The IDA & LIDA Models

Stan Franklin

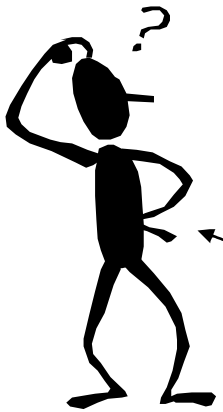
Computer Science Division &

Institute for Intelligent Systems

The University of Memphis

IDA: an Intelligent Distribution Agent

- Dialogue with sailors
- Read personnel data
- Check job requisition lists
- Enforce Navy policies
- Choose jobs to offer members
- Negotiate with them about jobs



Detailer

Telephone

Internet

IDA

Who's IDA

- Autonomous software agent
  - Environment—real world (computer, Java VM, network)
  - Senses—strings of characters
  - Actions—natural language email, many internal actions
  - Drives—to find and negotiate new jobs for sailors
- Supported by the US Navy
- Computational IDA
  - Complete, up and running
  - Tested, demonstrated, approved by the Navy

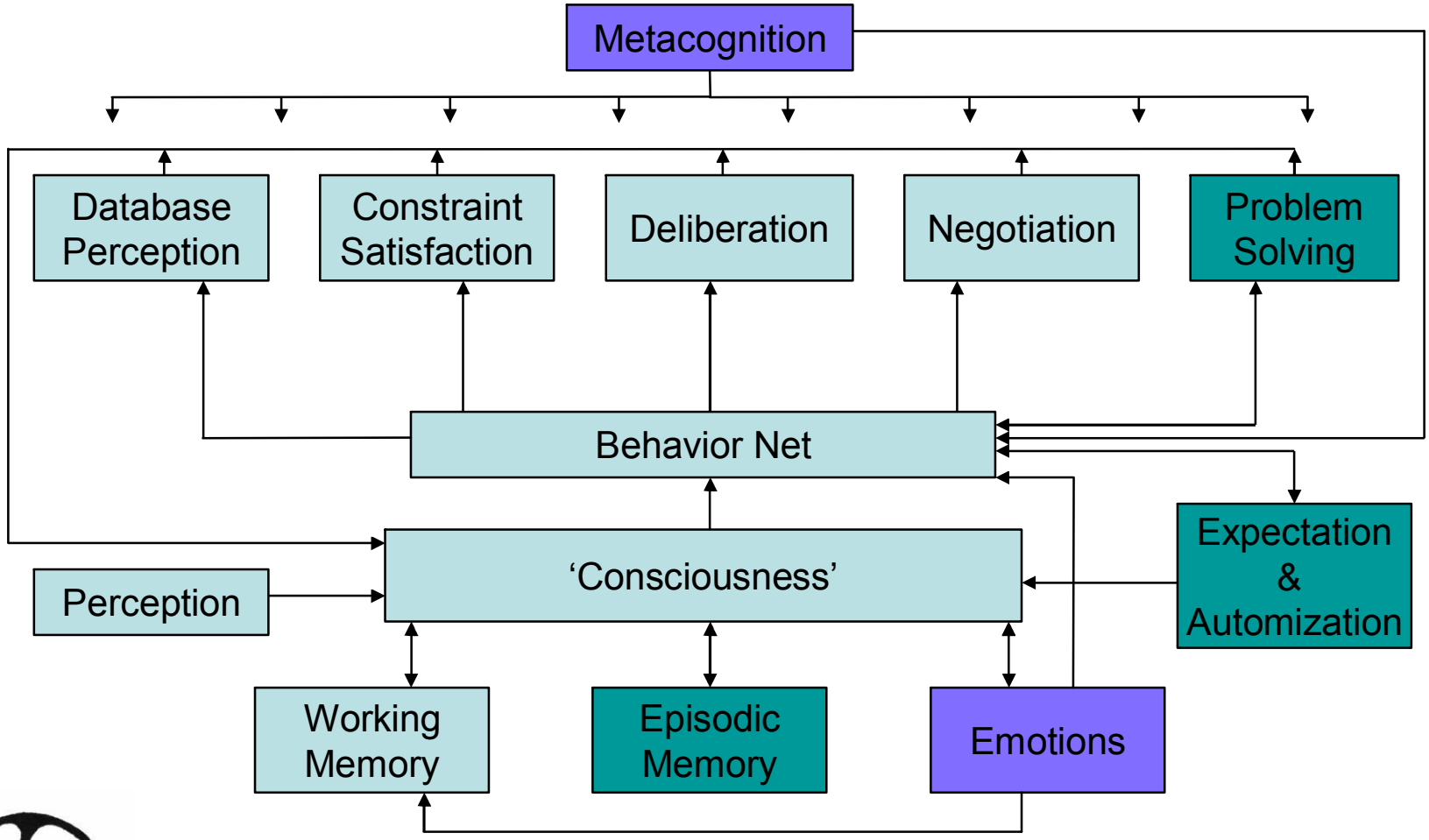
The IDA Model

- Conceptual model of cognition
- Computational model plus additional designed but unimplemented cognitive processes
- A general model such as SOAR, Act-R, C&I
- Models a broad swath of cognitive functions
- A functional integrative theory (FIT), producing empirically based, qualitative hypotheses about how minds work

The IDA Model's Cognitive Functions

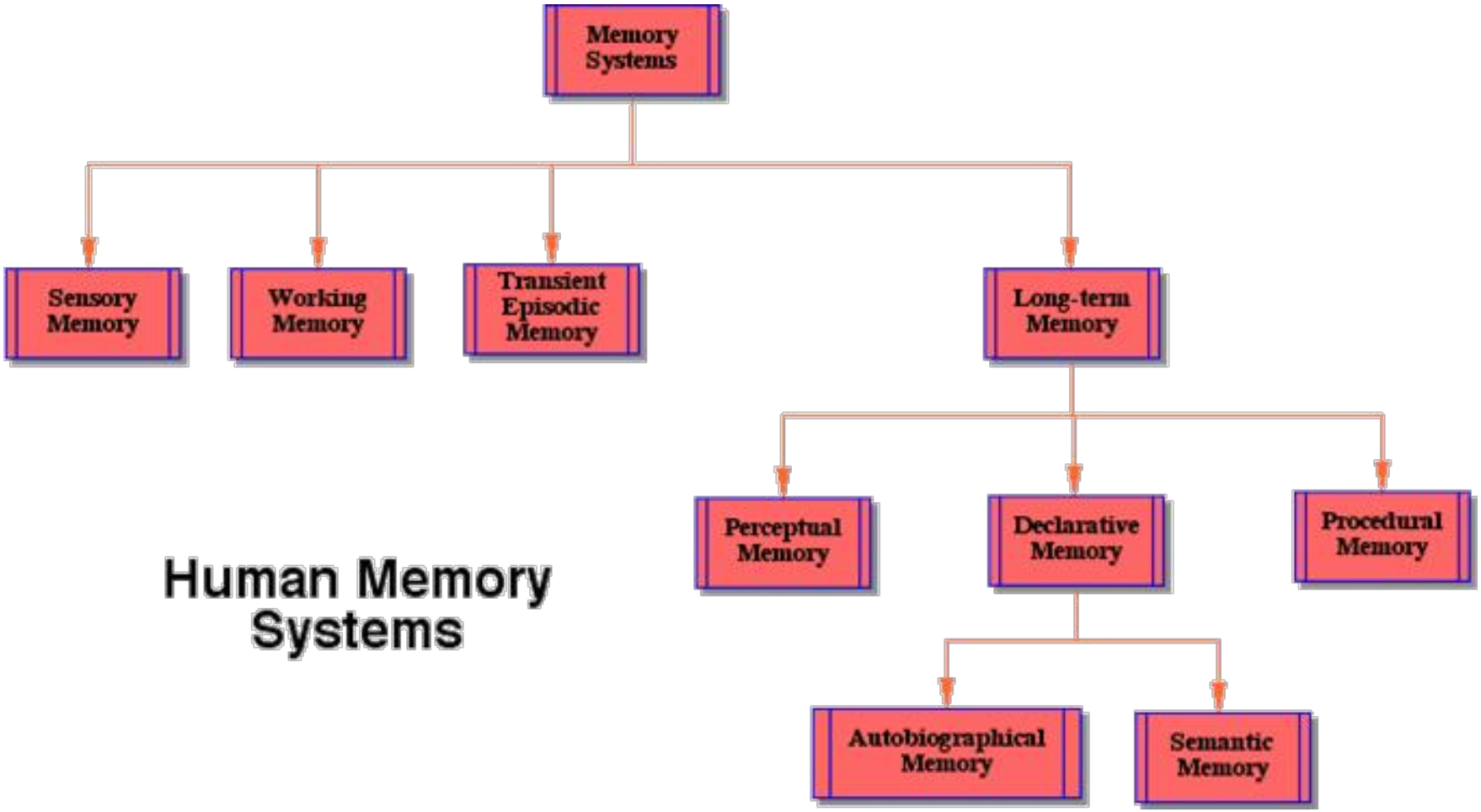
- Perception
- Working memory
- Episodic memory
- Long-term memory
- Consciousness
- Action selection
- Emotion
- Deliberation
- Volition
- Metacognition
- Automization
- Non-routine problem solving
- Language generation and understanding

IDA's Architecture



Cognitive Cycles

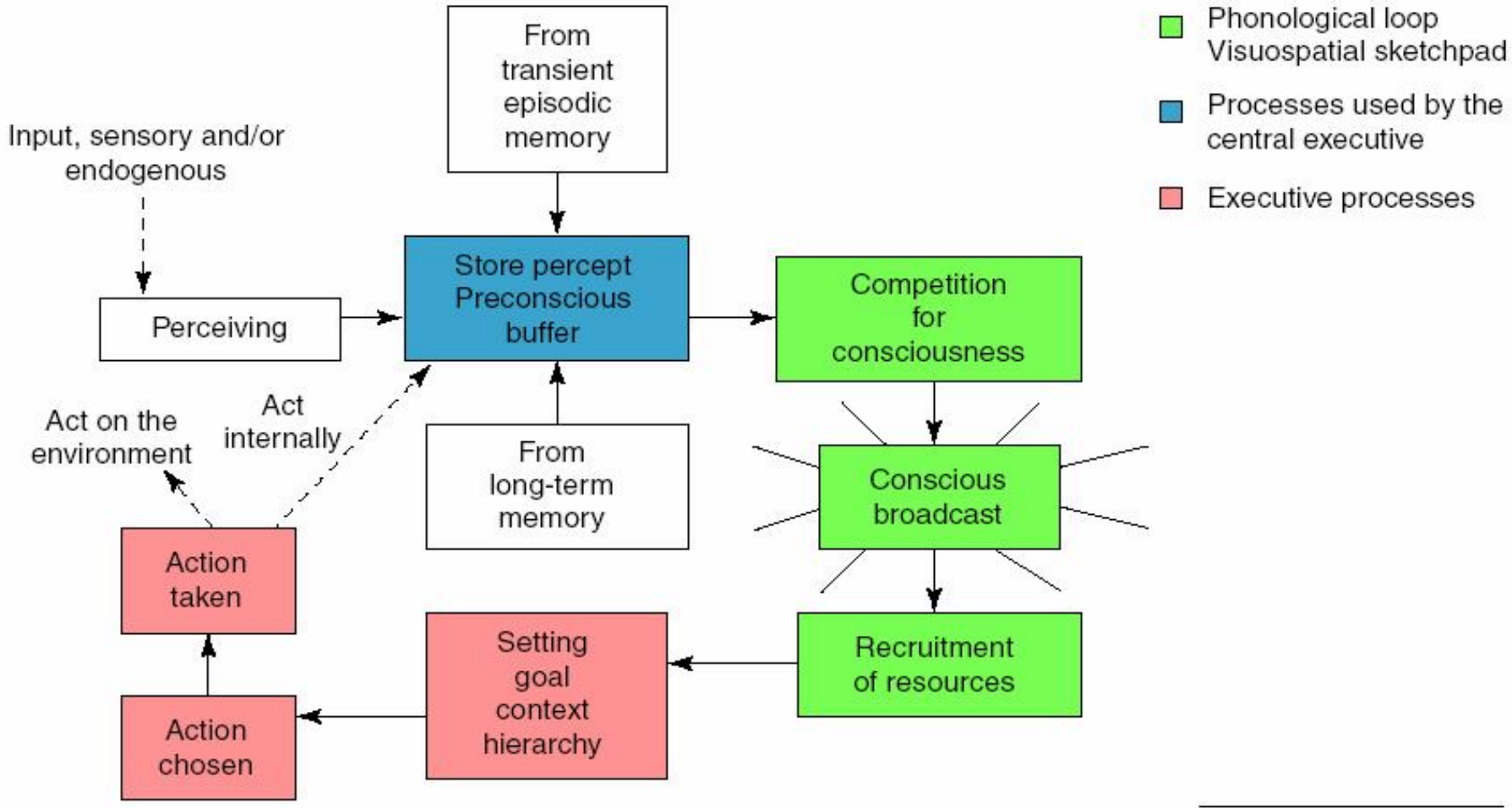
- Every autonomous agent operates by frequent iteration of sense-process-act cycles



Human Memory Systems

IDA's Cognitive Cycle

- Every autonomous agent must frequently sample its environment and act on it
- Cognition is the process of interpreting incoming stimuli and selecting actions
- The cognitive cycle fleshes out the stimulus–cognition–action process
- Provides a tool for the fine-grained analysis of various cognitive tasks

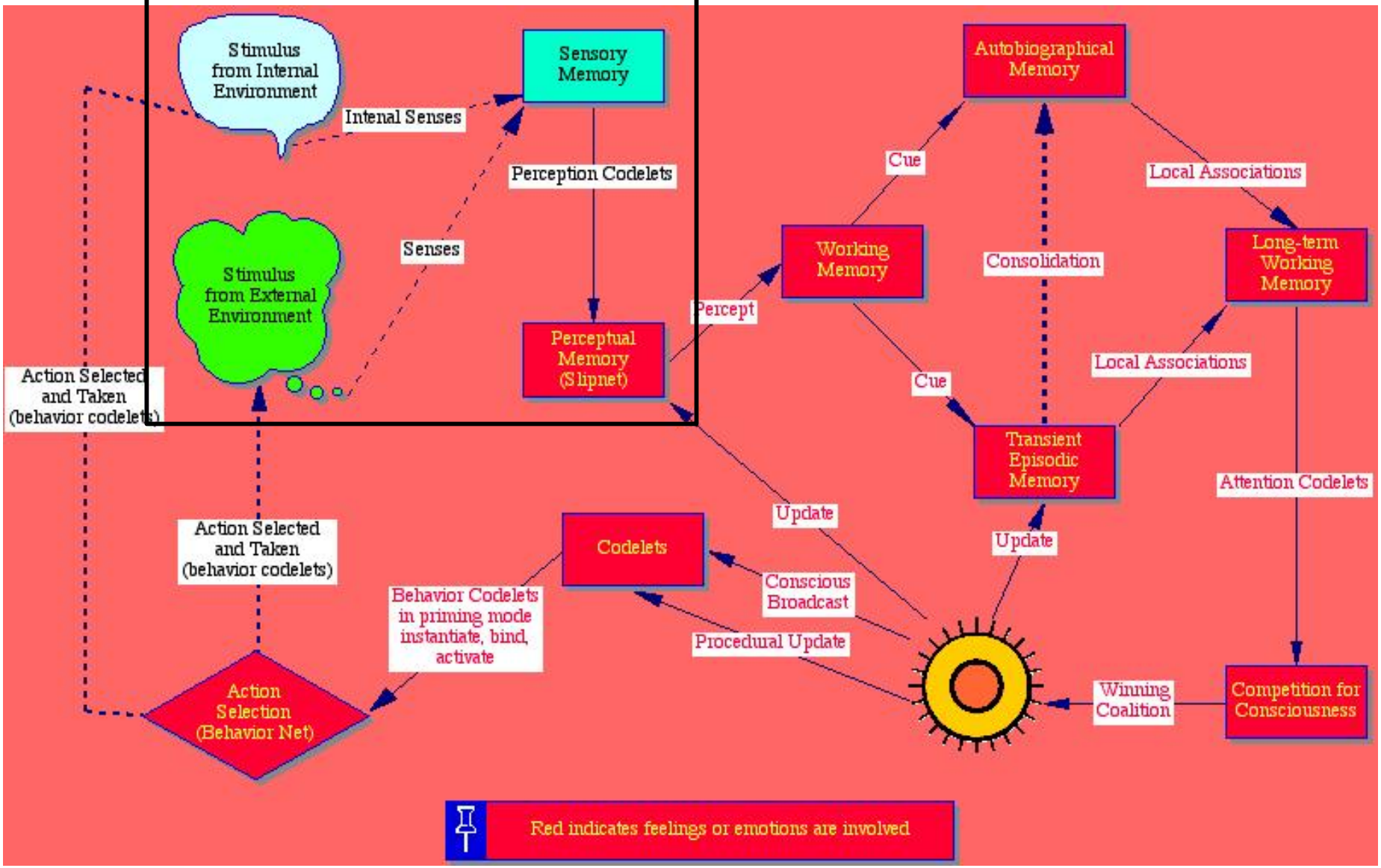

Phonological loop
Visuospatial sketchpad
Processes used by the central executive
Executive processes
From transient episodic memory
Input, sensory and/or endogenous
Store percept Preconscious buffer
Perceiving
Competition for consciousness
Act on the environment
Act internally
From long-term memory
Conscious broadcast
Action taken
Setting goal context hierarchy
Recruitment of resources
Action chosen

Cognitive Cycles

- In humans each cognitive cycle takes about 200ms
- An automatized cycle would take less time
- Cognitive cycles can cascade
- Cycles must maintain the seriality of consciousness
- Unconscious activity on each side of the conscious broadcast can operate in parallel
- Humans might have five to ten cognitive cycles per second

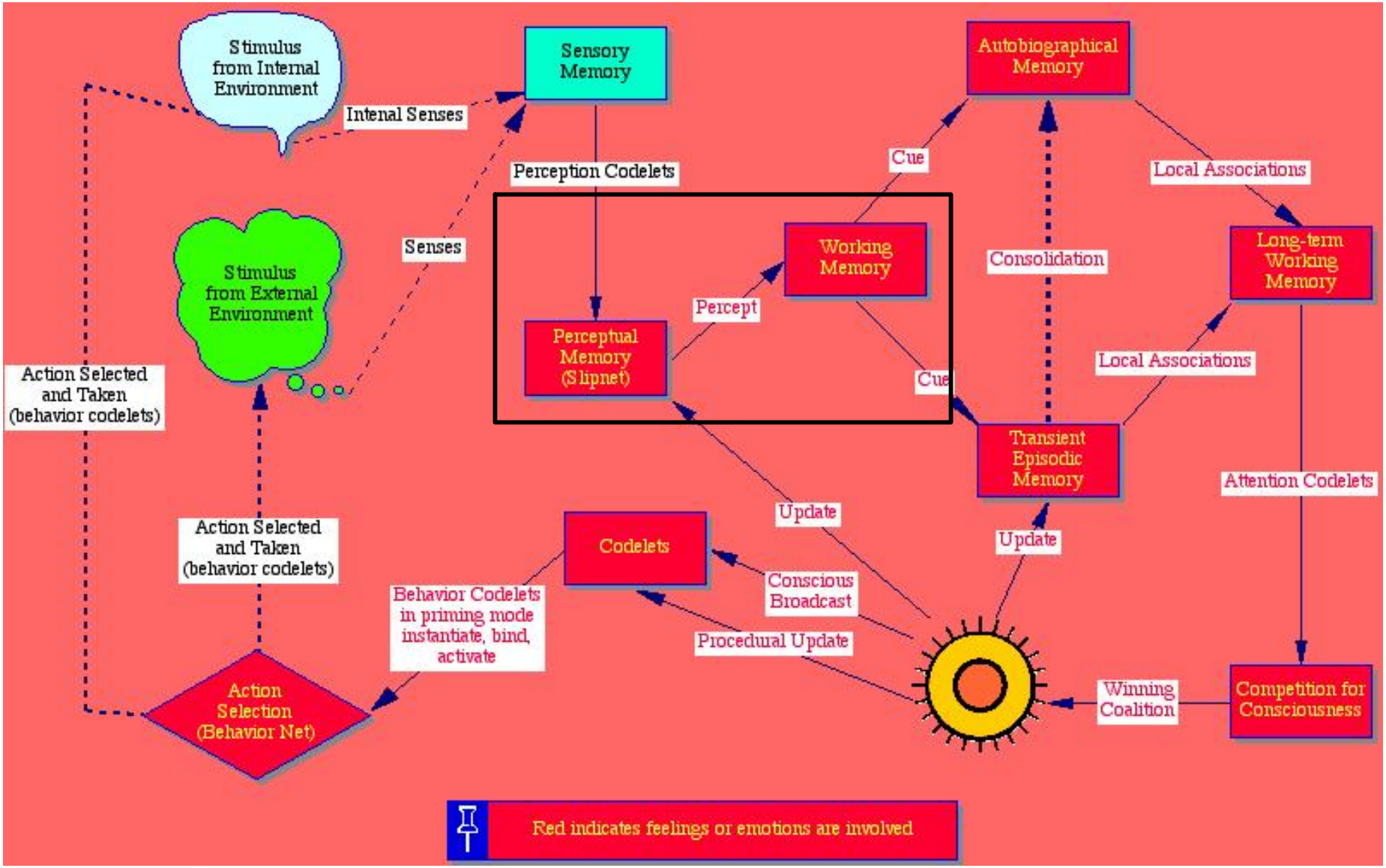
Steps in the Cognitive Cycle

1. Perception
2. Working memory
3. Local associations
4. Competition for consciousness
5. Conscious broadcast
6. Learning & recruiting resources
7. Setting goal-context hierarchy
8. Action chosen
9. Action taken


Stimulus from Internal Environment
Intenal Senses
Sensory Memory
Perception Codelets
Stimulus from External Environment
Senses
Perceptual Memory (Slipnet)
Percept
Working Memory
Cue
Autobiographical Memory
Local Associations
Consolidation
Long-term Working Memory
Cue
Local Associations
Transient Episodic Memory
Attention Codelets
Update
Update
Action Selected and Taken (behavior codelets)
Action Selected and Taken (behavior codelets)
Codelets
Conscious Broadcast
Behavior Codelets in priming mode instantiate, bind, activate
Procedural Update
Action Selection (Behavior Net)
Winning Coalition
Competition for Consciousness
Red indicates feelings or emotions are involved

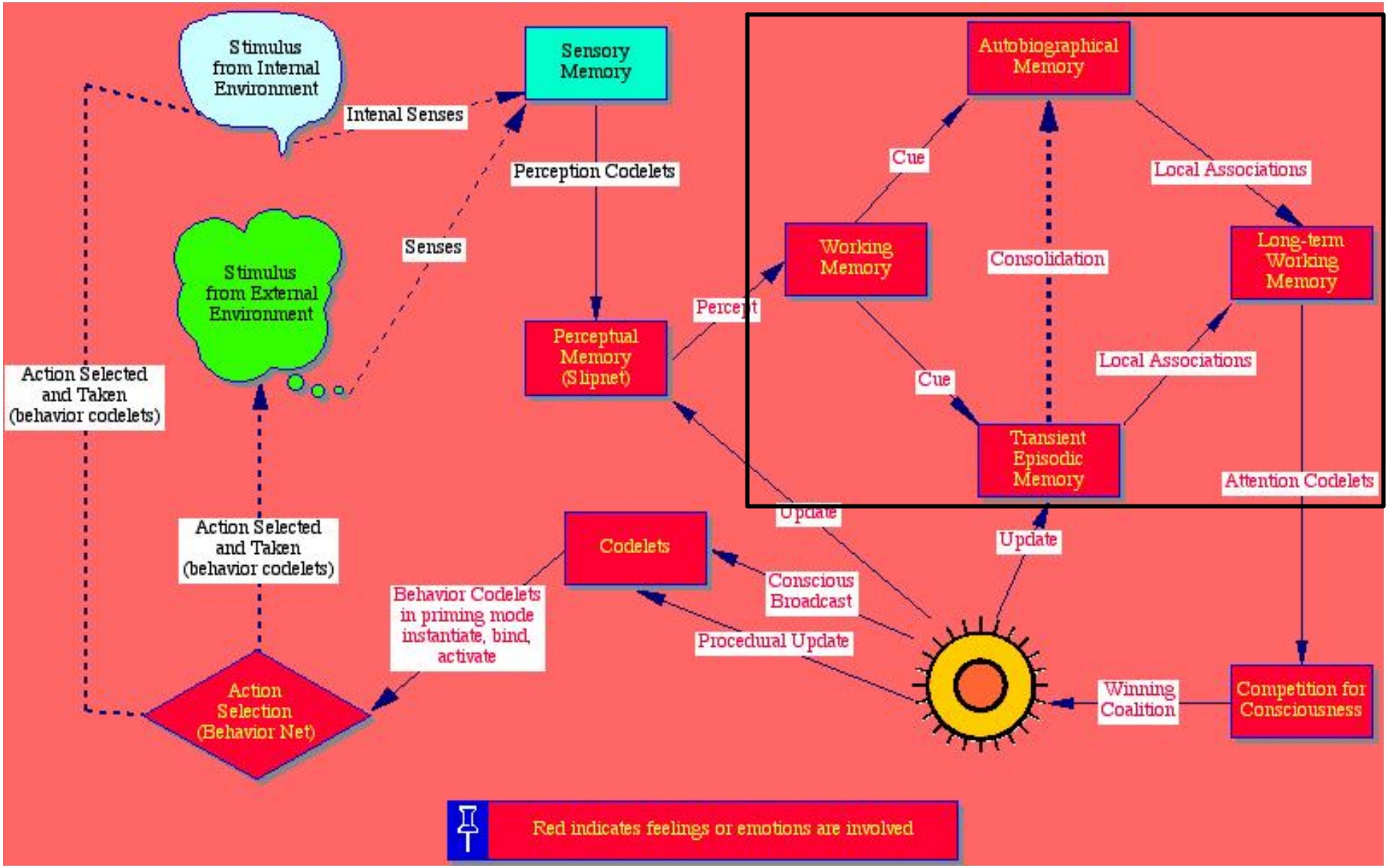
Perceiving

- Preconscious perception
- External or internal stimuli
- Construction of meaning
  - Identification
  - Categorization
  - Relations
- Includes feelings and emotions
- Filtering process produces a percept


Stimulus from Internal Environment
Intenal Senses
Sensory Memory
Autobiographical Memory
Perception Codelets
Cue
Local Associations
Stimulus from External Environment
Senses
Working Memory
Consolidation
Long-term Working Memory
Percept
Perceptual Memory (Slipnet)
Cue
Local Associations
Action Selected and Taken (behavior codelets)
Transient Episodic Memory
Attention Codelets
Update
Update
Action Selected and Taken (behavior codelets)
Codelets
Conscious Broadcast
Behavior Codelets in priming mode instantiate, bind, activate
Procedural Update
Action Selection (Behavior Net)
Winning Coalition
Competition for Consciousness
Red indicates feelings or emotions are involved

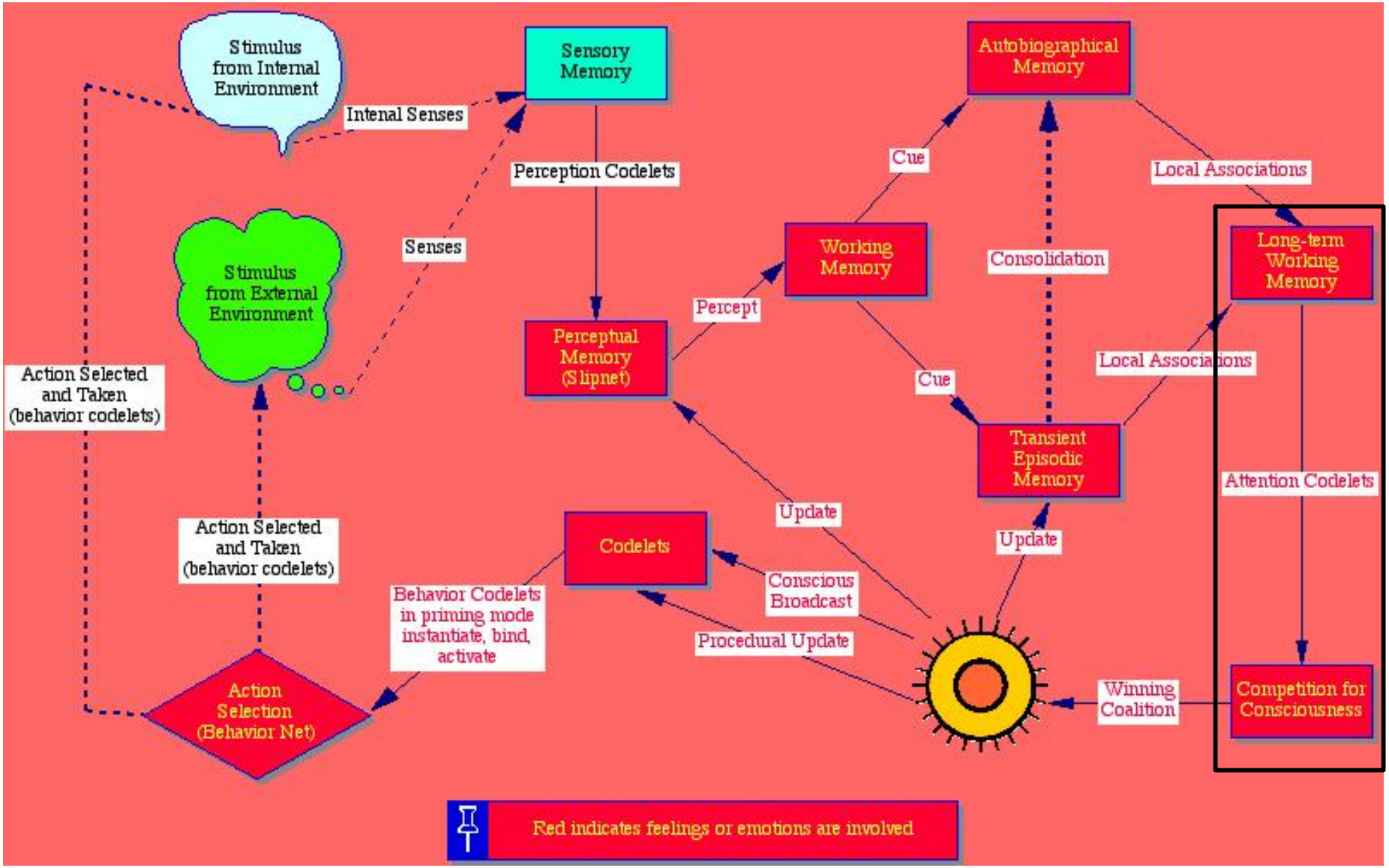
Store Percept in Working Memory

- Percept stored in preconscious buffers of Working Memory
  - Visuo-spatial sketchpad
  - Phonological loop
- Buffers may contain earlier contents also
- Decay time measured in tens of seconds


Stimulus from Internal Environment
Intenal Senses
Sensory Memory
Perception Codelets
Autobiographical Memory
Cue
Local Associations
Working Memory
Consolidation
Long-term Working Memory
Stimulus from External Environment
Senses
Percept
Perceptual Memory (Slipnet)
Cue
Local Associations
Action Selected and Taken (behavior codelets)
Transient Episodic Memory
Attention Codelets
Update
Update
Action Selected and Taken (behavior codelets)
Codelets
Conscious Broadcast
Behavior Codelets in priming mode instantiate, bind, activate
Procedural Update
Action Selection (Behavior Net)
Winning Coalition
Competition for Consciousness
Red indicates feelings or emotions are involved

Local Associations

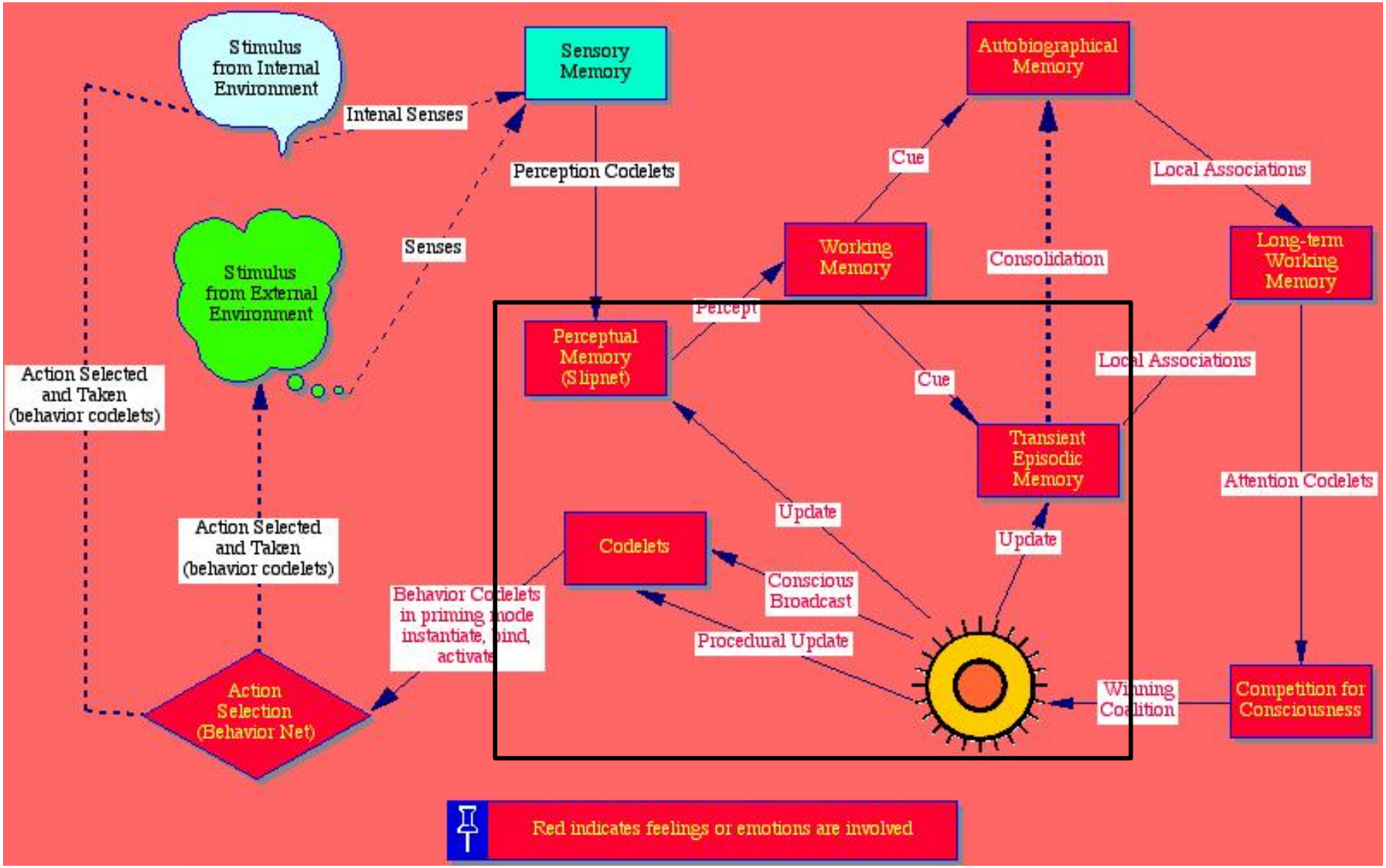
- Contents of preconscious Working Memory buffers serve as a cue
- Retrieves local associations from
  - Transient episodic memory
  - Declarative memory
- Contents of WM plus these associations enter
  - Baddeley's episodic buffer
  - Ericsson and Kintsch's Long-term Working Memory
- May include feelings, emotions, actions


Stimulus from Internal Environment
Intenal Senses
Sensory Memory
Autobiographical Memory
Perception Codelets
Cue
Local Associations
Stimulus from External Environment
Senses
Working Memory
Consolidation
Long-term Working Memory
Percept
Perceptual Memory (Slipnet)
Action Selected and Taken (behavior codelets)
Cue
Local Associations
Transient Episodic Memory
Attention Codelets
Update
Update
Codelets
Action Selected and Taken (behavior codelets)
Conscious Broadcast
Behavior Codelets in priming mode instantiate, bind, activate
Procedural Update
Action Selection (Behavior Net)
Winning Coalition
Competition for Consciousness
Red indicates feelings or emotions are involved

Competition for Consciousness

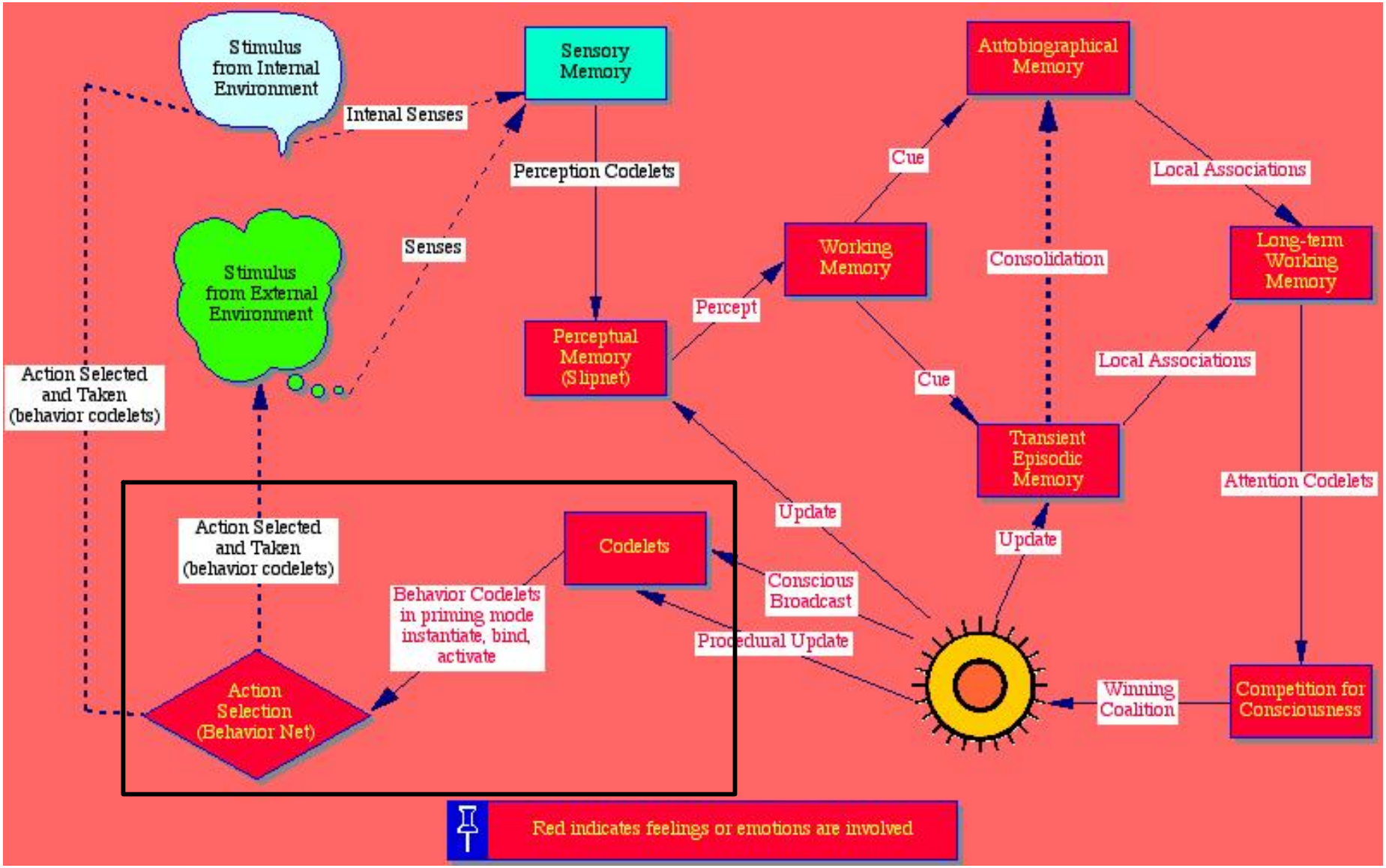
- Attention codelets view LTWM
- Form coalitions with information codelets
- Vie to bring various portions of contents to consciousness
- Coalition from a previous cycle can win

- Factors include
  - Relevancy
  - Importance
  - Urgency
  - Insistence
  - Recency


Stimulus from Internal Environment
Intenal Senses
Sensory Memory
Autobiographical Memory
Perception Codelets
Cue
Local Associations
Stimulus from External Environment
Senses
Working Memory
Consolidation
Long-term Working Memory
Percept
Perceptual Memory (Slipnet)
Cue
Local Associations
Action Selected and Taken (behavior codelets)
Transient Episodic Memory
Attention Codelets
Update
Update
Codelets
Conscious Broadcast
Action Selected and Taken (behavior codelets)
Behavior Codelets in priming mode instantiate, bind, activate
Procedural Update
Action Selection (Behavior Net)
Winning Coalition
Competition for Consciousness
Red indicates feelings or emotions are involved

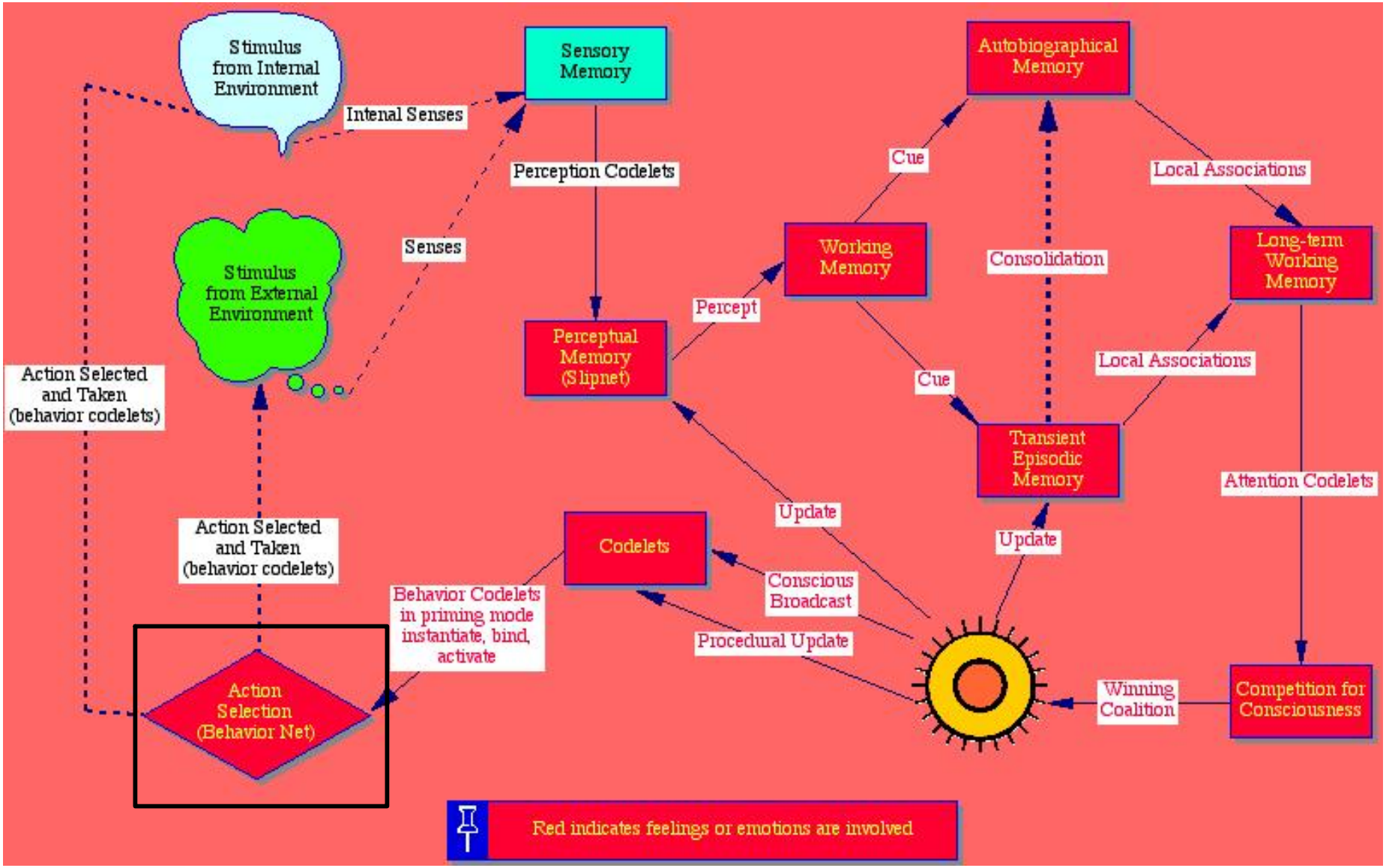
Conscious Broadcast

- Coalition with highest average activation is chosen
- Is said to be in the spotlight, or to occupy the global workspace
- The information content of the coalition is broadcast to all codelets
- GW theory postulates this broadcast as the moment of phenomenal consciousness


Stimulus from Internal Environment
Intenal Senses
Sensory Memory
Perception Codelets
Autobiographical Memory
Cue
Local Associations
Stimulus from External Environment
Senses
Working Memory
Consolidation
Long-term Working Memory
Percept
Perceptual Memory (Slipnet)
Action Selected and Taken (behavior codelets)
Cue
Local Associations
Transient Episodic Memory
Attention Codelets
Update
Update
Action Selected and Taken (behavior codelets)
Codelets
Conscious Broadcast
Behavior Codelets in priming mode instantiate, bind, activate
Procedual Update
Action Selection (Behavior Net)
Winning Coalition
Competition for Consciousness
Red indicates feelings or emotions are involved

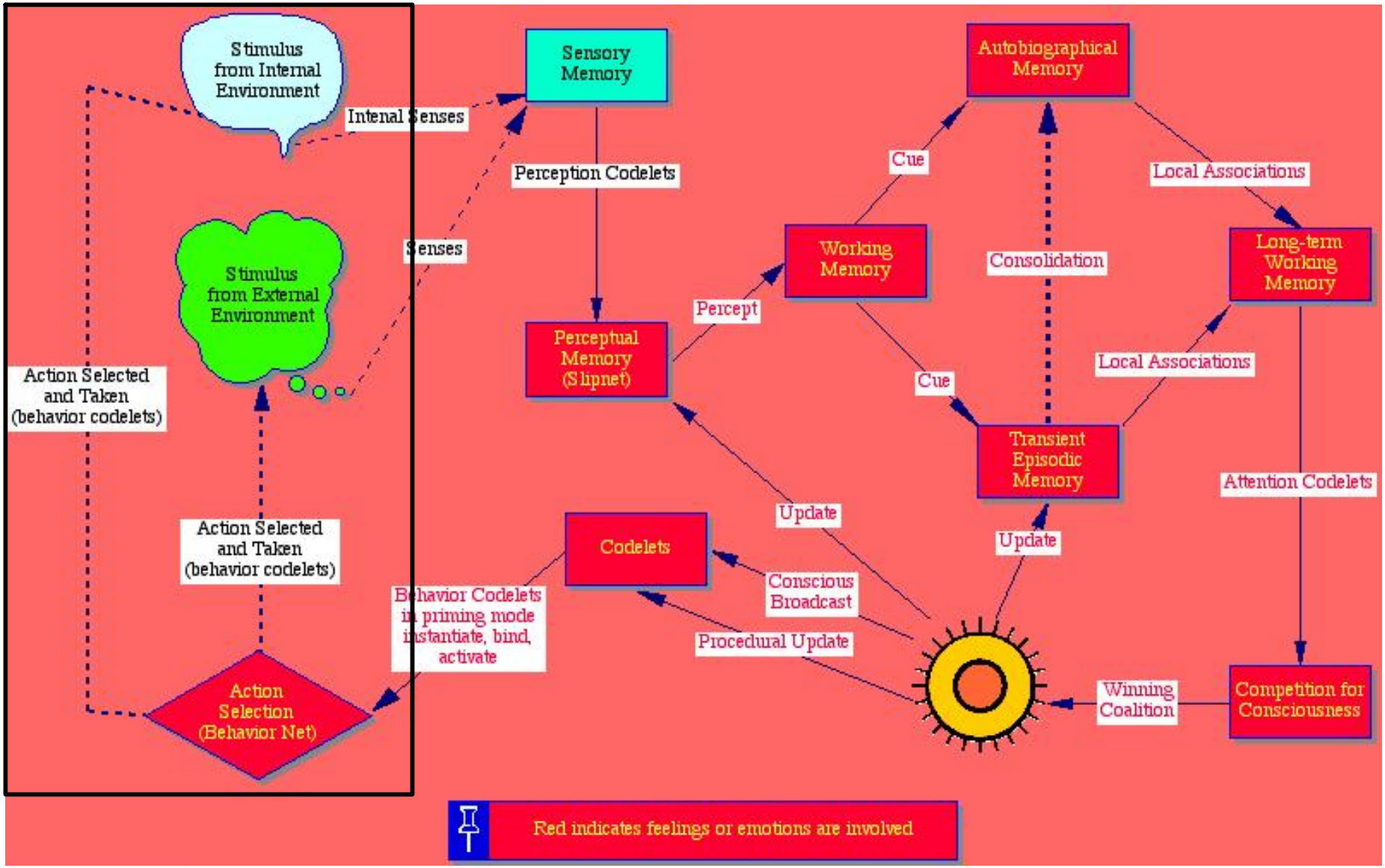
Setting Goal Context Hierarchy

- Relevant behavior codelets respond to broadcast
- Instantiate goal context hierarchy (behavior stream) if needed
- Bind variables using information from conscious broadcast
- Send environmental and feeling activation to appropriate behaviors


Stimulus from Internal Environment
Intenal Senses
Sensory Memory
Perception Codelets
Autobiographical Memory
Cue
Local Associations
Stimulus from External Environment
Senses
Working Memory
Consolidation
Long-term Working Memory
Percept
Perceptual Memory (Slipnet)
Action Selected and Taken (behavior codelets)
Cue
Local Associations
Transient Episodic Memory
Attention Codelets
Update
Update
Action Selected and Taken (behavior codelets)
Codelets
Conscious Broadcast
Behavior Codelets in priming mode instantiate, bind, activate
Procedural Update
Action Selection (Behavior Net)
Winning Coalition
Competition for Consciousness
Red indicates feelings or emotions are involved

Action Chosen

- Behaviors (goal contexts) get activation from
  - Drives (feelings and emotions)
  - Environment
  - Other behaviors
- The single behavior is chosen that
  - Is executable
  - activation over threshold
  - higher activation than other such behaviors


Stimulus from Internal Environment
Intenal Senses
Sensory Memory
Perception Codelets
Autobiographical Memory
Cue
Local Associations
Stimulus from External Environment
Senses
Working Memory
Consolidation
Long-term Working Memory
Percept
Perceptual Memory (Slipnet)
Action Selected and Taken (behavior codelets)
Cue
Local Associations
Transient Episodic Memory
Attention Codelets
Update
Update
Codelets
Action Selected and Taken (behavior codelets)
Conscious Broadcast
Behavior Codelets in priming mode instantiate, bind, activate
Procedural Update
Action Selection (Behavior Net)
Winning Coalition
Competition for Consciousness
Red indicates feelings or emotions are involved

Action Taken

- Chosen behavior binds variables in its behavior codelets
- Then releases its behavior codelets along with at least one expectation codelet
- These behavior codelets perform the task of the behavior
- This action may effect the external or internal environment or both
- Action doesn’t occur when dreaming

Processes requiring multiple cycles

- Deliberation
- Volition
- Non-routine problem solving
- Language understanding & generation
- Metacognition

Consciously Mediated Action vs. Voluntary Action Selection

- Voluntary action selection
  - Go to the fridge for orange juice
  - Choice between go or wait, orange juice or coke or water
- Consciously mediated action
  - Find and grasp the handle
- Automatized, unconscious actions
  - Pull the refrigerator door open

IDA Totally Hand Crafted

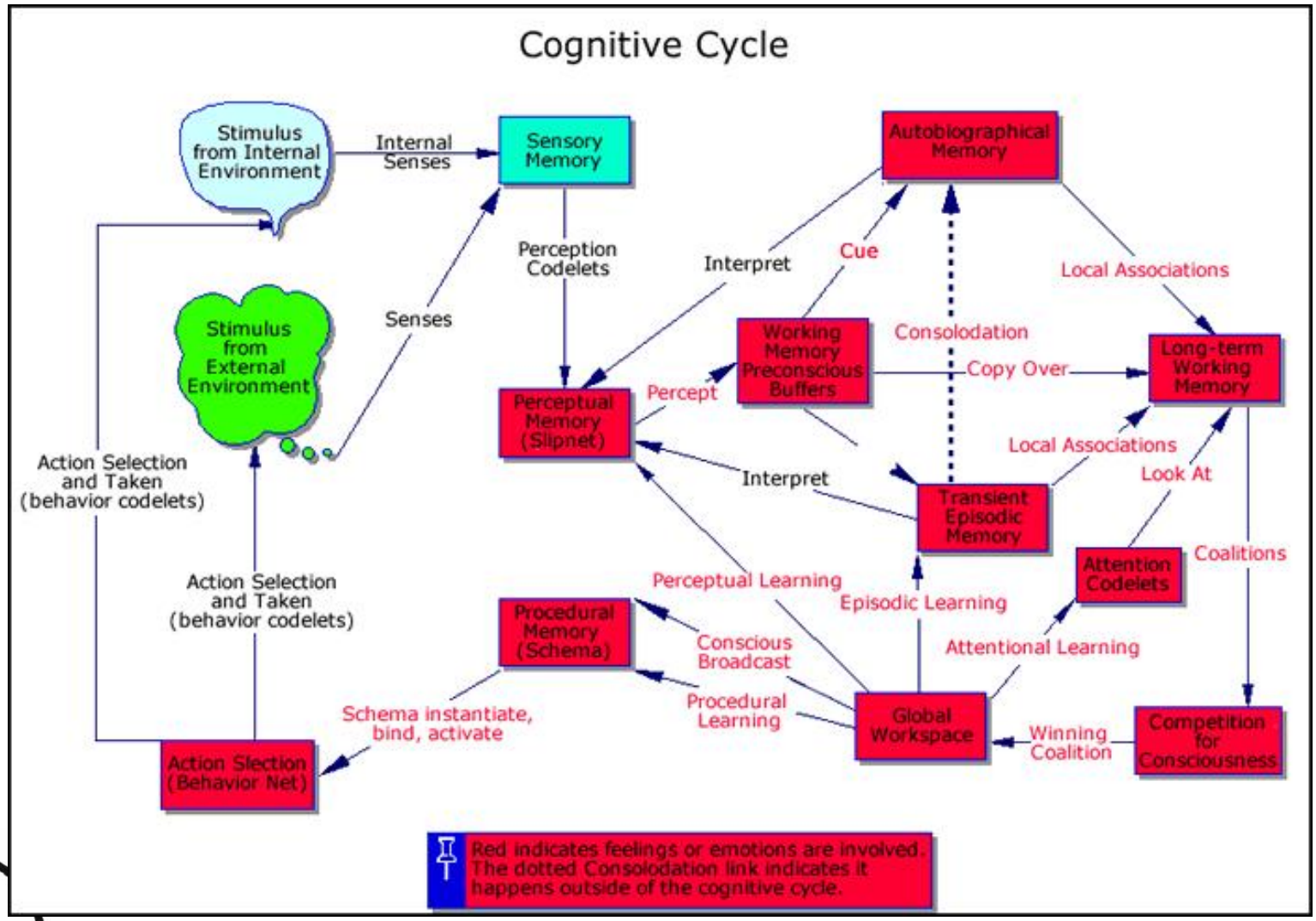
LIDA — Learning IDA

LIDA is IDA with learning added

Learning occurs

- Perceptual learning
  - Identification, classification, relations
- Episodic learning
  - To transient episodic memory
  - Doesn’t happen during dreaming
- Procedural learning
  - Reinforces actions from previous cycles

LIDA Cognitive Cycle



Learning Mechanisms in the LIDA Technology

- Perceptual learning via a Slipnet
- Episodic learning via Sparse Distributed Memory
- Procedural learning via a Scheme Net

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

A mechanism for perceptual learning

- Semantic net with activation passing
- Nodes represent features, individuals, categories, relations (situations)
- Links, excitatory (isa), inhibitory (lateral)
- Total activation = current + base-level
- Percept composed of nodes over threshold
- Learning modifies base-level activation and creates new nodes and links

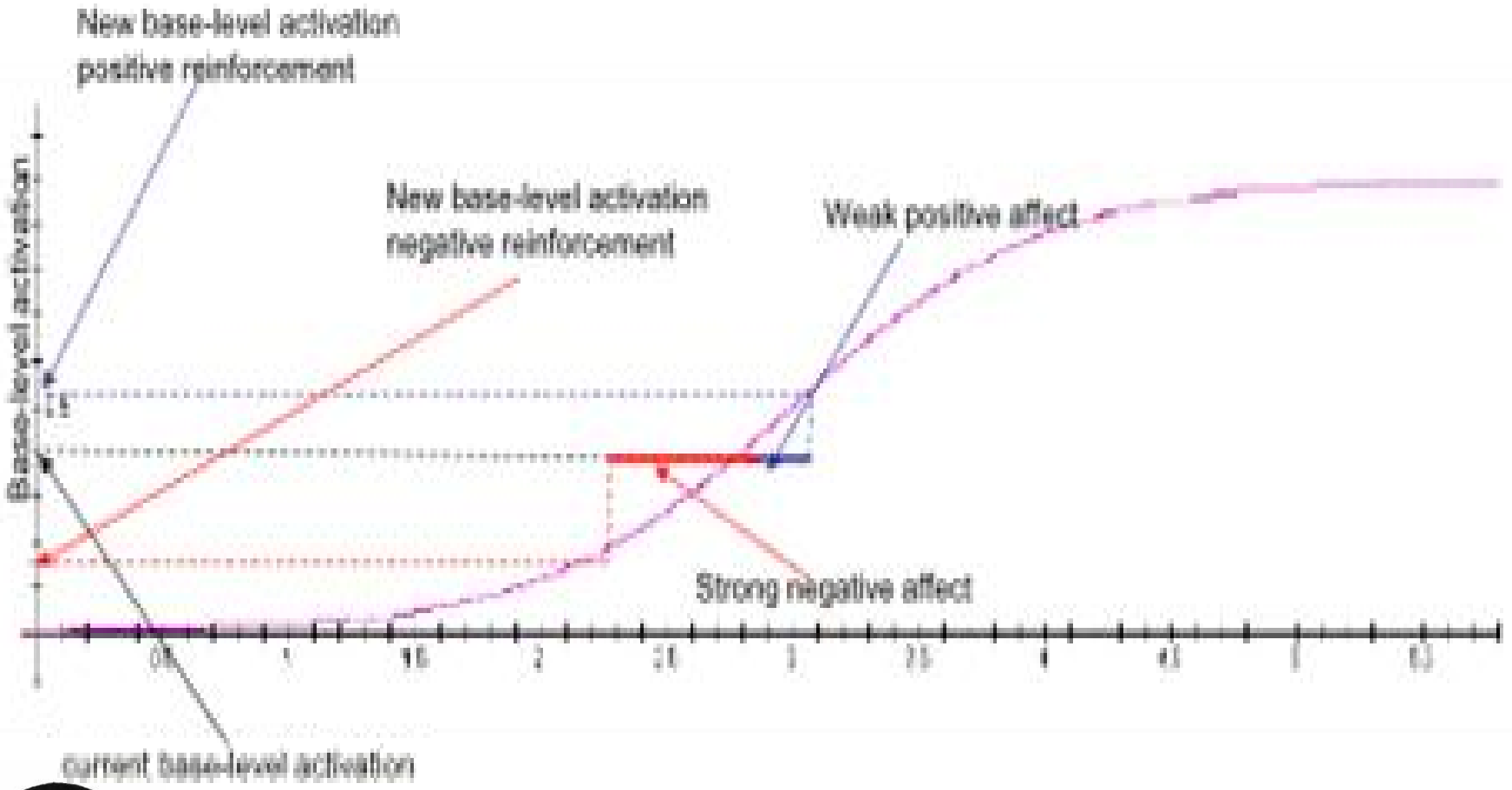
A mechanism for episodic learning

- Sparse distributed memory
  - Few hard locations, HUGE address space
  - Each hard location contributes to the encoding of many different events
  - Each event is encoded to many different hard locations
- Associative and content addressable
- Psychological properties
  - Knows when it doesn't know
  - Tip of the tongue phenomena

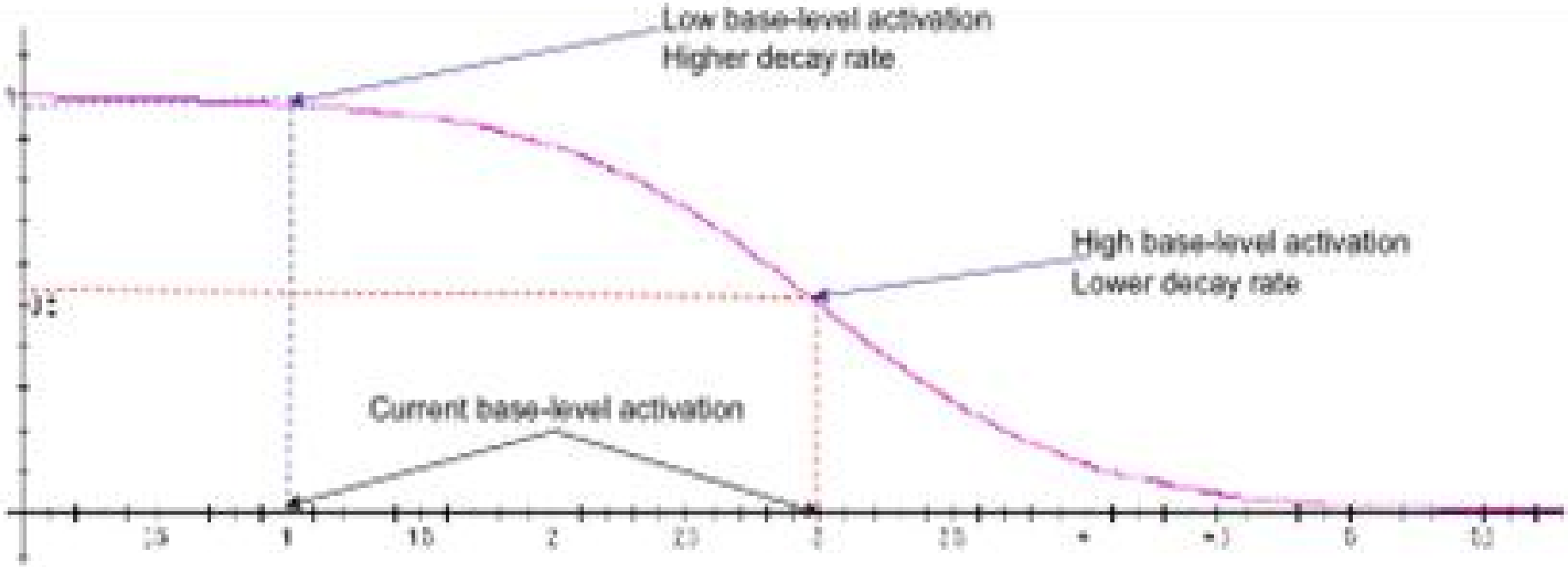
A Mechanism for Procedural Learning

- Action selection via a scheme net
- Scheme (context, action, result, activation)
- Activation = current + base-level
- Learning reinforces base-level activation and creates new schemes
- Support multiple actions, both parallel and sequential

Modifying Base-level Activation



Decay Curve



- Low base-level activation — rapid decay
- Saturated base-level activation — almost no decay

Selectionist & Instructionalist Learning

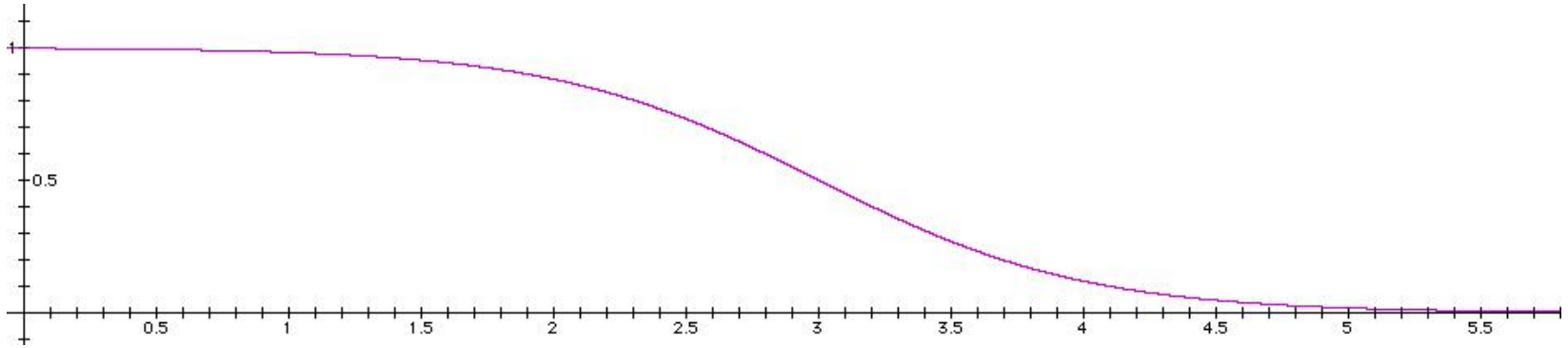
- Selectionist Learning
  - selected for reinforcement from a redundant repertoire
- Instructionalist Learning
  - new representations constructed
- LIDA learns in both modes

LIDA Research Directions

- Domain-independent LIDA technology
  - Almost complete
- Control of real-world cognitive robots
  - Collaboration with roboticists (Kawamura, etc.)
- Cognitive software agent controller for an image database
  - DARPA funding pending

Learning

- Consciousness suffices for learning
- Learning rate rises with arousal (feelings and emotions)
- Learning occurs quickly and easily, but decays rapidly



Email and Web Addresses

- Stan Franklin
  - franklin@memphis.edu
  - www.cs.memphis.edu/~franklin
- “Conscious” Software Research Group
  - www.cs.memphis.edu/~csrg