Cognitive Systems

F10

2020 edition

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PSI 3560 – COGNITIVE SYSTEMS

class F10

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GENERAL APPROACHES TO COGNITIVE MODELLING

Dynamic systems approach

Session F10

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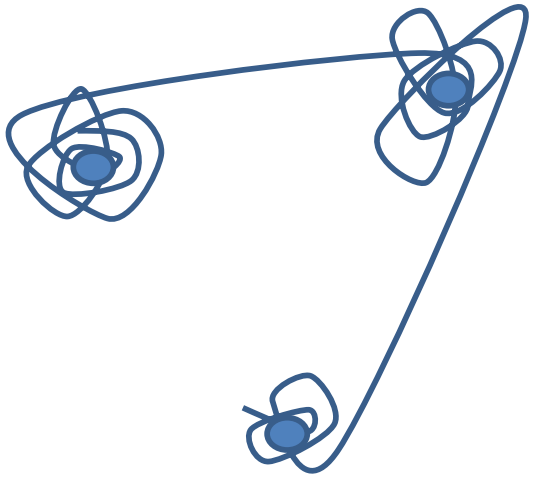
Summary

– First Session (7:30 – 9:10)

- Dynamic Systems
  - Cognitive Systems
    - Oscillators
    - Rhythms
    - Synchronism

- Section 1

Dynamic Systems



- Oscillators
  - Dynamic systems
  - Natural oscillation
    - Natural oscillation mode (frequency)
  - Reacting to stimulus
    - Disturbance around natural mode
    - Coupled oscillators – mutual influences
    - Chaotic oscillators – coupling multiple oscillators

- Attractors
  - Defining a region (condition)
    - Convergence
    - Oscillation orbit
  - Preferential

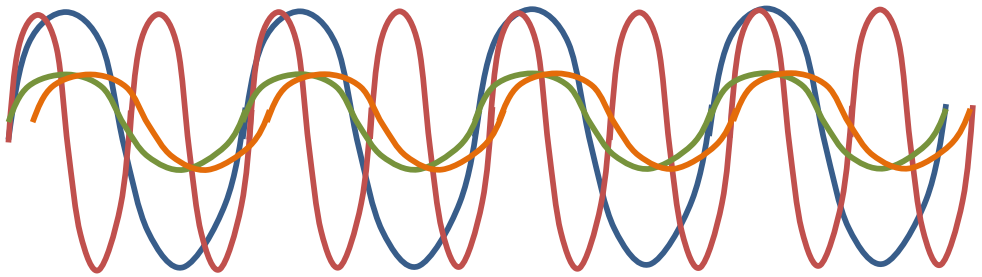
Dynamic Systems behavior

- Features of dynamic behavior
  - Time dependence
  - Dynamic response
    - Differential variability
  - Structural dynamics
    - Attractors
    - Topological variability
      - Dynamical stochastic variability
      - Order structure
        - » Topological order
        - » Temporal (dynamic order)
          - Synchronization, rhythm

Dynamic Systems

- Modulation – signal coupling
  - One signal inhibiting or amplifying another
  - One signal imposing boundaries to another

- Waves
  - Any signal can be described by a composition of sinusoidal signals (Fourier decomposition)
  - Sinusoidal signal
    - Amplitude
    - Frequency
    - Phase



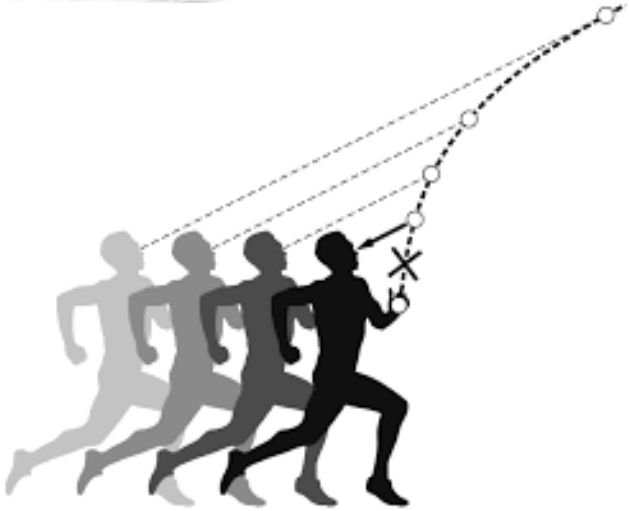
Dynamic Systems and Neural System

- Stochastic nature of neurons and assemblies
  - Statistical behavior
  - Statistical structure
    - Neurons are irregular, but alike (in specific regions)

- Pacemaker
  - A referential rhythm to the system
  - Found in natural live beings

Dynamics and cognition

- What, when, why ?
  - Time dependence in behavior
    - Not just change and motion…
      - The behavior itself depends on time
      - The same for:
        - » Perception
        - » Cognition
      - To say that behavior, perception and cognition depend on time implies on that
        - » Their mechanisms are themselves functions of time



Dynamic systems approach to cognition

- Cognitive agents live and behave in dynamic environments
  - Things happen
  - Beings interact
  - Dynamics is part of them
    - How they interact (behave)
    - How they learn and adapt
      - *Everything is about learning and adapting*
  - The coupling of the cognitive system into the dynamic environment requires itself to be dynamic? Probably yes

Dynamic systems approach to cognition

- Cognitive system
  - Continuously adapts to new experiences (learns)
  - Keep important and frequent things in its memory
    - Keeps registers of things
      - On different time scales (short to long term)
    - Use them to further improve abilities
  - A dynamic system with memory
    - A continuously adapting and evolving dynamic system
    - Recurrent Neuronal Networks show such properties

Dynamic systems approach to cognition

- The sense of self (each one)
  - Unique
  - Your history
  - Is recognized as such (itself)
  - Embedded into your body
    - Brain & Body
    - Our memories
      - Episodic
      - Motor
      - Semantic (in connection to our own history)

- Section 2

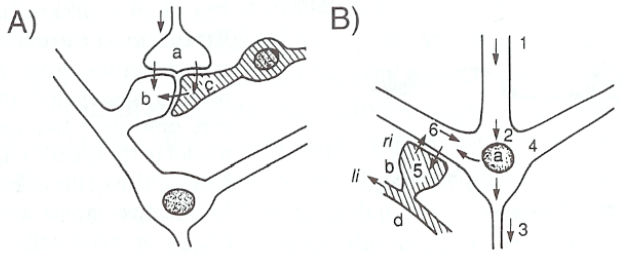
Brain Dynamics

- Brain Dynamics
  - Scales/Levels: from neurons to cortices
    - Neuronal level
    - Circuit and Assembly level
    - Network level
    - Global level

- On all different scales we observe
  - Signaling (transferring information)
    - Coding
    - Representation
    - Communication

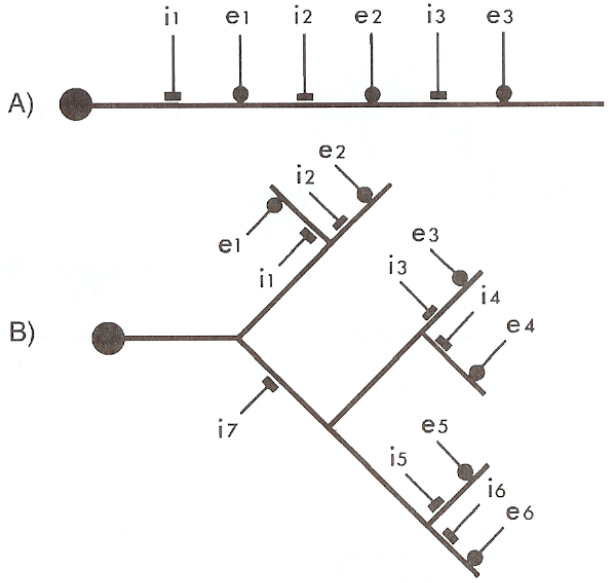
Brain Dynamics

- Neurons
  - Dendritic tree (synapses)
    - Topologies
      - Connectivity
    - Connections (synapses)
      - Neurotransmitters
      - Neuroreceptors
    - Biochemical & Electrical phenomena
      - Signal (information) processing & delivering



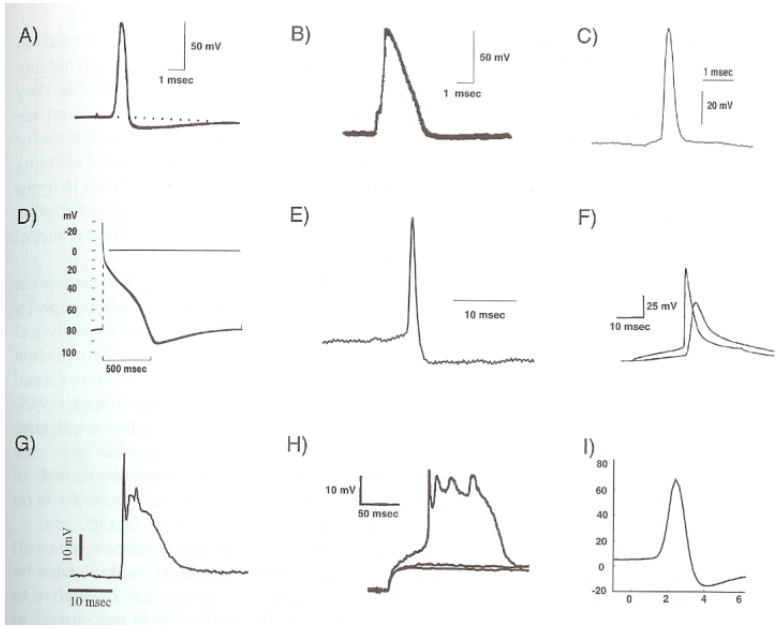
Brain Dynamics

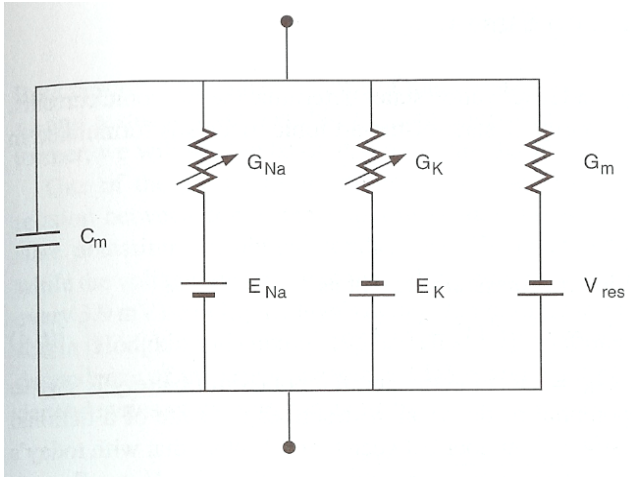
- Neurons
  - Dendritic tree (synapses)
    - Topologies and excitatory/inhibitory features implies on a diversity of combinatorial structures
      - A kind of logic
      - Morpho-electrotonic structure



Brain Dynamics

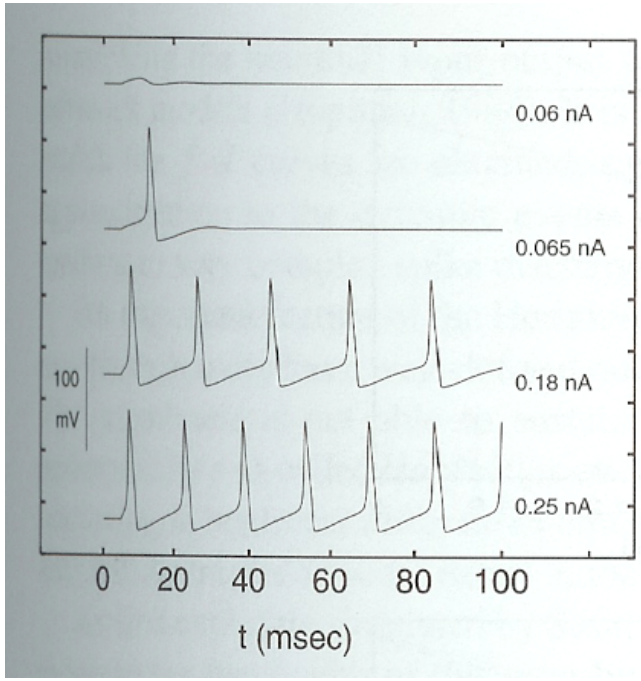
- Neurons
  - Axon (propagation)
    - Time domain
      - Different types of pulses
      - Coding
        - » Representations?
          - *Micro Mental Objects*
        - » Electrical signals
      - Physiologic models
        - » Electrical properties of bio systems (neurons)
          - Cellular membrane
          - Sodium Potassium
        - » Electrical circuits

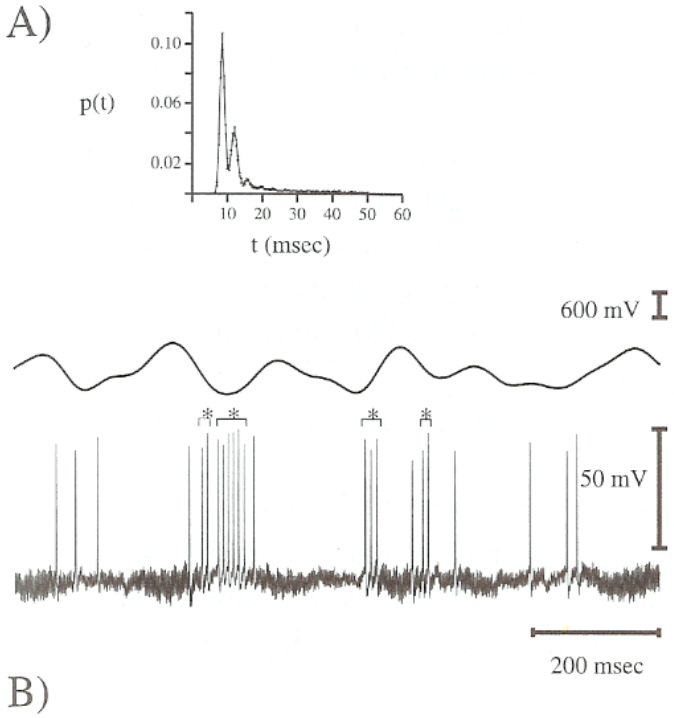




Brain Dynamics

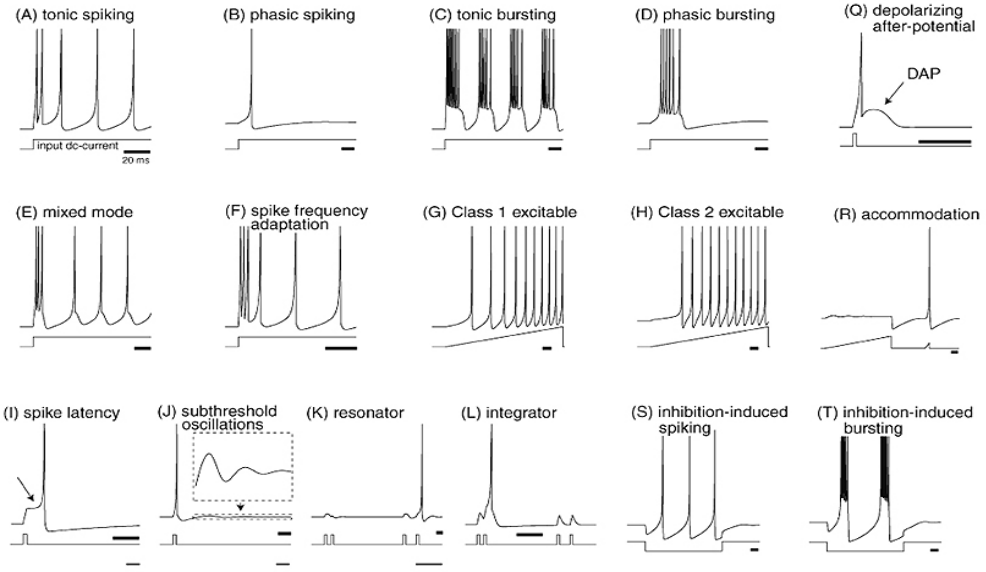
- Neurons
  - Time domain
    - Different types of pulses
    - Different time scales (higher or lower frequencies)





Brain Dynamics

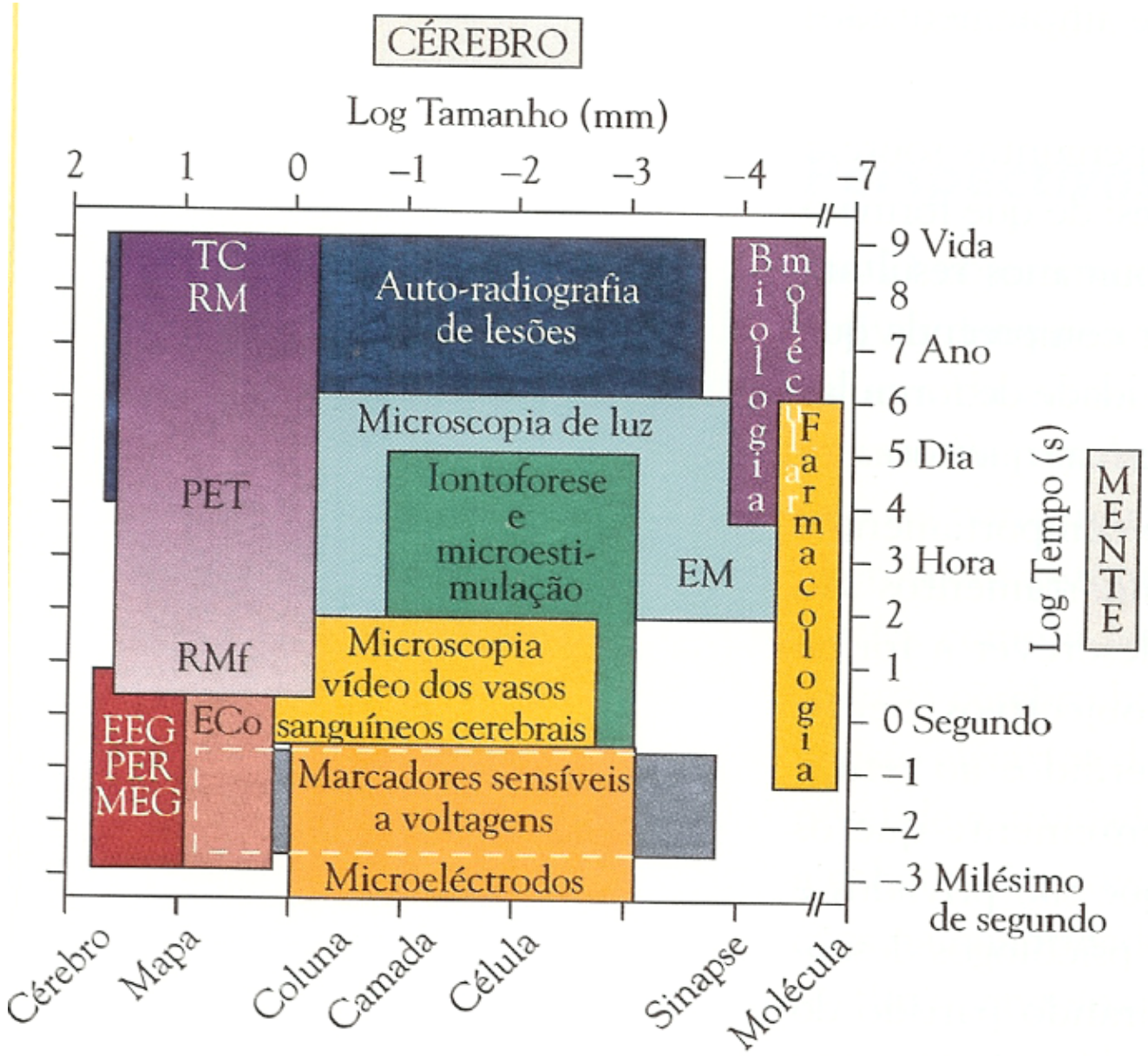
- Neurons
  - Signaling (communicating – transferring information)
  - Time domain
    - Rich diversity of pulses – triggered under different conditions
    - Different patterns
      - Codes
      - Representations
    - The micro language of thought



Brain Dynamics

- Observation Scales
  - Spatial
    - Molecule
    - Brain
  - Temporal
    - Millisecond
    - Lifetime

Micro/Meso/Macro



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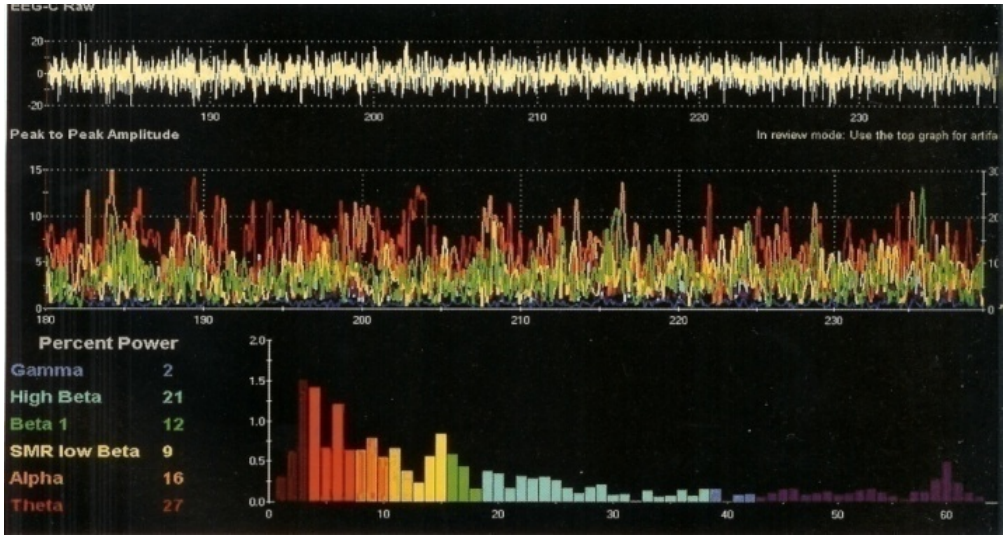
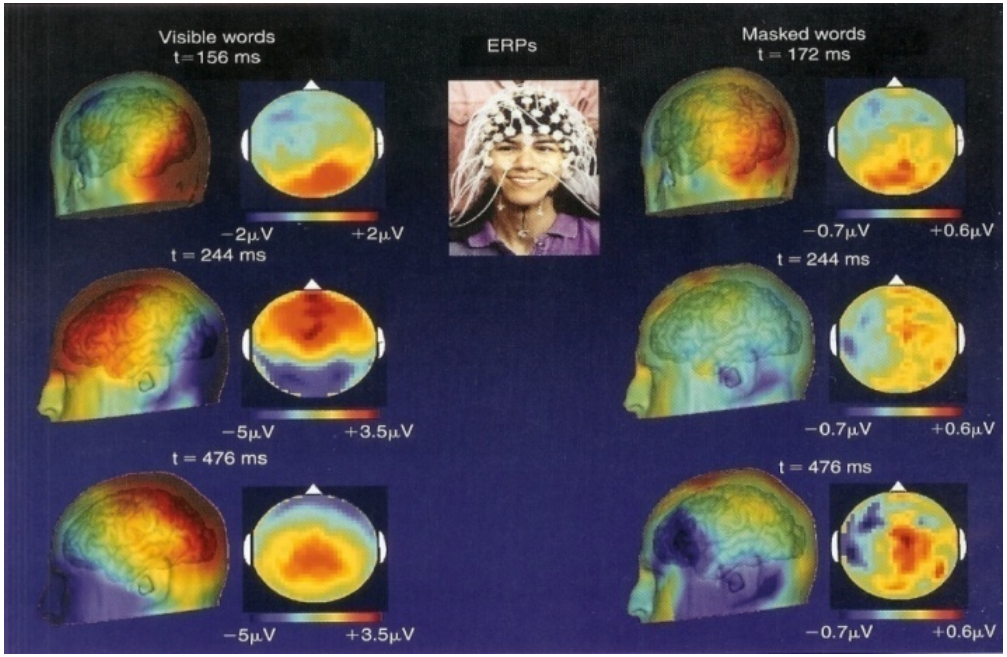
Brain Dynamics

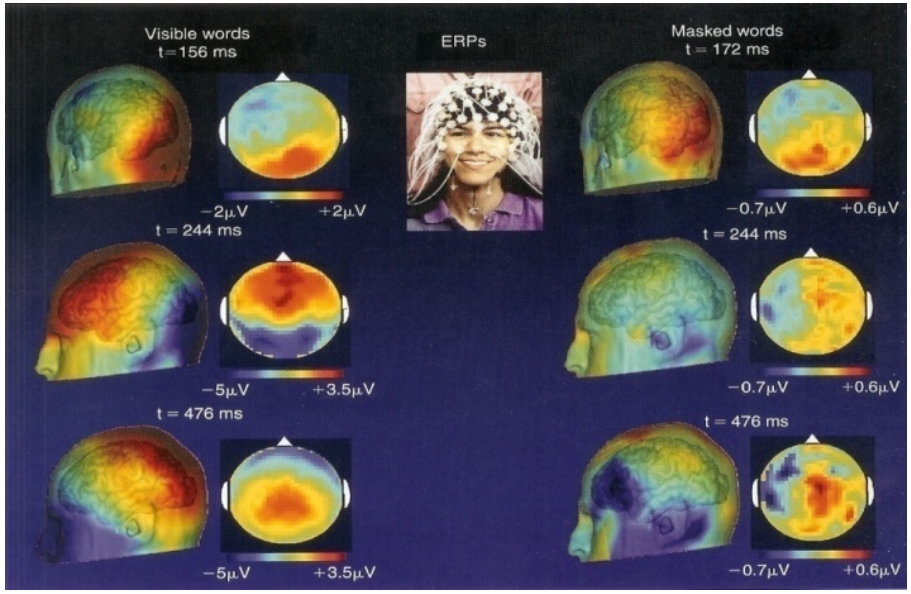
- Types of analysis
  - Electroencephalogram
    - Scalp
  - Electrode Implant
    - Assembly
  - CT
    - brain
  - fMR / PET / ERP
    - brain

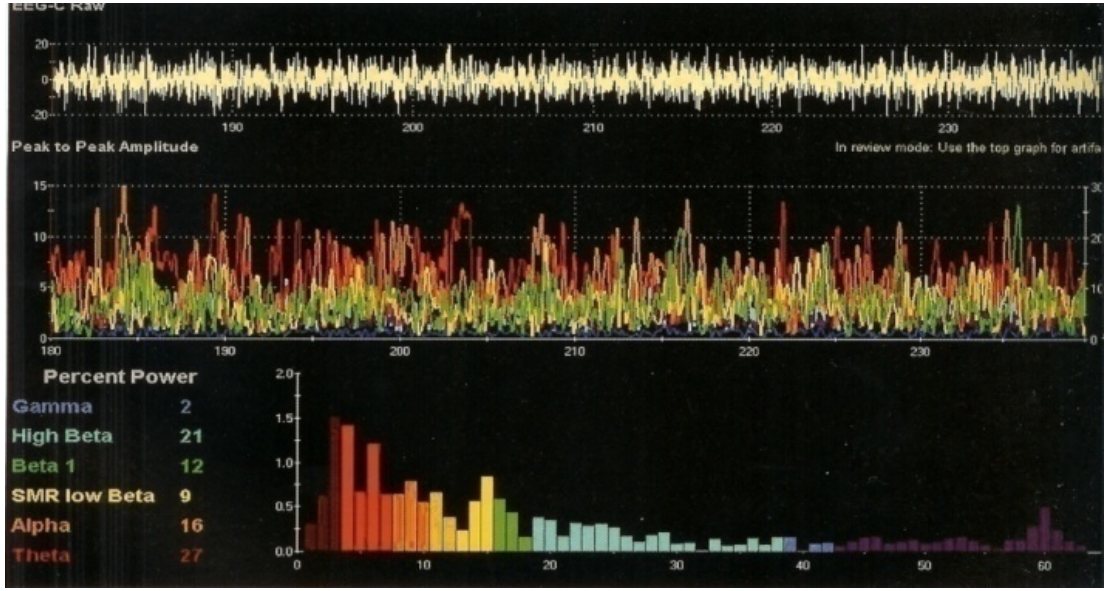




Brain Dynamics

- Analysis by comparison of expected and unexpected patterns





- Section 3

Brain Dynamics

- Strongly coupled dynamic system
  - Rhythms
    - Many know (identified) rhythms
    - From sleeping (dreaming) to Awaken
  - Synchronism
  - Resonance

State	Frequency range	State of mind
Delta	0.5Hz–4Hz	Deep sleep
Theta	4Hz–8Hz	Drowsiness (also first stage of sleep)
Alpha	8Hz–14Hz	Relaxed but alert
Beta	14Hz–30Hz	Highly alert and focused

- Synchronism / Resonance
  - Assemblies / Regions
  - Higher coherence between parts

Brain Dynamics

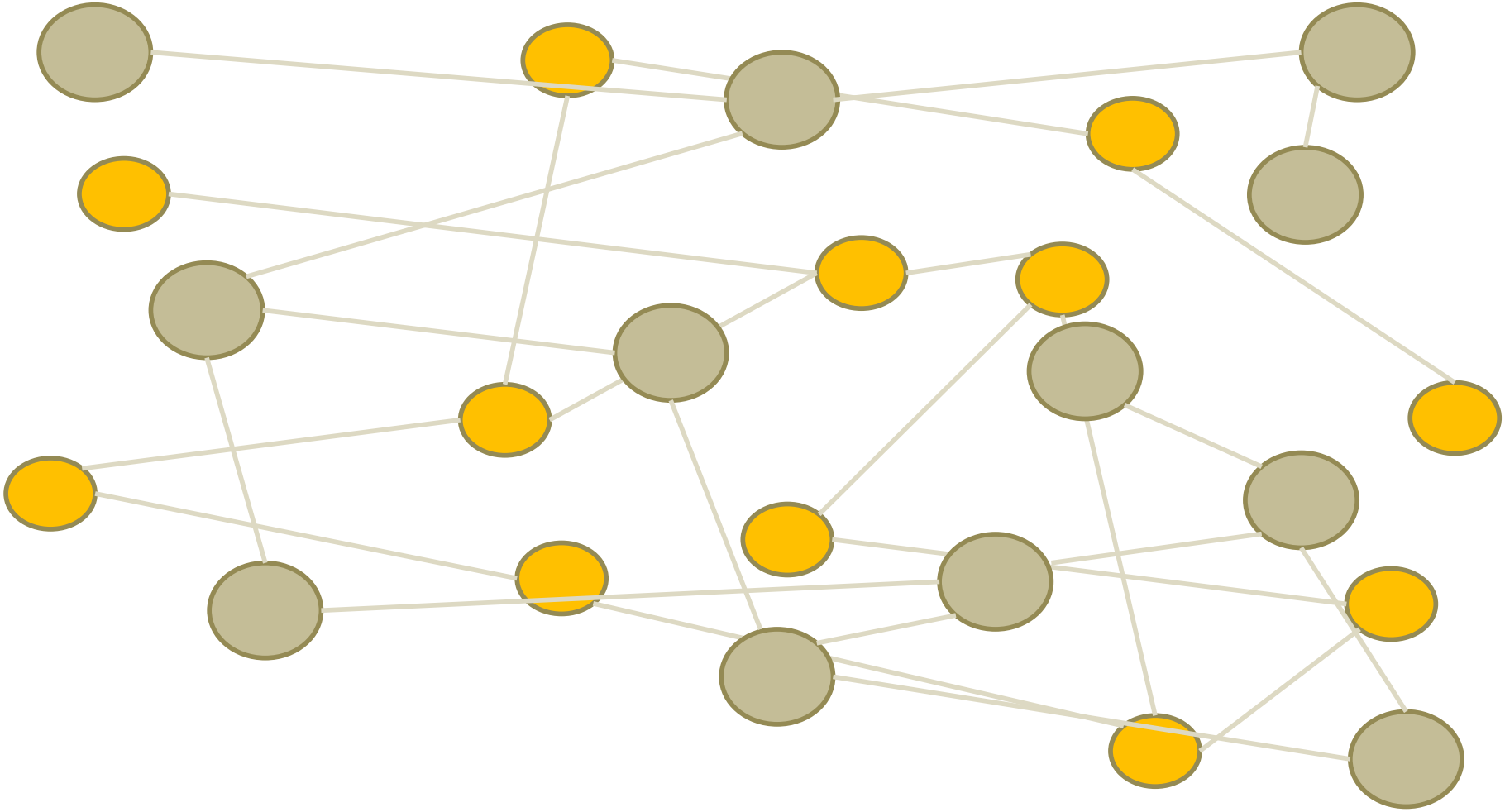
- Mapping State Evolution
  - S1 > S2 > S3 > S4 > S5 > S6 likely
  - S1 > S4 > S2 > S3 > S5 > S6 possible
  - S1 > S9 > S5 > S2 > S3 > S8 unlikely

  - In accordance with some patterns
    - Huge diversity is possible
    - But not anything is expected
  - There is some cause consequence
    - Bio physical constraints guide the evolution through successive states
  - Robustness is necessary to keep the system working properly

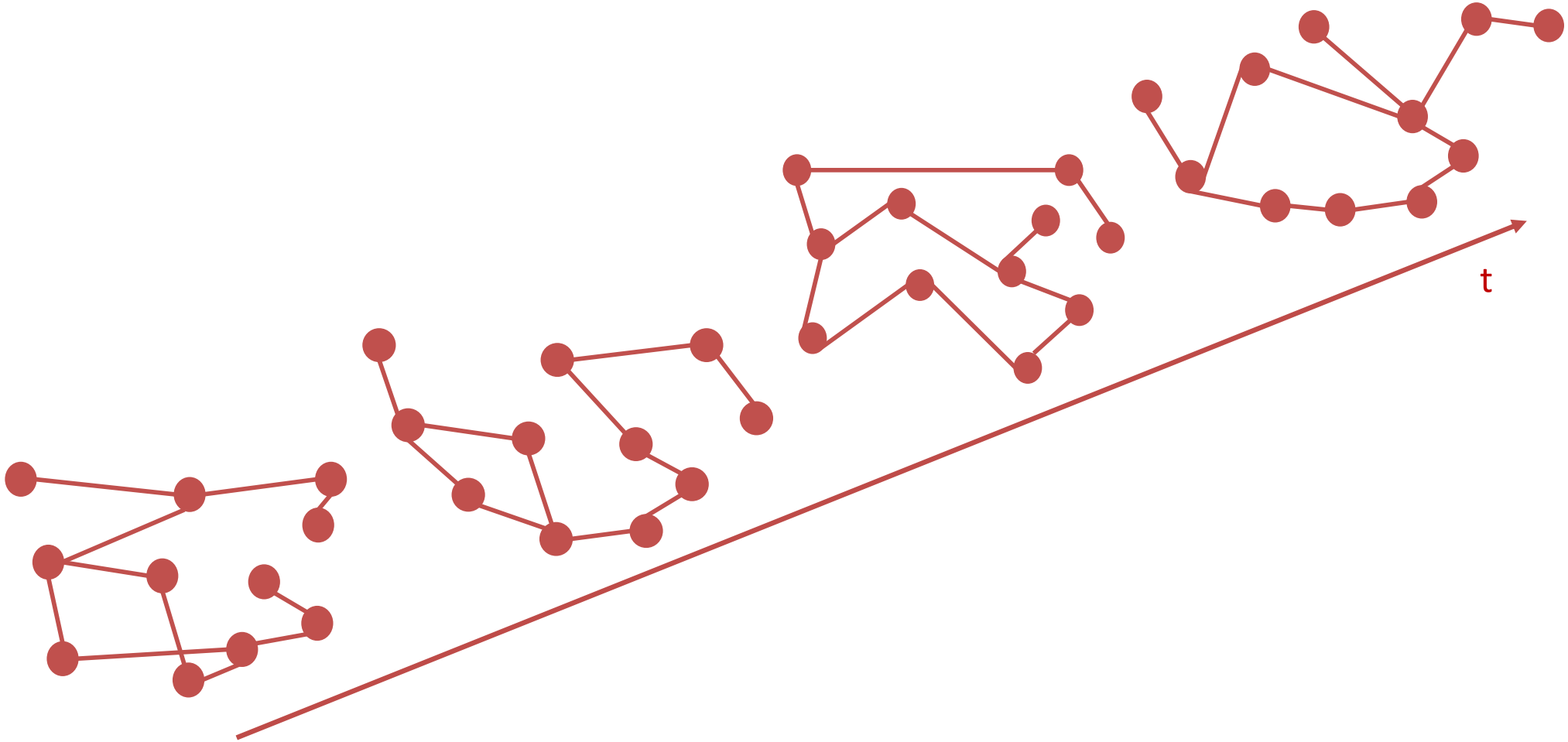
Brain Dynamics

- Some equilibrium
  - Things change normally slowly
- Some regularity
  - Some level of regularity behind any pattern
- Some coherence
  - Coherence is expected almost every time
- Some expectation
  - Expectations should be confirmed
  - and are used guide decisions

Brain Dynamics



Brain Dynamics



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This is all for today.

See you next week !