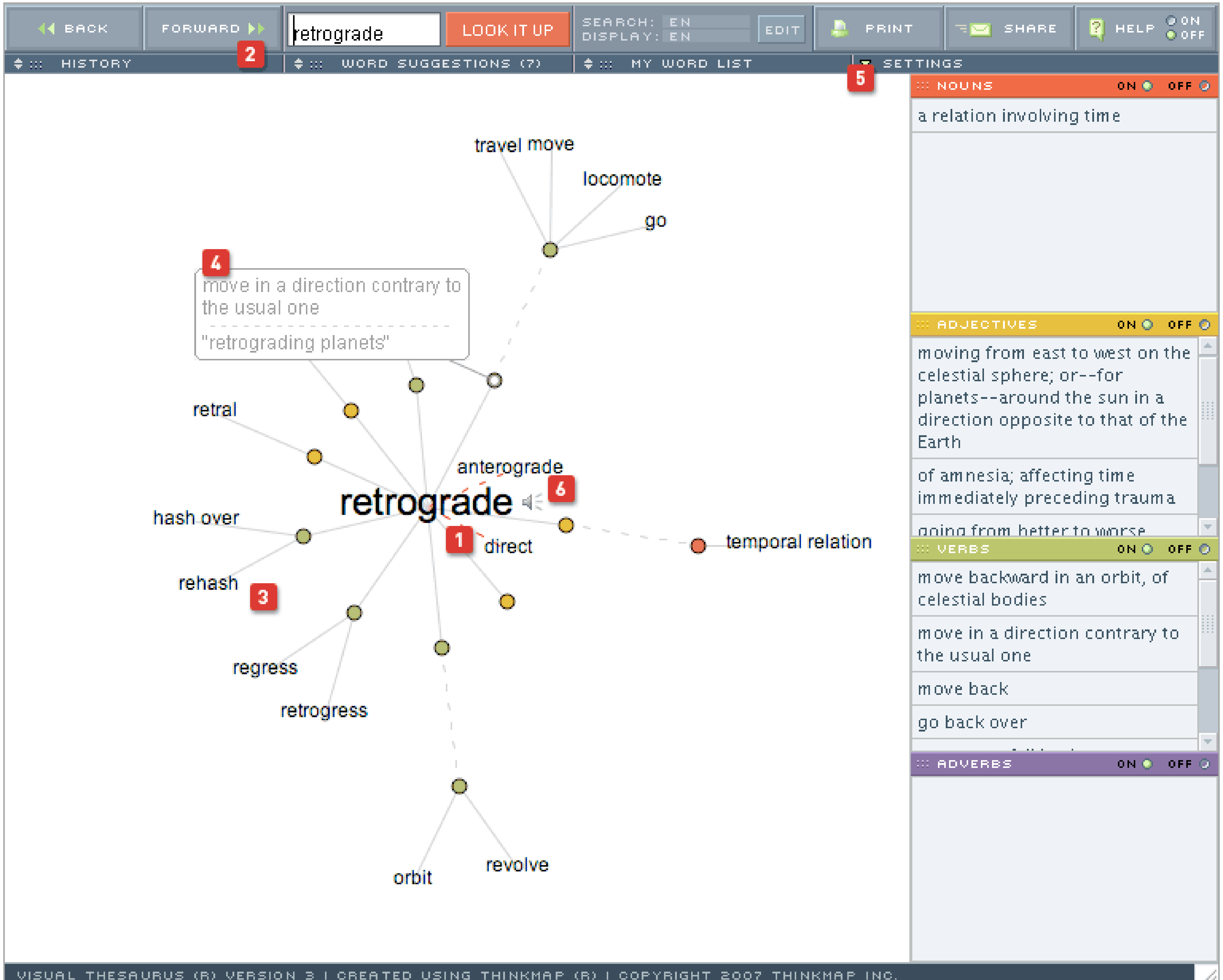


- http://www.technologyreview.com/files/13733/bluebrain_x600.jpg
- http://www.technologyreview.com/Biotech/19767/



http://www.caida.org/research/topology/as_core_network/2007/images/ascore-simple.2007_big.png

Visual Thesaurus

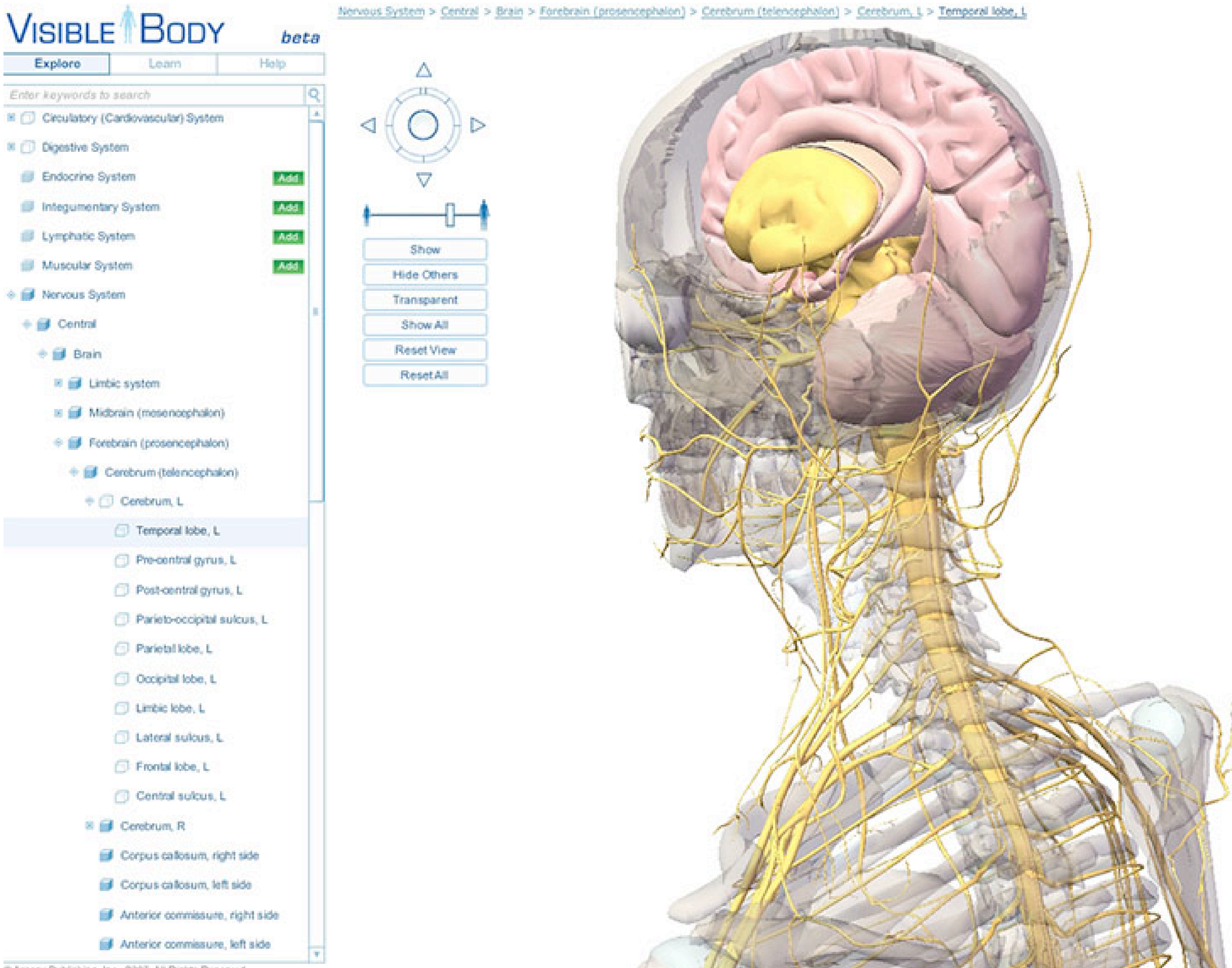


http://www.visualthesaurus.com/howitworks/images/screen.gif

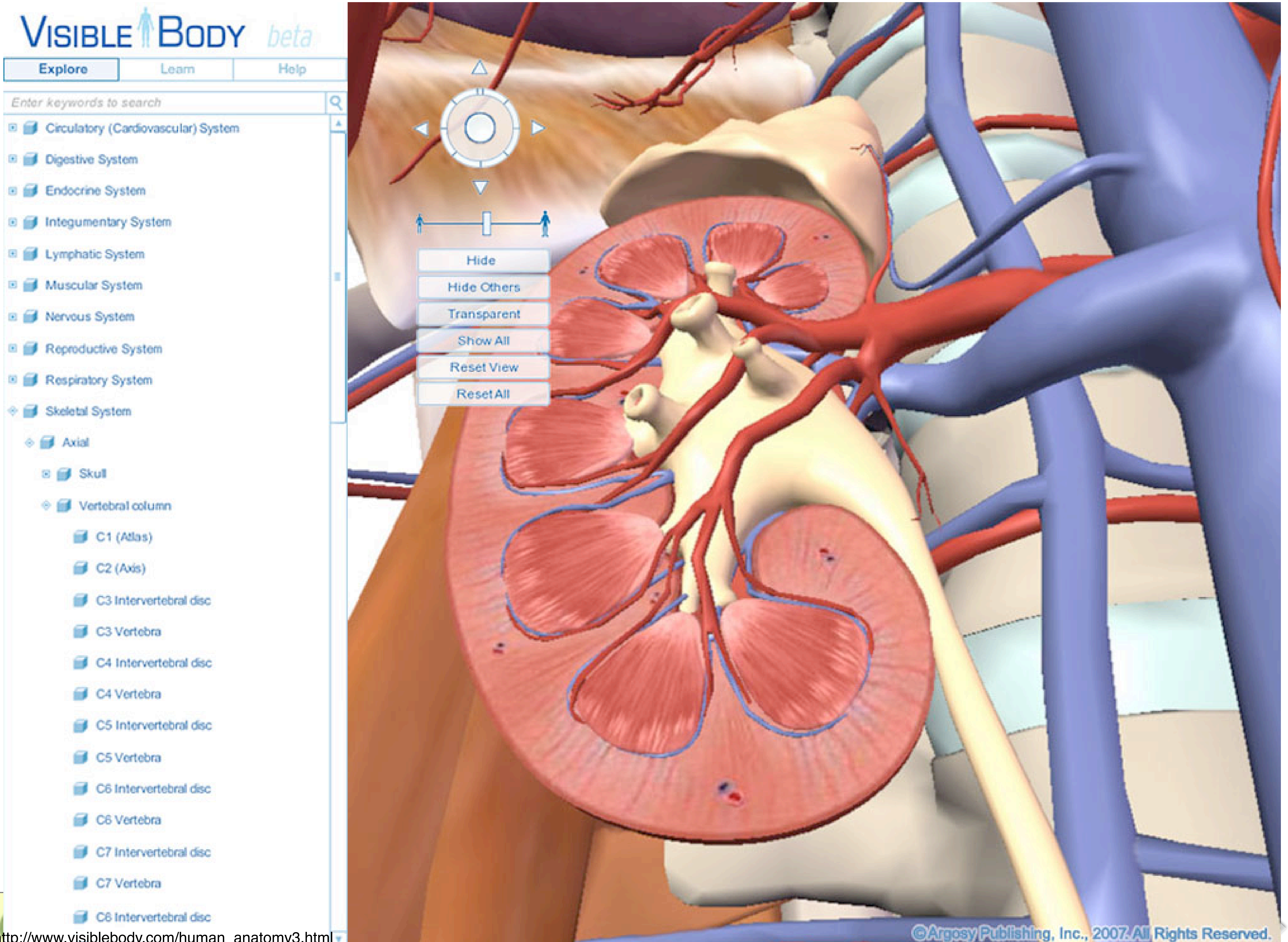
Visible Body Overview

- complete, fully interactive, 3D human anatomy model
- developed by Argosy Publishing
  - http://www.visiblebody.com/
- highly detailed, anatomically accurate, 3D models of all human body systems
- includes content covered in an undergraduate-level Anatomy and Physiology course

Visible Body Example: Brain



http://www.visiblebody.com/nervous_system2.html



http://www.visiblebody.com/human_anatomy3.html

Visible Body Operations

- With the Visible Body, you can:
  - Search for and locate anatomical structures by name.
  - Hide, rotate, see through, and explore parts of human anatomy.
  - Move the model in three-dimensional space
    - clicking directly on the model or using the virtual joystick.
  - Zoom in and out, using either the on-screen zoom slider or a mouse scroll wheel.
  - Click on systems or structures to make them transparent or hide them entirely.
  - Click on anatomical structures to reveal names.