Creatures: Entertainment Software Agents with Artificial Life

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Ali
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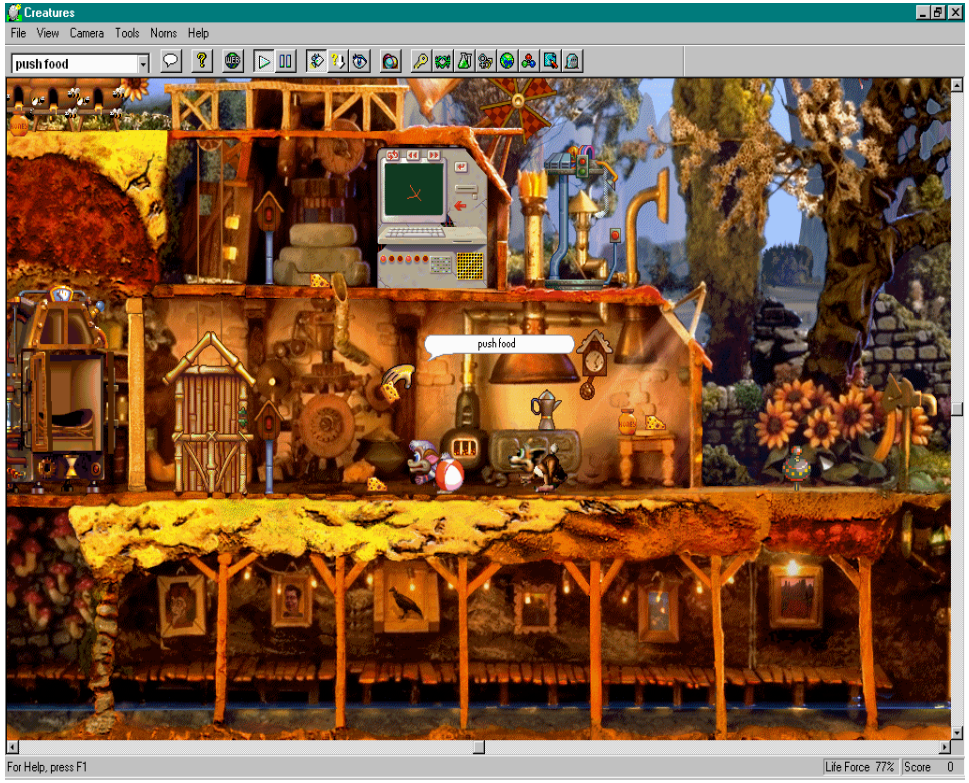
Environment

- The creatures live in a 2D environment with multi-plane depth cueing.
- There are objects the creatures can interact with (toys, food, etc.)
- User's mouse pointer in the environment appears as a human hand.
- The user can move objects in the environment, and can attract the attention of a creature by waving the hand in front of it, or by petting it (a positive feedback) or slapping it (to generate a negative feedback)



Creatures

- Creatures appearance is specified genetically (coloring, hair type, etc.)
- Creatures size increase until maturity as it grows.
- Senescence genes may become activated in old age, killing the creature.
- The creatures have a simulated sense of sight, sound, and touch.
- Creatures can learn simple verb-object language, either from keyboard input from the user, or by playing on a teaching machine, or interacting with other creatures.

Inside the Creature

- Each creature is composed of genetically specified neural network and a genetically specified biochemistry.
  - Neural Network
    - responsible for the sensory-motor control and learning
  - Biochemistry
    - responsible for energy metabolism and hormonal regulation of behavior.

Neurons

- The neuron's internal state is computed from a genetically defined function called SV-Rule.
- After a neurons State is computed, a relaxation function is applied to it, which exponentially returns it towards a definable 'rest state'.

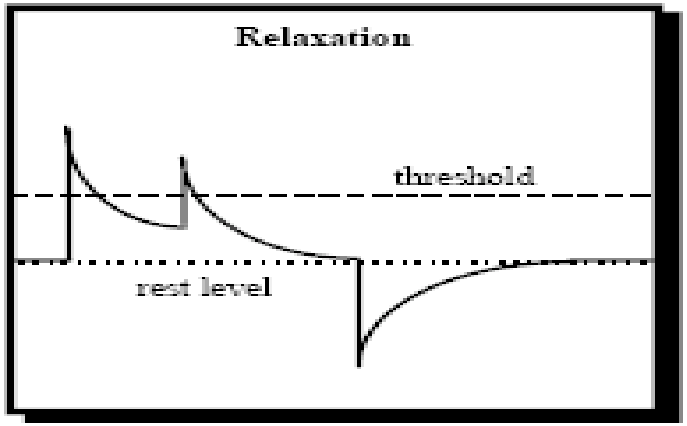


Table 1 Neuron Parameters

Type 1/2 inputs	Each cell may possess 0, 1 or 2 classes of input dendrites, each feeding signals from a different source lobe
State	Internal state, computed from genetically defined expression
Threshold	Output = (State>Threshold) ? State : 0
Relaxation Rate	Exponential recovery rate from current State towards Rest State
Rest State	Natural State value when unperturbed
Input gain	modulates inputs
State Function() (SVRule)	Expression to compute new State from input signals

Table 2 SVRule examples

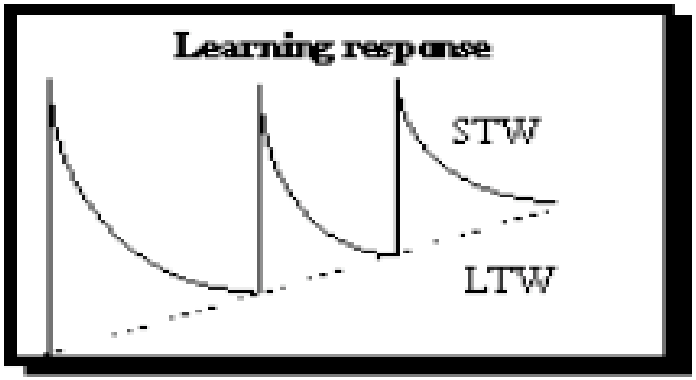
state PLUS type0 Sum of inputs is added to previous state
state PLUS type0 MINUS type1 Type0 inputs are excitatory and type1 are inhibitory
anded0 State is sum of type0 inputs or zero if not all inputs are firing. Previous state is ignored
state PLUS type0 TIMES chem2 State is raised by current input modulated by chemo-receptor

Dendrite Structure

- The initial synaptic connections at birth are made according to some genetic rules. As the creature grows the dendrites will migrate and form new connections and old and unwanted connections will atrophy and disappear to free up resources (using 'strength' and sv-rule parameters)
- Figure shows the effect of learning on STW, and LTW. After a disturbance, both STW and LTW relax exponentially towards each other. The STW reacts strongly to individual reinforcement episodes, while the LTW effectively computes a moving average of many STW disturbances.

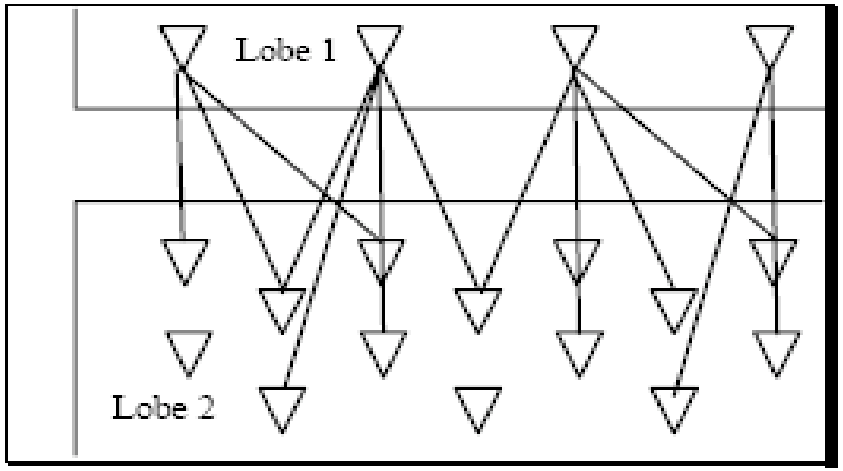
Table 3 Dendrite Parameters

STW	Short-term weight, used to modulate input signals
LTW	Long-term weight. Acts as rest state for STW and provides statistical response to reinforcement
STW relaxation rate	Rate at which STW relaxes back towards LTW
LTW relaxation rate	Rate at which LTW rises towards STW
Susceptibility	Current susceptibility to reinforcement
Susceptibility relaxation rate	Half-life of Susceptibility parameter
Strength	Controls dendrite migration
Reinforcement SVRule	Expression to compute changes in STW
Susceptibility SVRule	Expression to compute changes in sensitivity to reinforcement
Strength gain SVRule	Expression to compute Strength increase
Strength loss SVRule	Expression to compute atrophy



Creatures Brain

- The creatures brain is composed of a neural network, which is subdivided into objects called ‘lobes’.
  - Each lobe defines the electrical, chemical and morphological characteristics of a group of ‘cells’.
  - Cells in each lobe form connections to one or more cells in up to two other lobes to perform the various functions and sub functions of the net.
  - Initially the model contains 1000 neurons grouped into 9 lobes with 5000 synapses.



Brain Structure

- Attention Directing
  - incoming signals from objects in the environment compete for the creatures attention. Once the creature's gaze is fixed on an object, the object becomes the recipient for any actions the creature chooses to take.
- Decision Making.
  - Perception lobe, which combines several groups of sensory inputs into one place.
  - Concept Space, in which event memories are laid down and evoked.
  - Decision Layer, where relationship memories are stored and action decisions get taken.

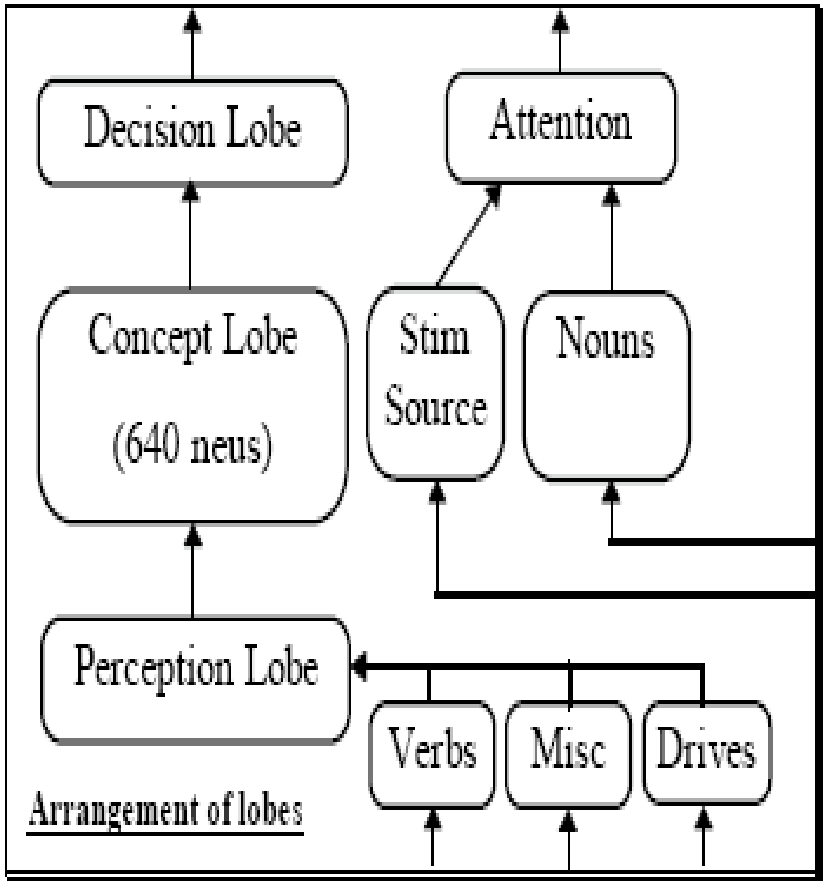
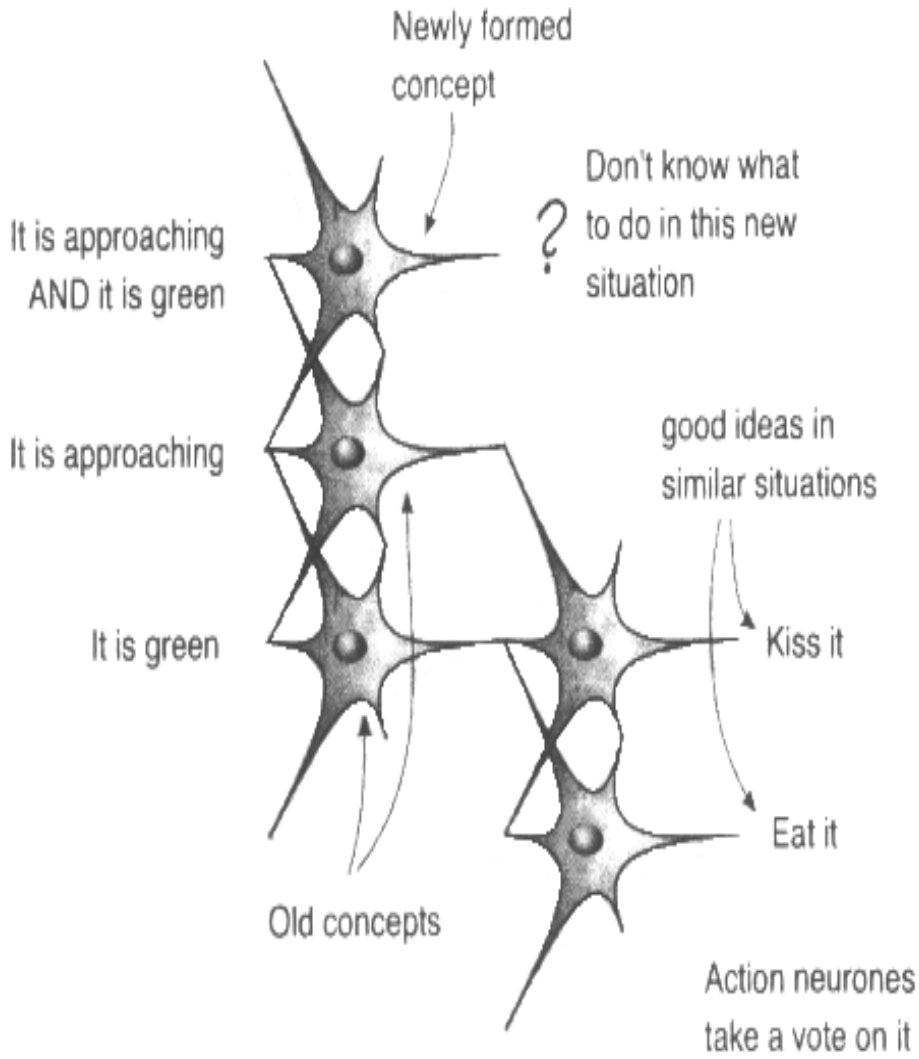


Figure 5: Brain Model

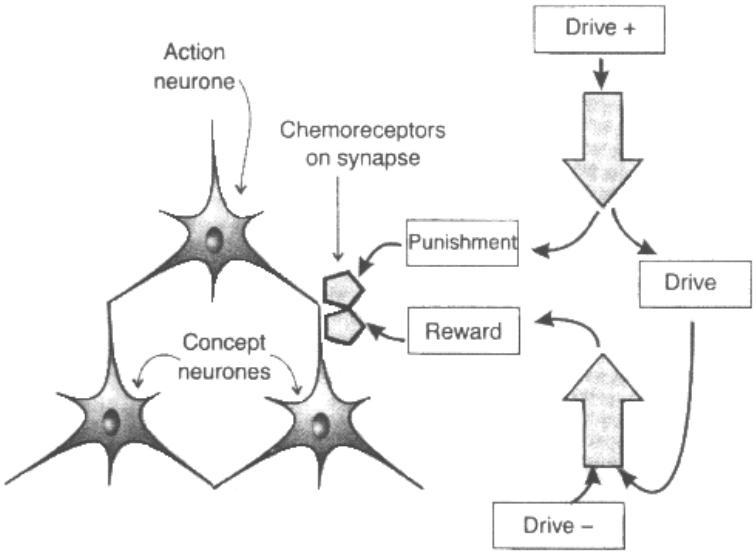
Generalizations

- Creatures are capable of forming generalizations from earlier, related situations.
  - Two sensory situations are related if they share one or more sensory features. Each of the sub situations represents a previously learned experience and each can offer useful advice on how to react in a new situation.



Learning

- The creature learns from the result of the actions it takes, by either being rewarded or punished for that action. This is done by measuring the effect of the actions on a set of "drives".
  - For example, any action that increases a creature's "pain" drive is bad, and must be punished, while anything that decreases its "hunger" drive is good, and should be rewarded.
- Drives are represented by a set of chemicals, the higher the concentration of the chemical the more critical the drive.

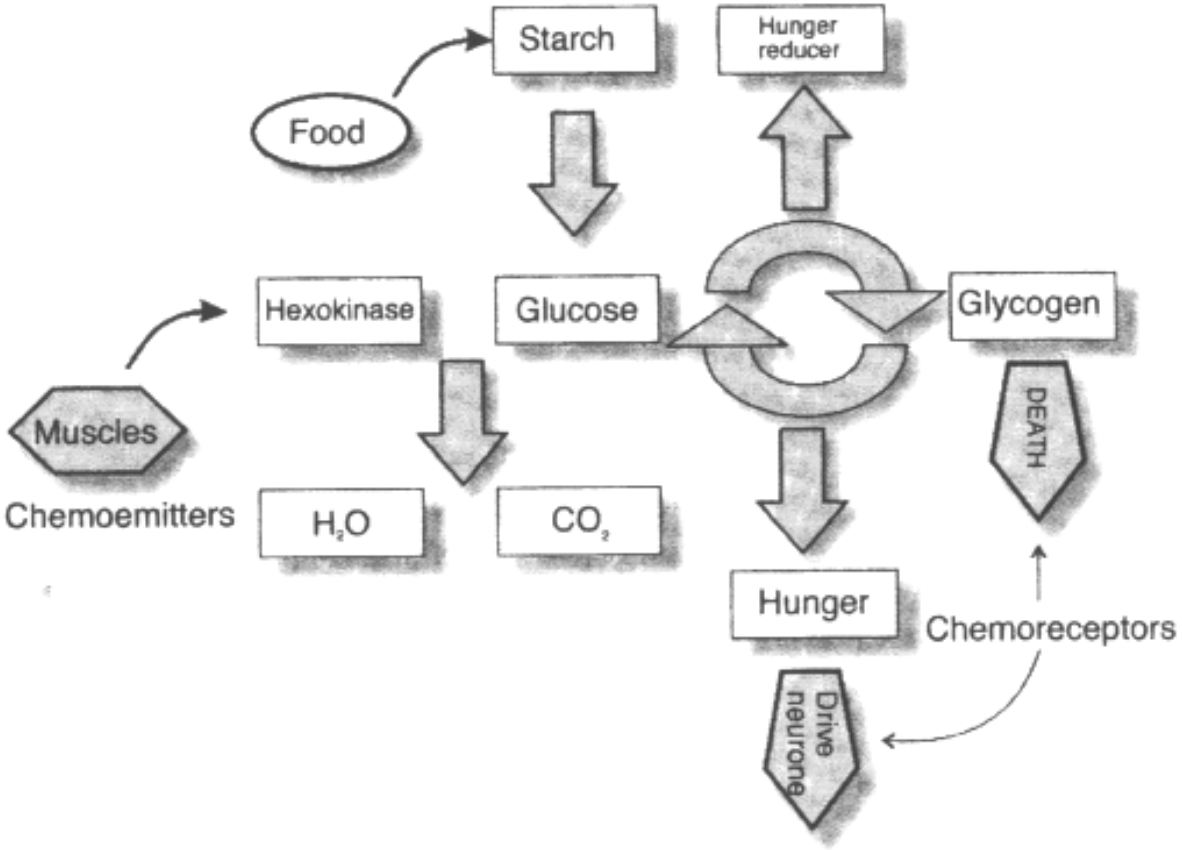


- Drive level change reactions
  - DriveRaiser => Drive + Punishment
  - DriveReducer + Drive => Reward

Creatures Biochemistry

- Chemicals
  - Arbitrary numbers [0, …, 255] representing the chemical, and a number representing its concentration
- Emitters
  - The chemicals are produced by the chemo-emitters.
- Reactions
  - Convert one or more chemicals into one or more products by lowering the concentration of reactants and increasing the concentration of products.
    - $[A]_i + [B]_j \Rightarrow [C]_k + [D]_l$
- Receptors
  - Chemical concentrations are monitored by chemo-receptors.
- Biochemical structures
  - Receptors and emitters are attached to synapses within the brain lobes to allow feedback paths within the brain. Paths are implemented to control synaptic atrophy and migration, and also provide drive reduction and learning reinforcement.

Digestive and Repertory System



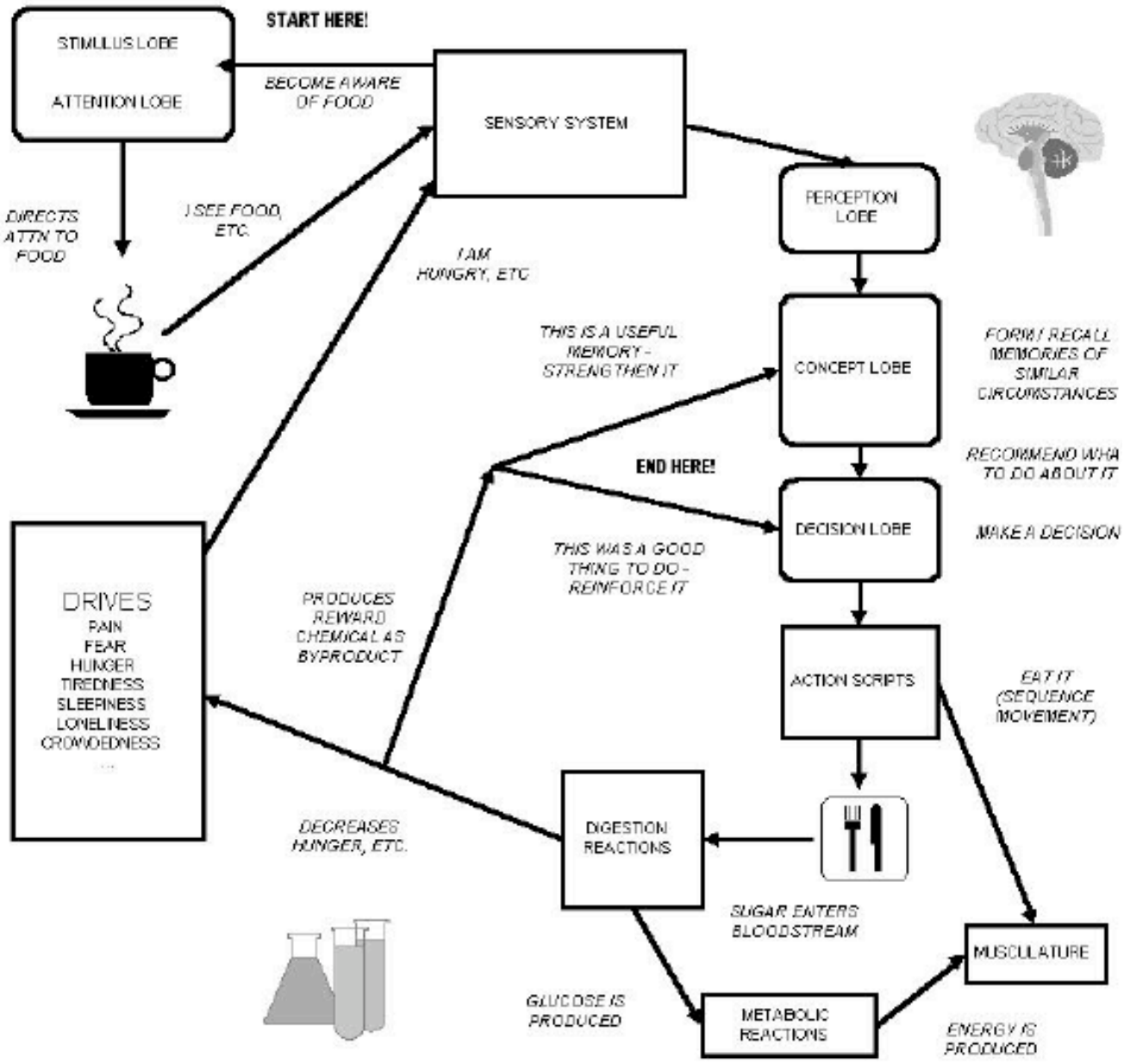


Figure 7. **Summary of interactions within a creature, and between the creature and its environment**

Genetics

- The creatures structure and function are determined by its genes.
- The genome is a string of bytes, divided into genes by punctuation marks.
- Each gene has a header that determines what operations can be performed on it during reproduction (omission, duplication, mutation).
- Each gene header has a value determining when a gene will be activated.
- Each gene carries the instruction for both sexes, but only the unsexed and appropriately sexed genes get expressed in the phenotype.
- During reproduction parental genes are cross and spliced at gene boundaries. Occasional crossover errors can introduce gene omission and duplication. Also occasional random mutation is applied to gene bodies.
- The genome is rescanned at intervals, to give new genes the opportunity to be expressed, to provide for changes in the creatures structure and behavior (ex. during puberty).