Neuronal Circuits: An Evolutionary Perspective

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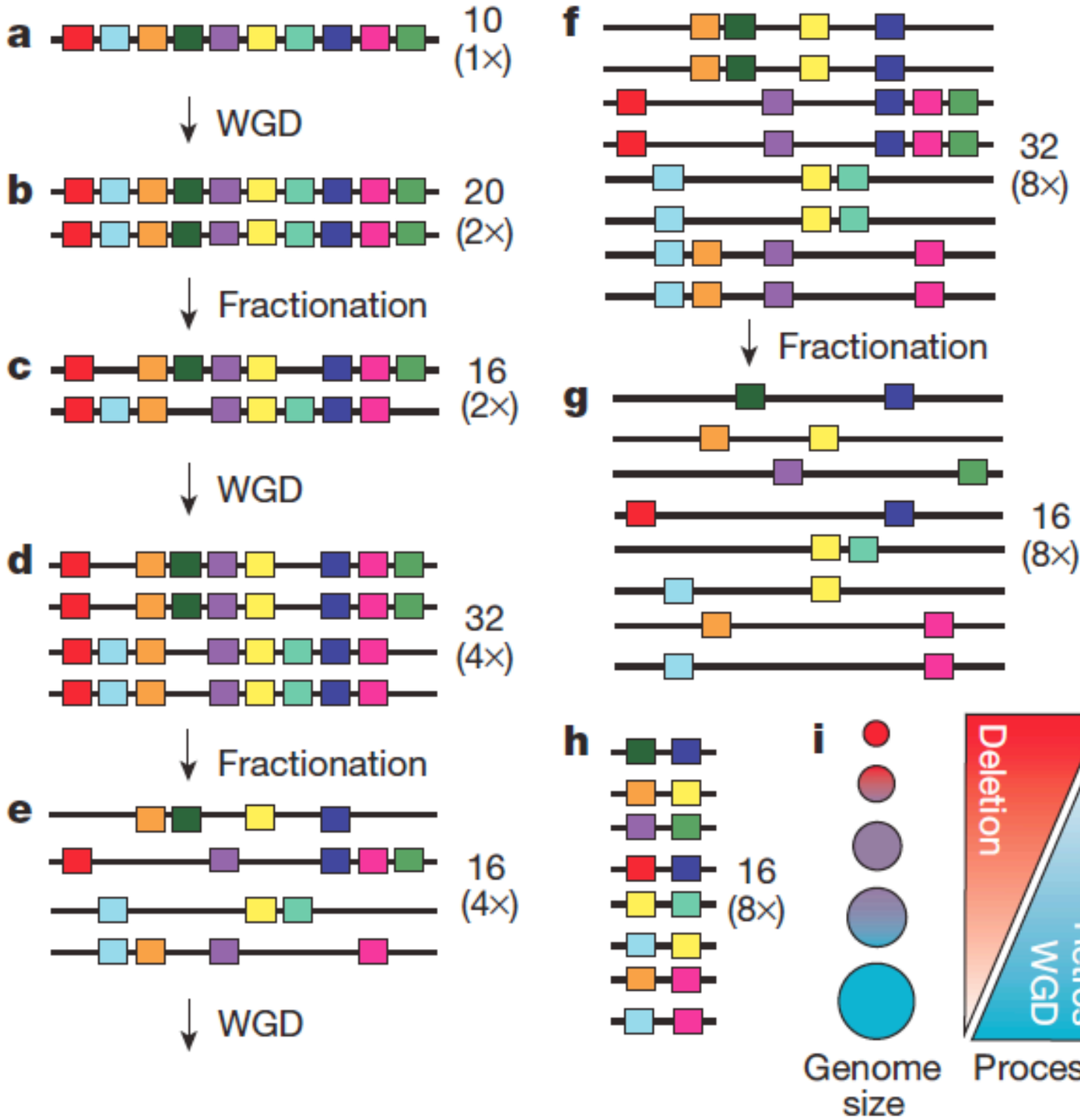
The effects of evolution: 4 determinants

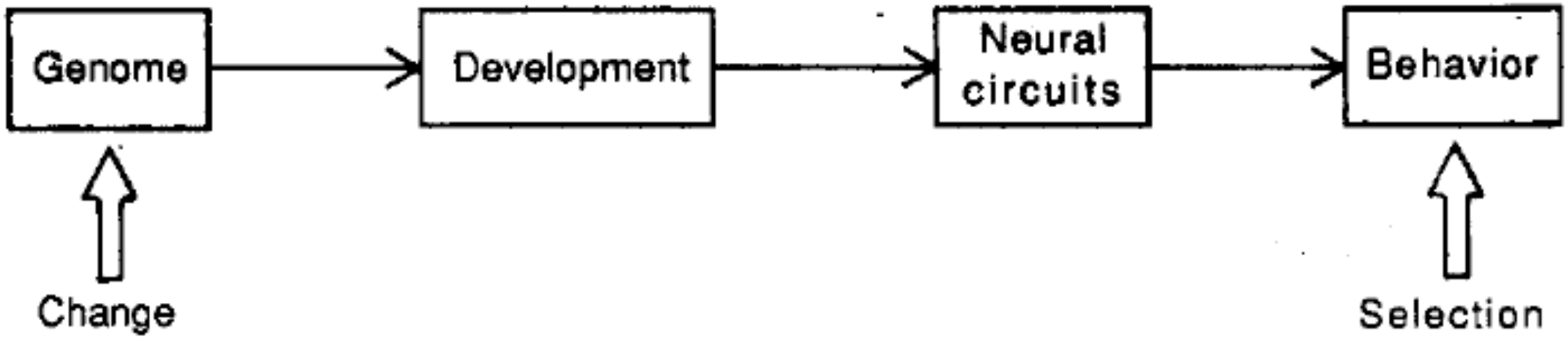
1. Adaptive influences linked to behavioral output
2. Developmental constraints
3. Historical influences
4. Architectural features

Absolute optimization need not occur

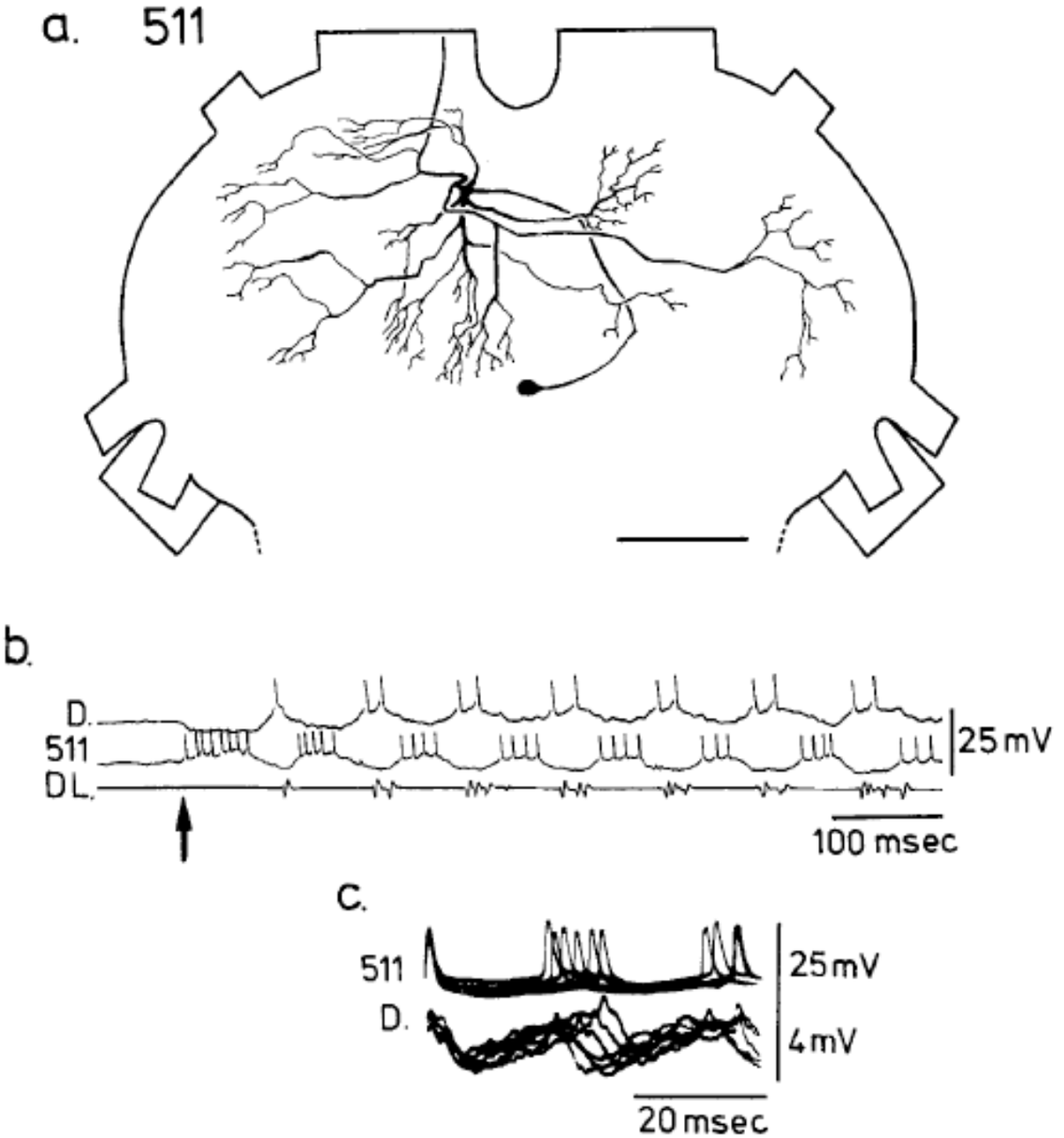
‘Junk’ DNA


a
10
(1×)
WGD
b
20
(2×)
Fractionation
c
16
(2×)
WGD
d
32
(4×)
Fractionation
e
16
(4×)
WGD
f
32
(8×)
Fractionation
g
16
(8×)
h
16
(8×)
i
Deletion
Retros
WGD
Genome size
Process

Change occurs at the level of genes and selection pressures operate on behavior

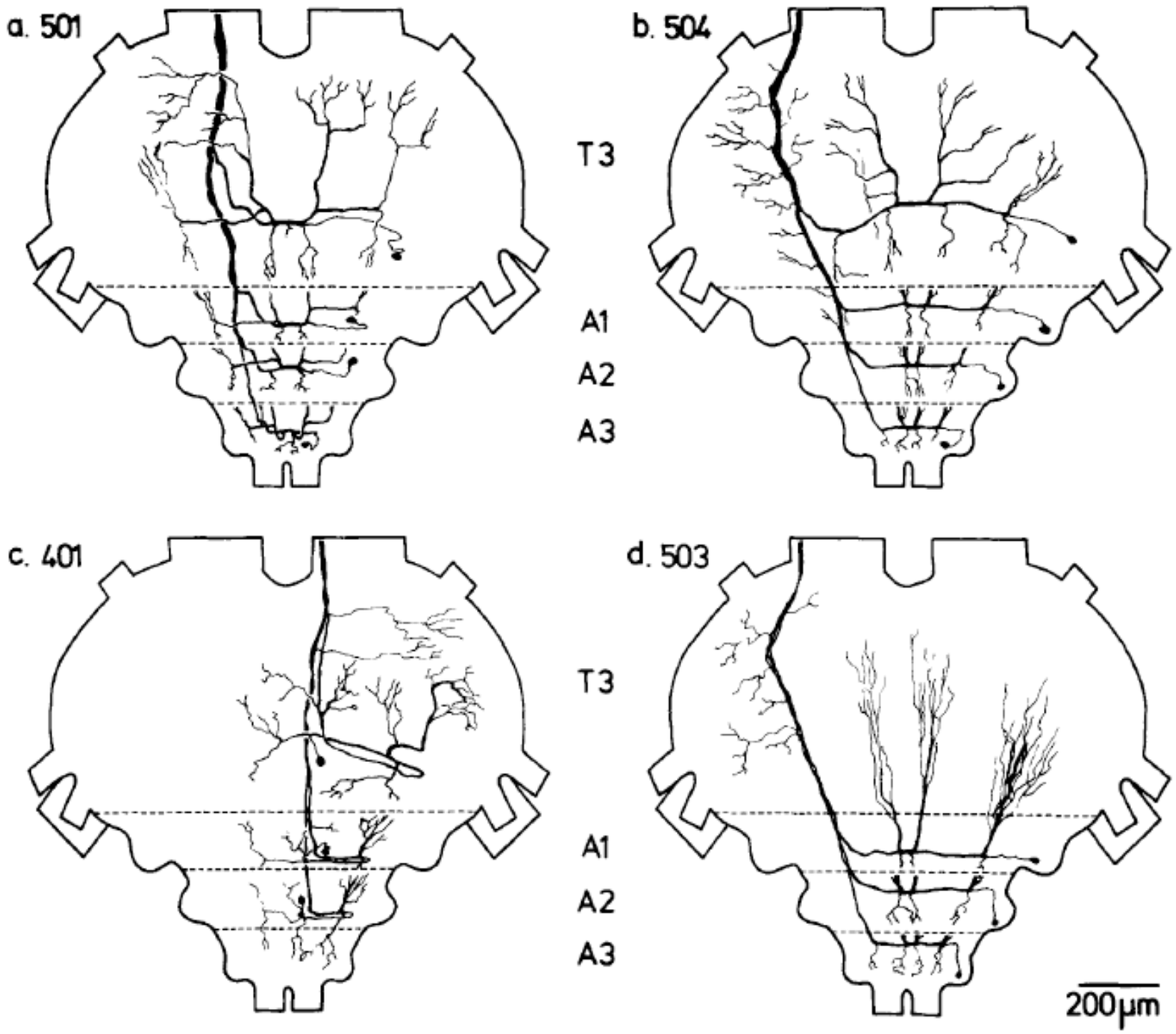


Locust flight



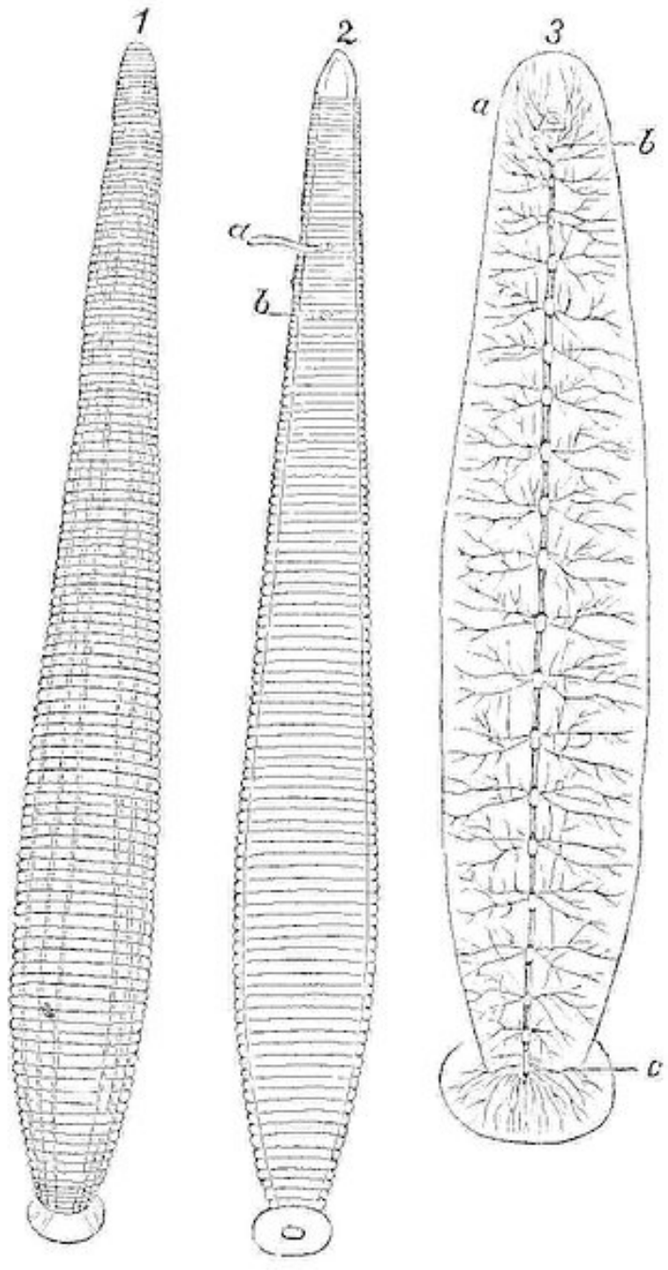
Robertson and Pearson 1983

Abdominal interneurons contribute to locust flight although wings are thoracic

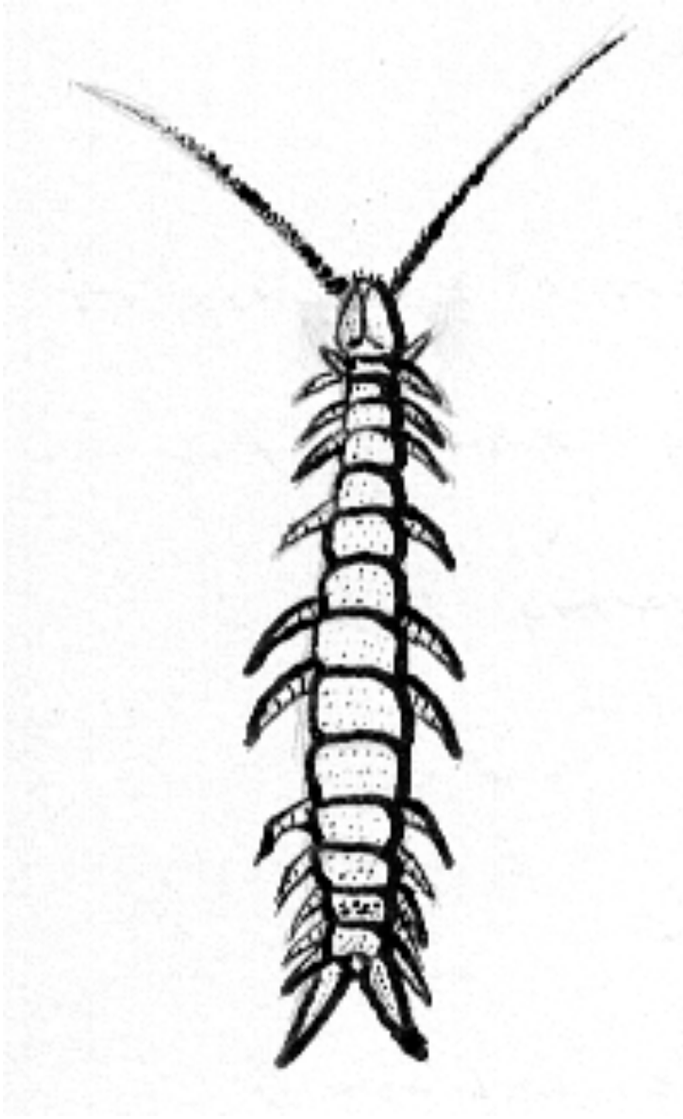


Robertson and Pearson 1983

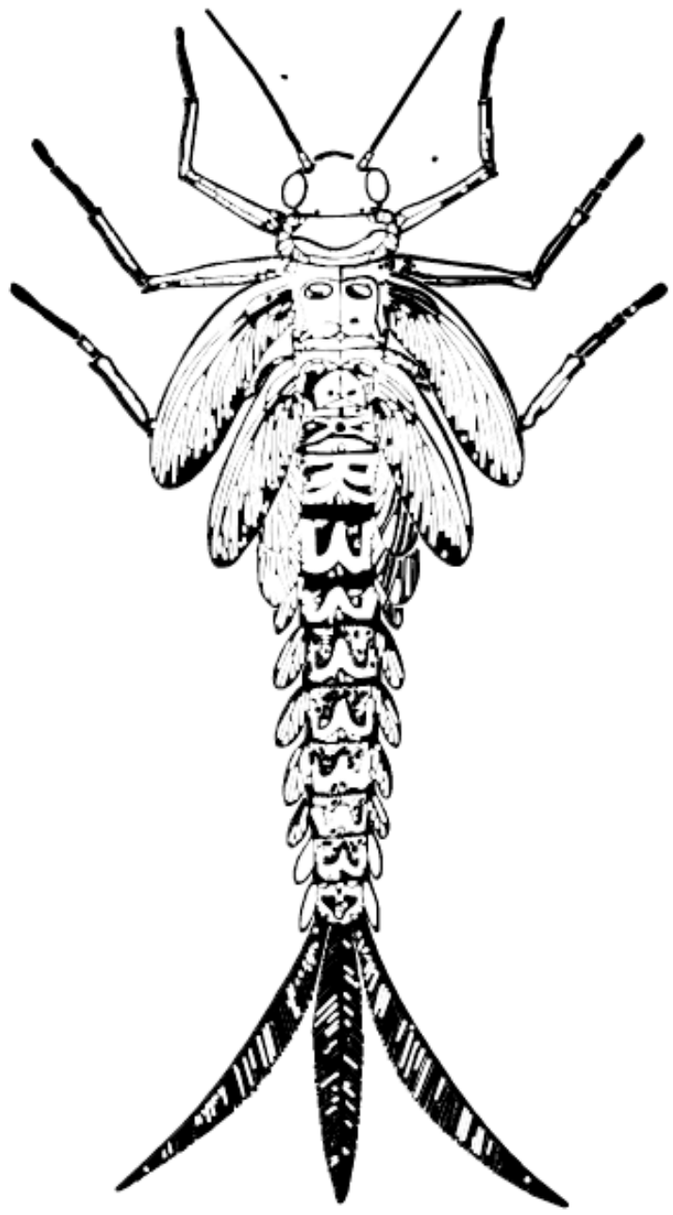
Flight originally evolved in insects with wings on all segments



Swimming



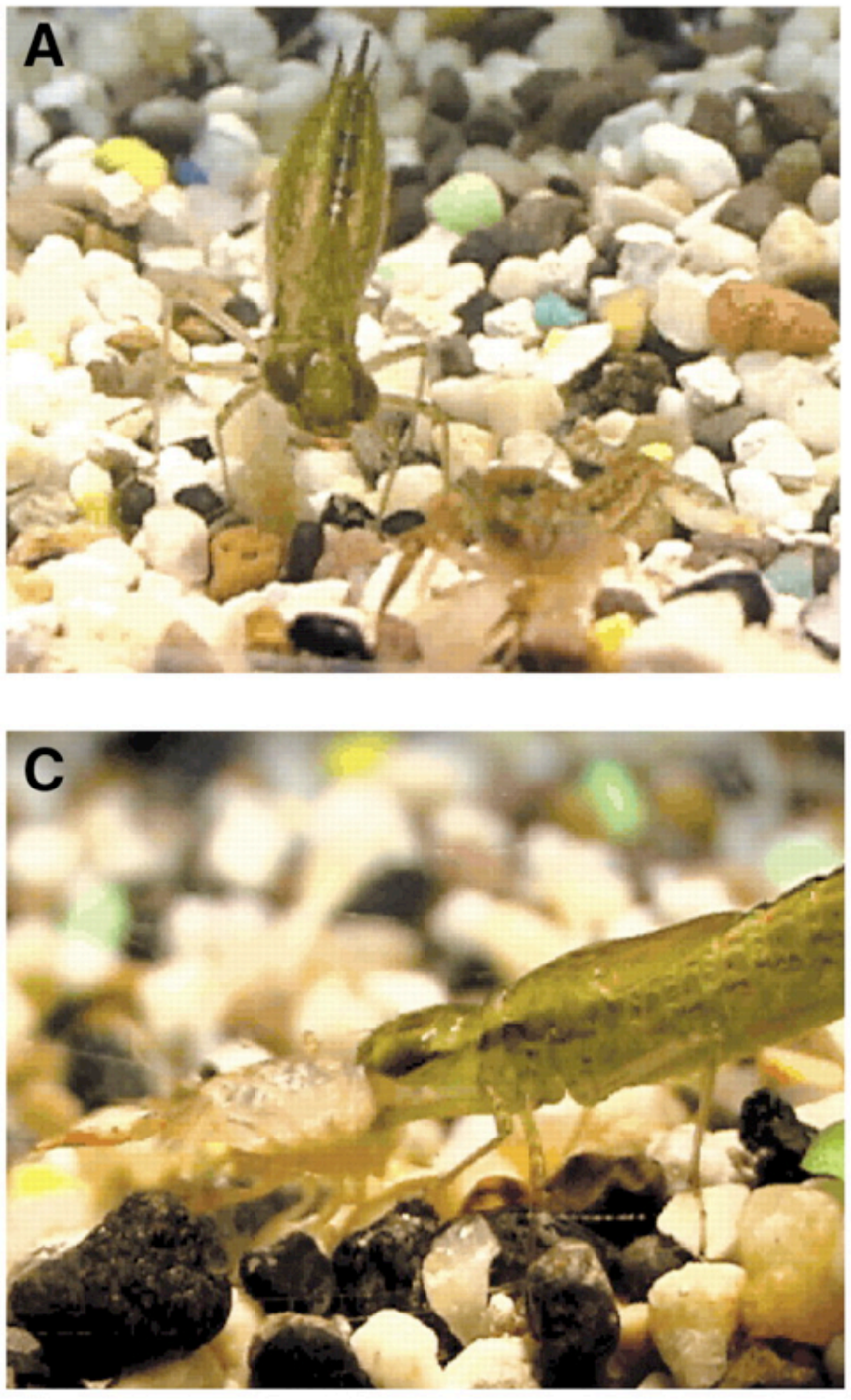
Walking



Flying

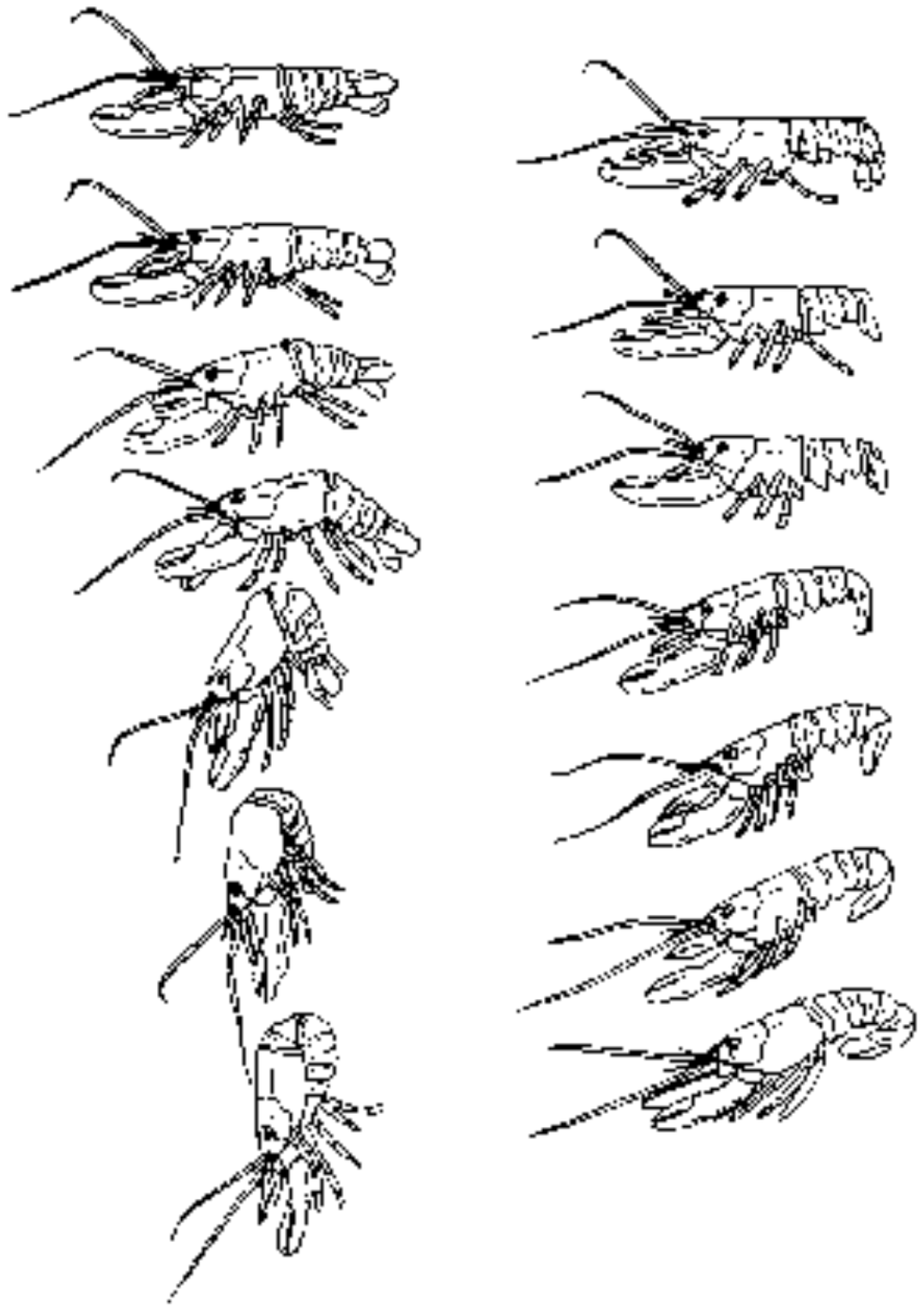
The Crayfish

Crayfish tail flip escape response

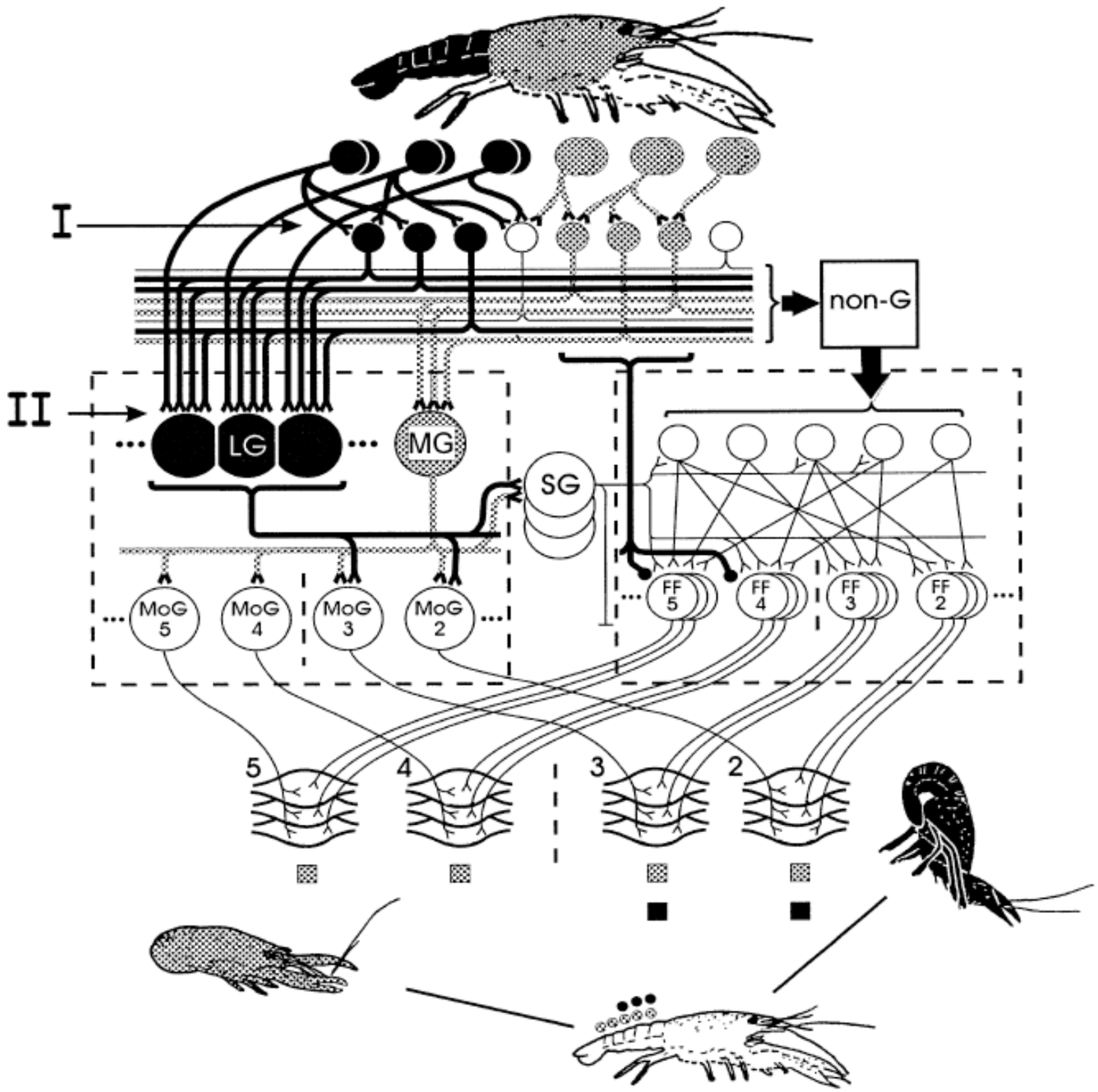


Herberholz et al. 2004

Tail flip escape responses

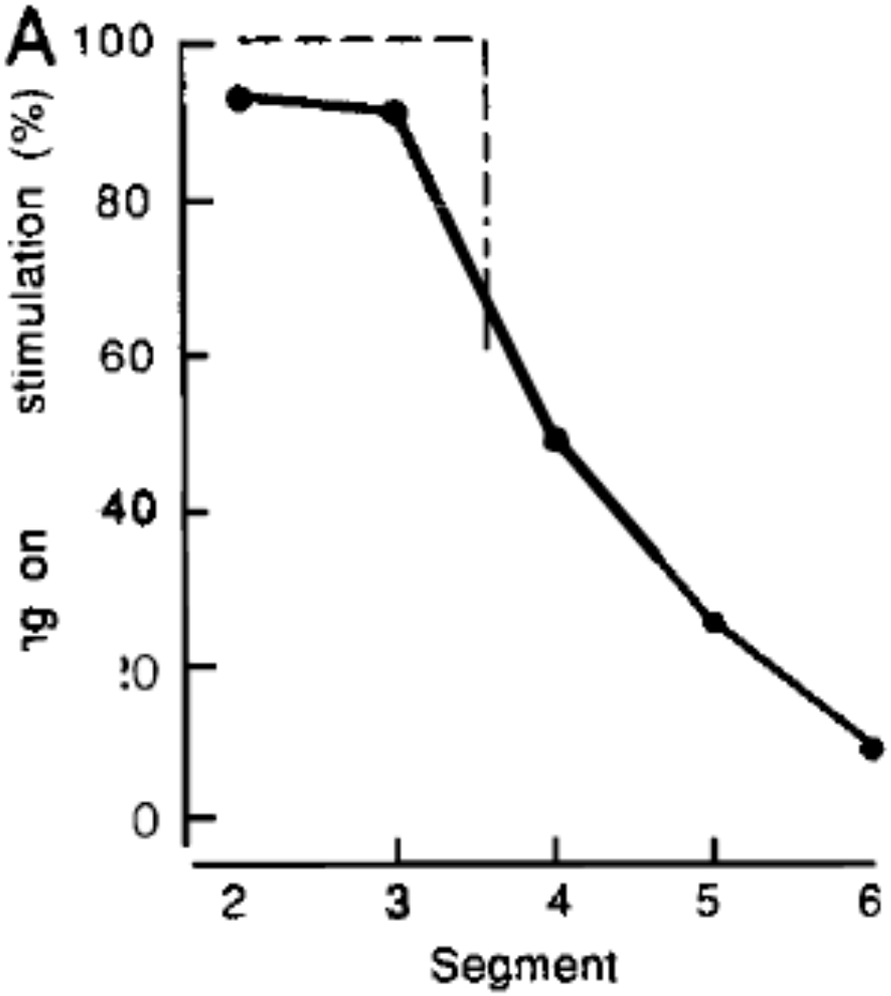


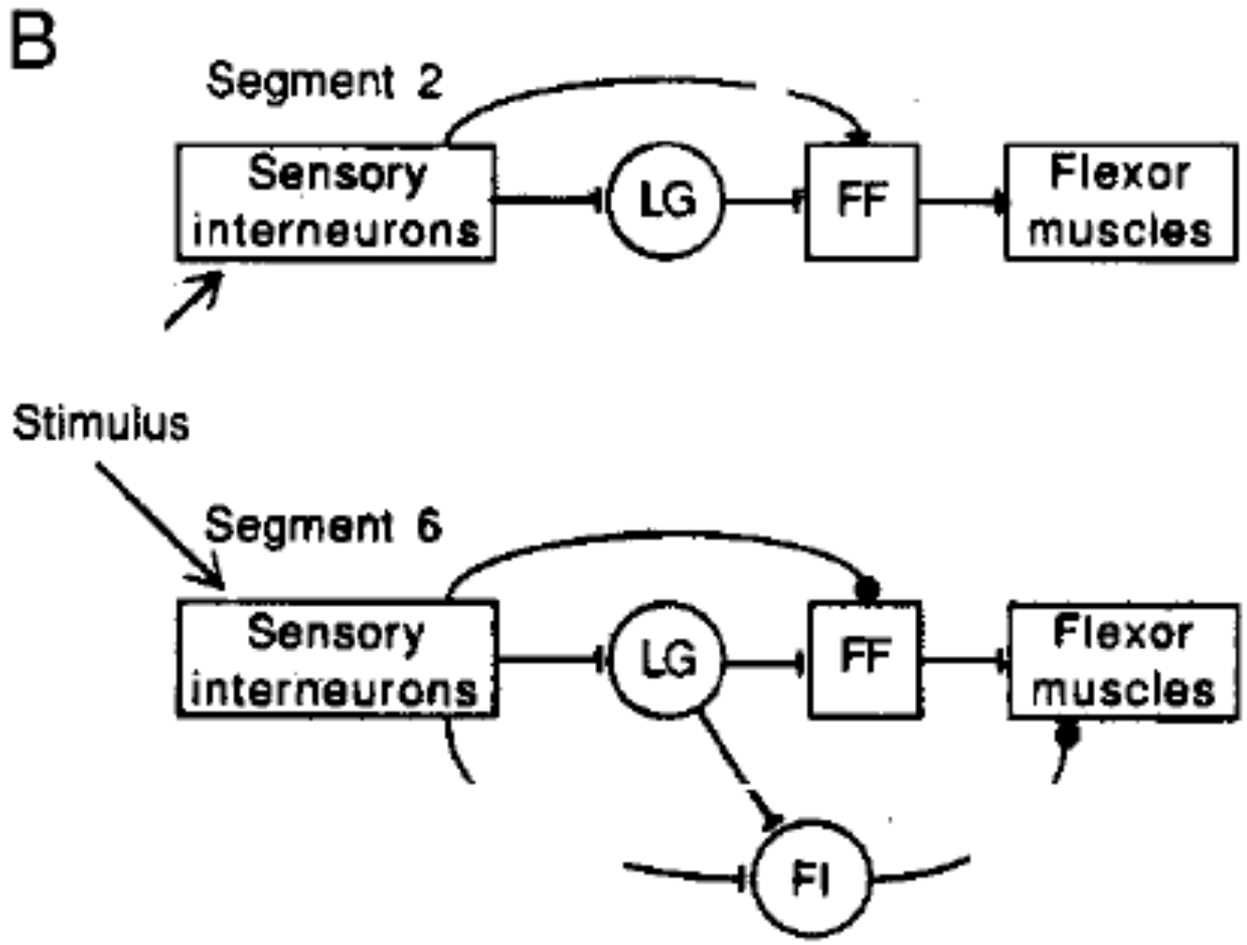
Lateral giant neuron-mediated escape tail flips



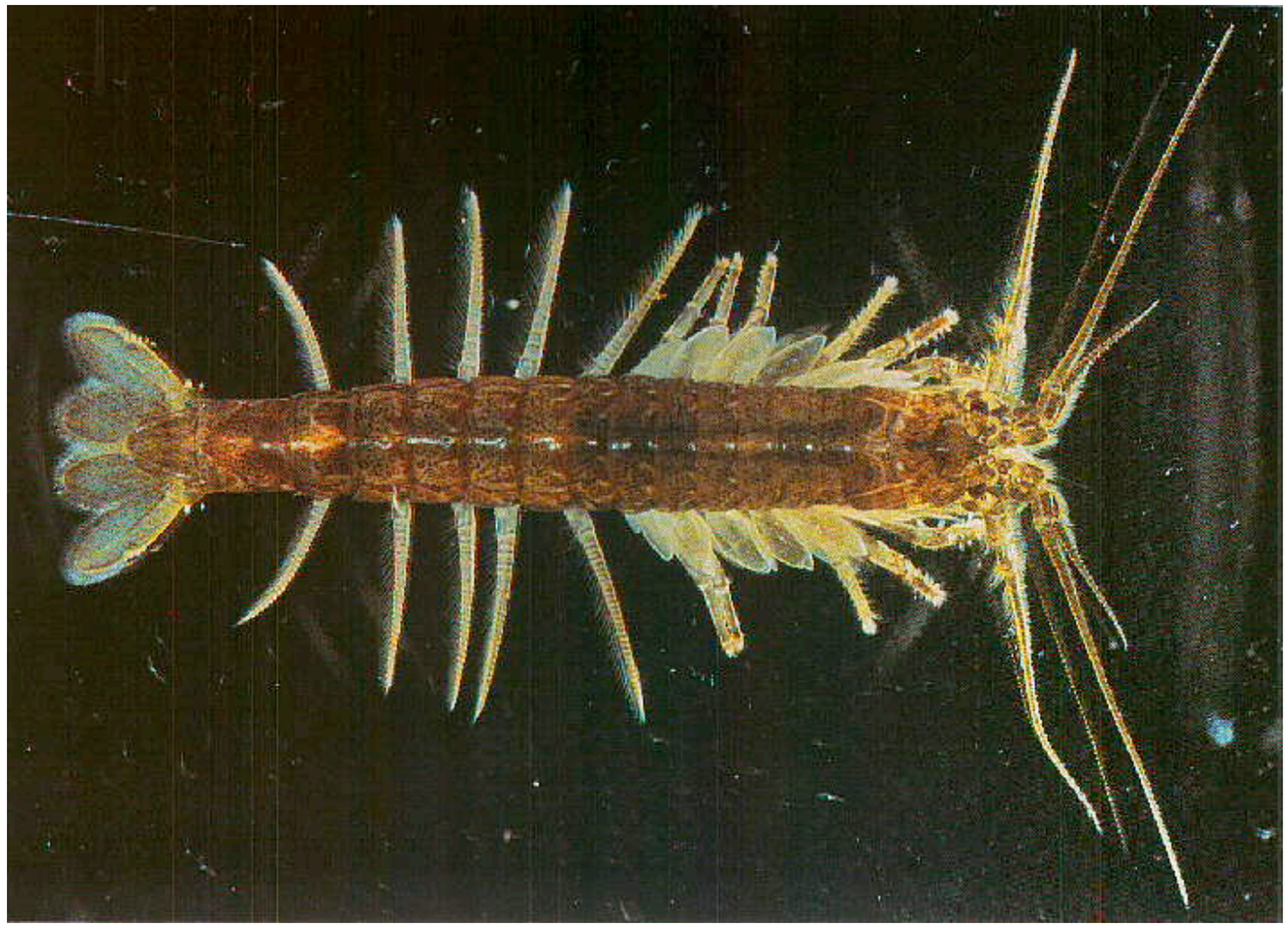
Krasne and Edwards, 2002

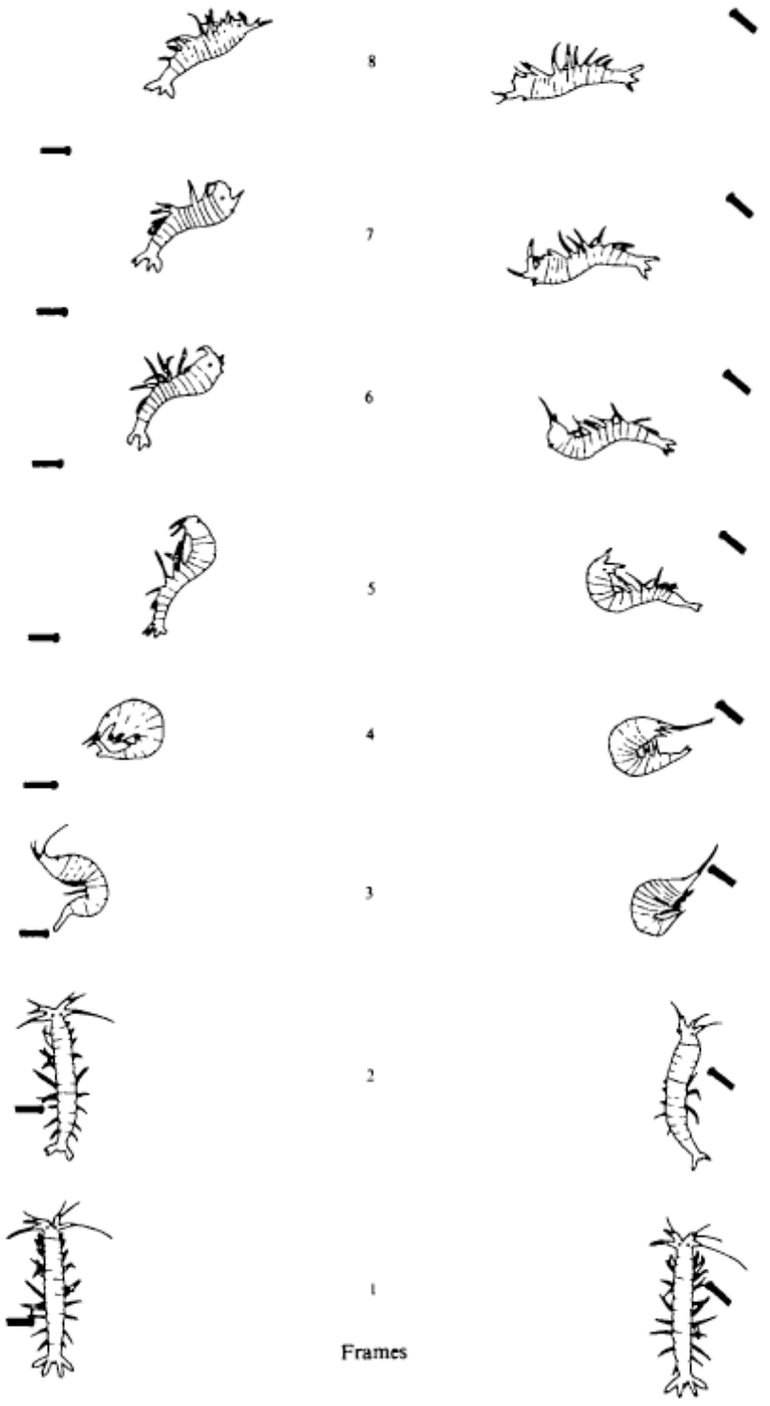
LG-mediated tail flip





Anaspides - a living fossil





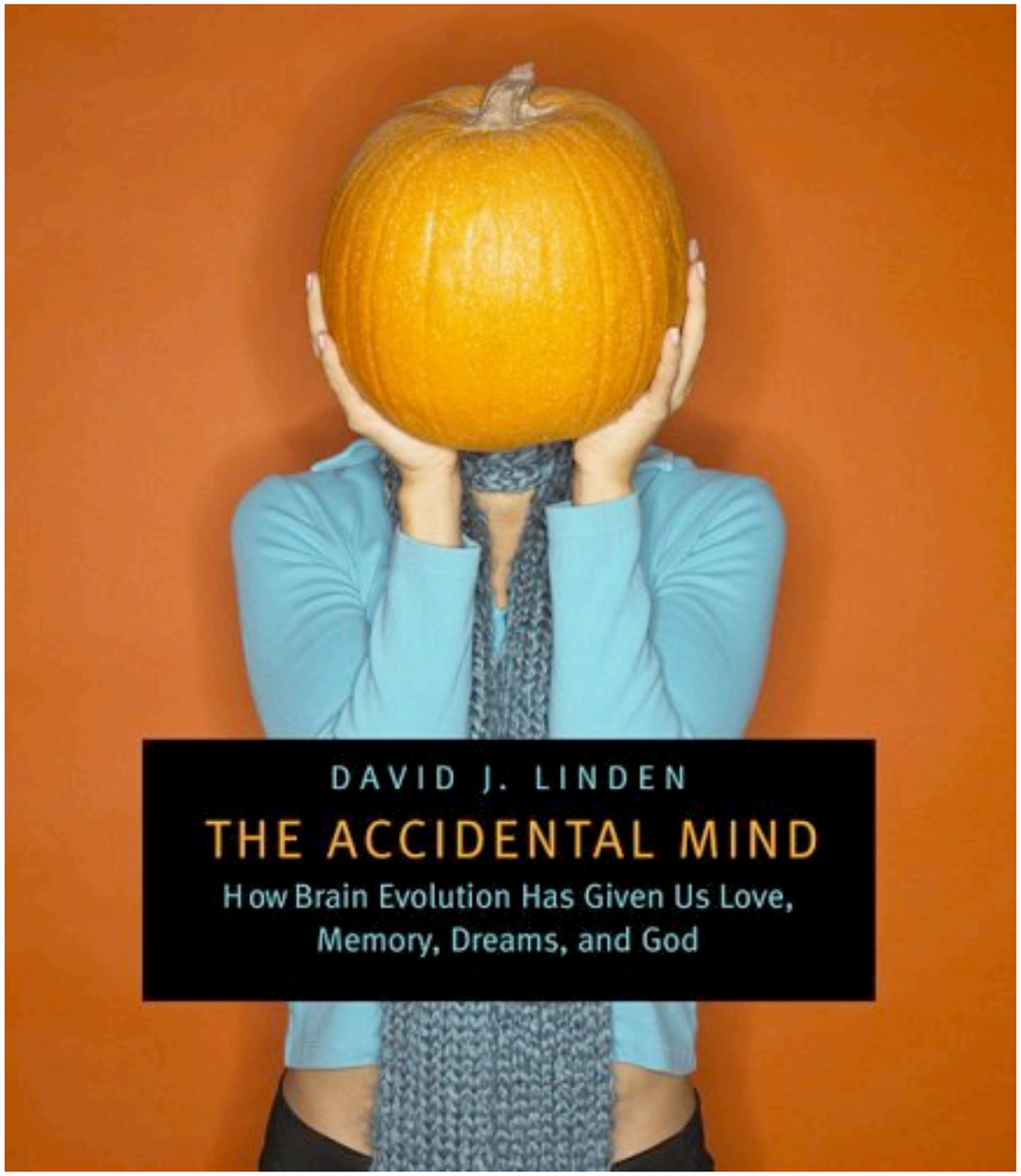
Silvey and Wilson 1978

How should we interpret structure and function in neural circuits?

1. Certain features of neural circuits may not have significance
2. Evolution does not work logically or with long-term perspective
3. Broad impact of genetic change on developmental processes is likely to have both beneficial and deleterious consequences

Take home messages

1. Many organizational features of circuits are not functional but represent developmental, historical or architectural limits
2. Comparative studies may be the best way to determine whether circuit features are functionally necessary
3. Existing but functionless circuit elements may subserve future functions after further evolution but that is not why they exist



.....at every level of brain organization, from regions and circuits to cells and molecules, the brain is an inelegant and inefficient agglomeration of stuff, which nonetheless works surprisingly well.....In many cases, the brain adopted solutions to particular problems in the distant past that have persisted over time and have been recycled for other uses or have severely constrained the possibilities for further change. In the words of the pioneering molecular biologist Francois Jacob, "Evolution is a tinkerer, not an engineer."

The brain is Jerry-rigged

- **Definition of *JERRY-RIGGED***

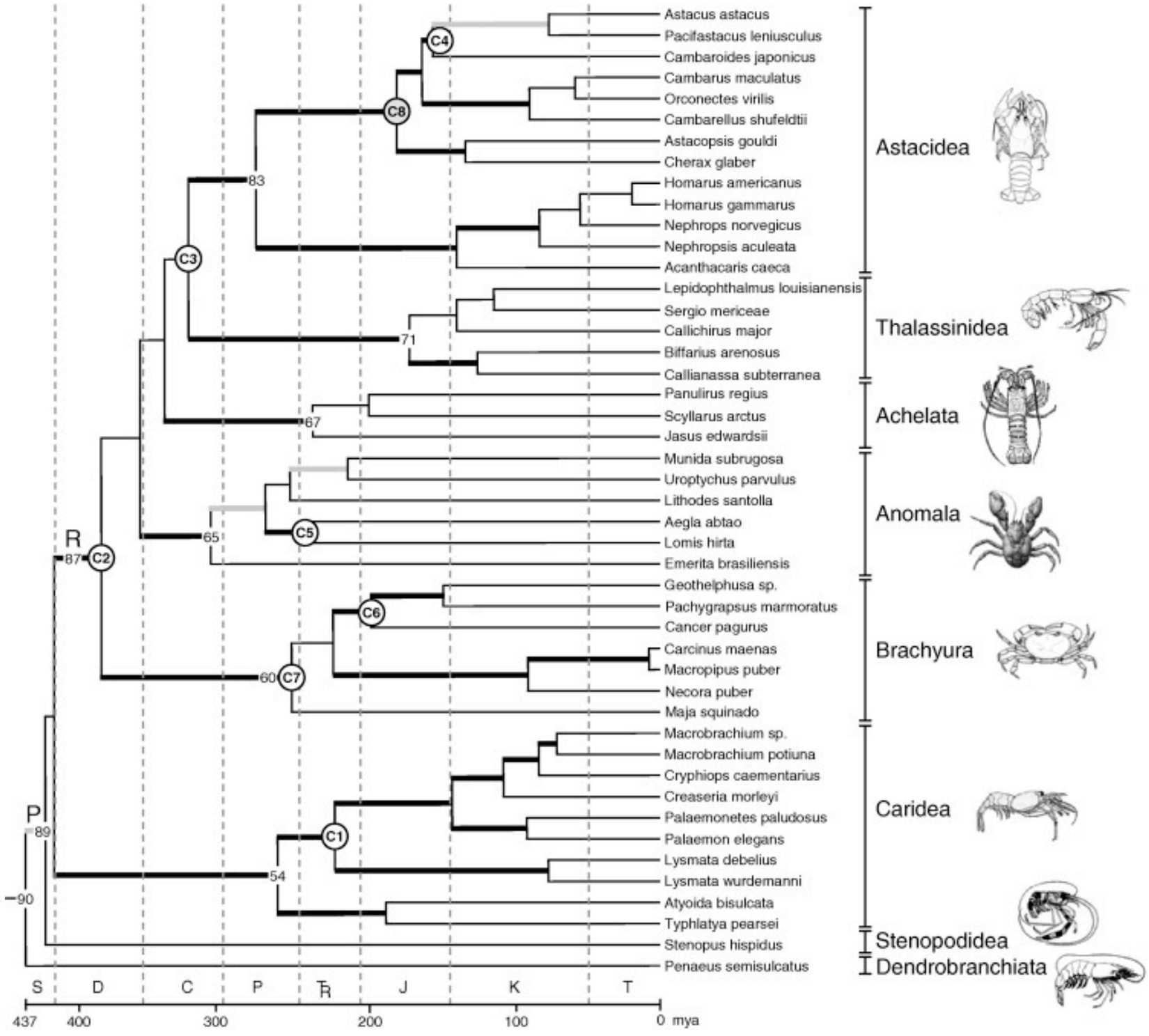
: organized or constructed in a crude or improvised manner
<a *jerry–rigged* plan>

probably blend of *jerry-built* and *jury-rigged*
First Known Use: 1959

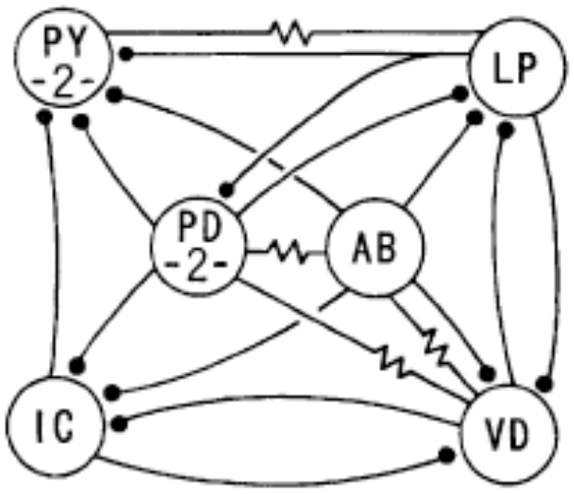
The evolution of neuronal circuits underlying species-specific behavior

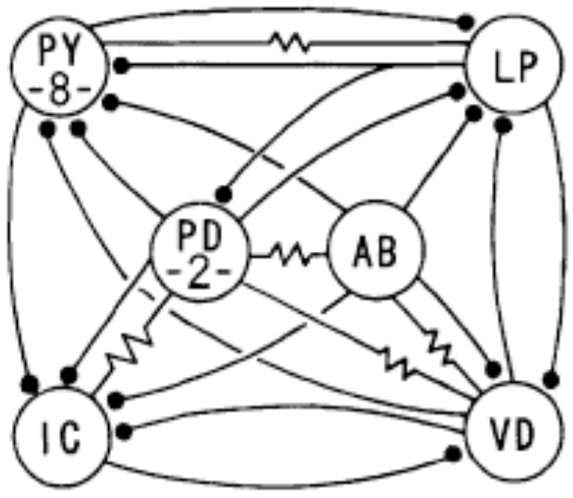
Paul S Katz* and Ronald M Harris-Warrick†

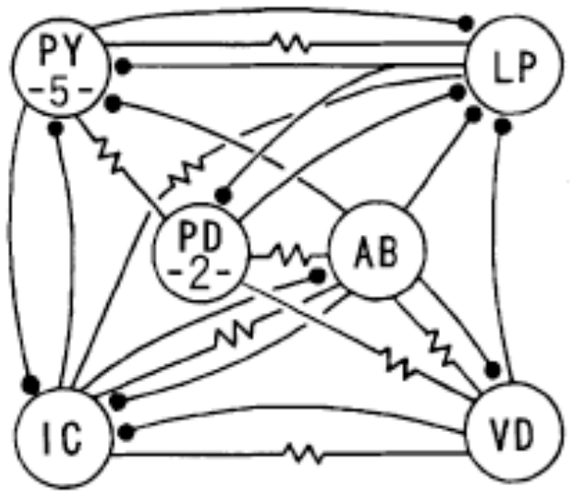
Decapod phylogeny (covers ~400my of evolution)



Pyloric CPGs very similar across distantly related Decapods







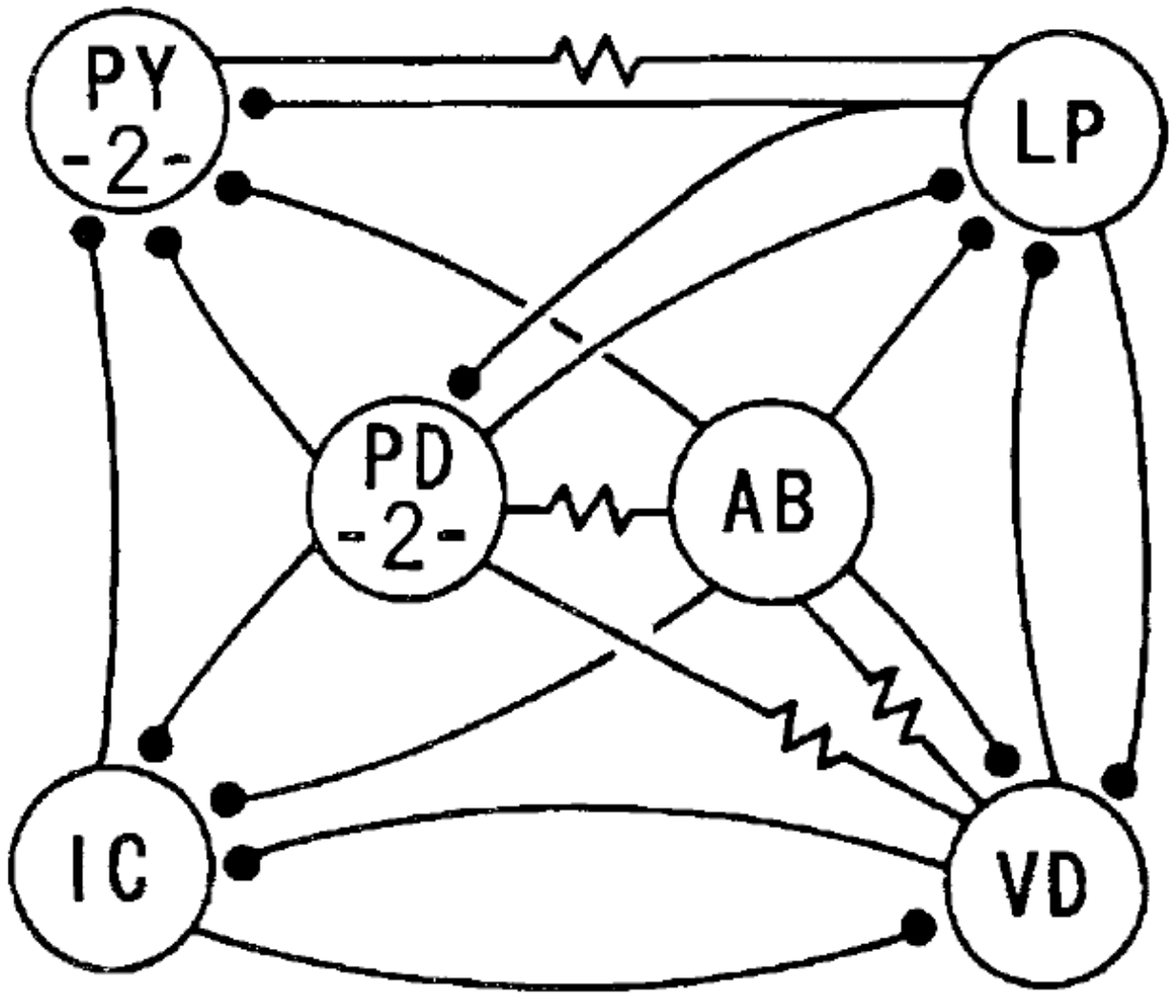
Shrimp Lobster Crab

Tazaki and Tazaki, 1997

Developmentally plausible routes of change

Number

Synaptic strength



Neuromodulators

Switch in transmitters

Circuit wiring has remained stable throughout decapod evolution but function varies greatly

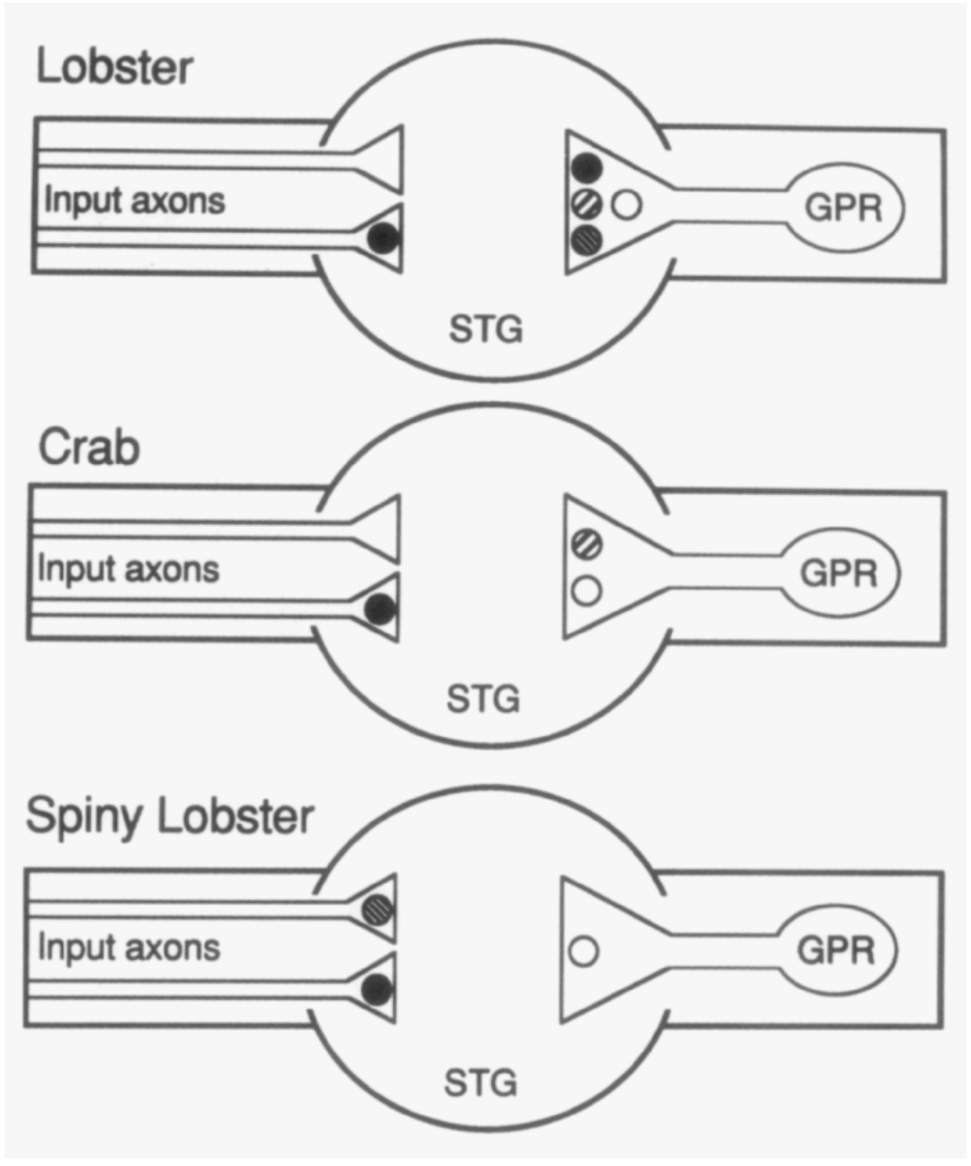
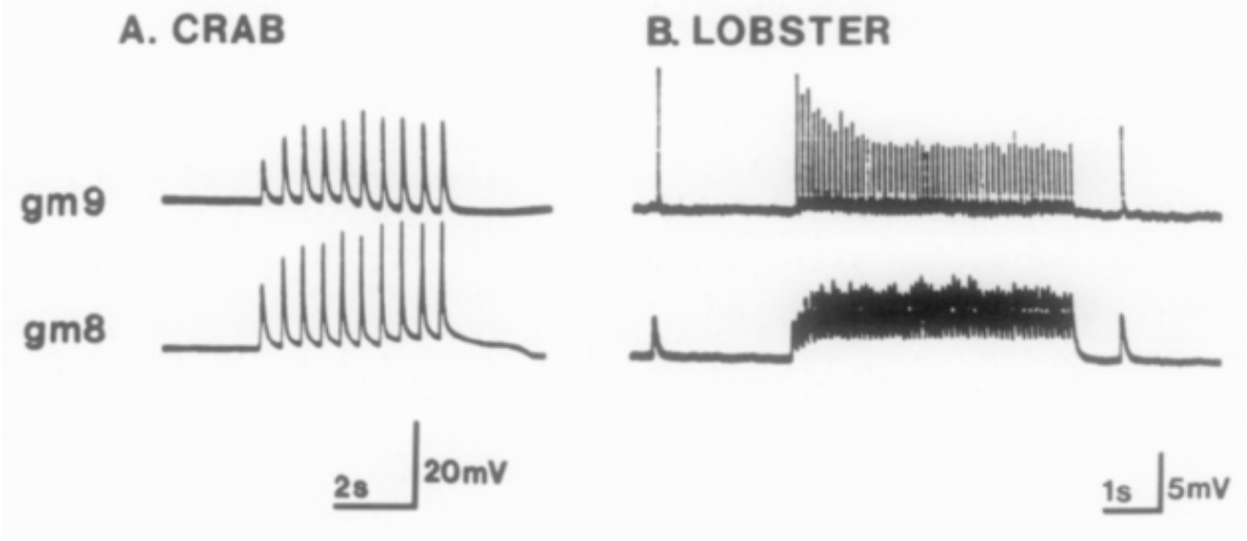


Table 1. The effect of serotonin on pyloric neurons

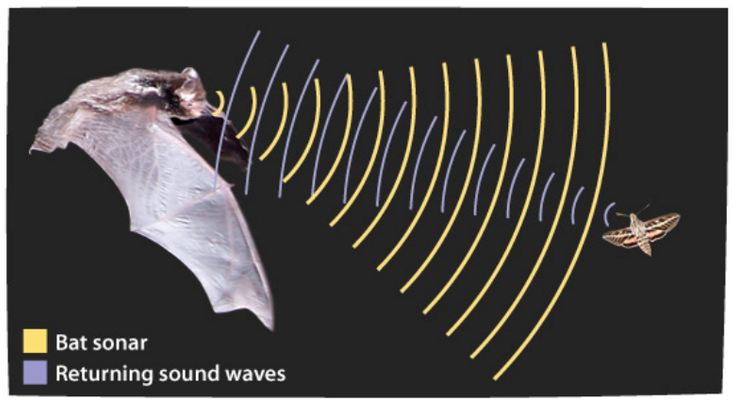
	Neuron		
Species	LP	PY	VD
Spiny lobster	Inhibit	No effect	Inhibit
Crab	Excite	Inhibit	No effect

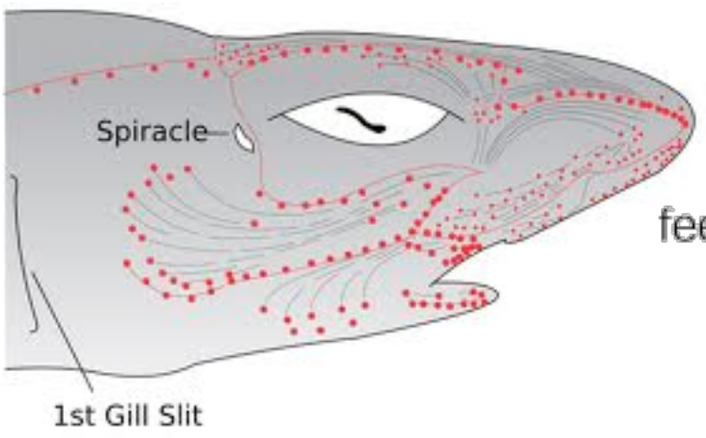


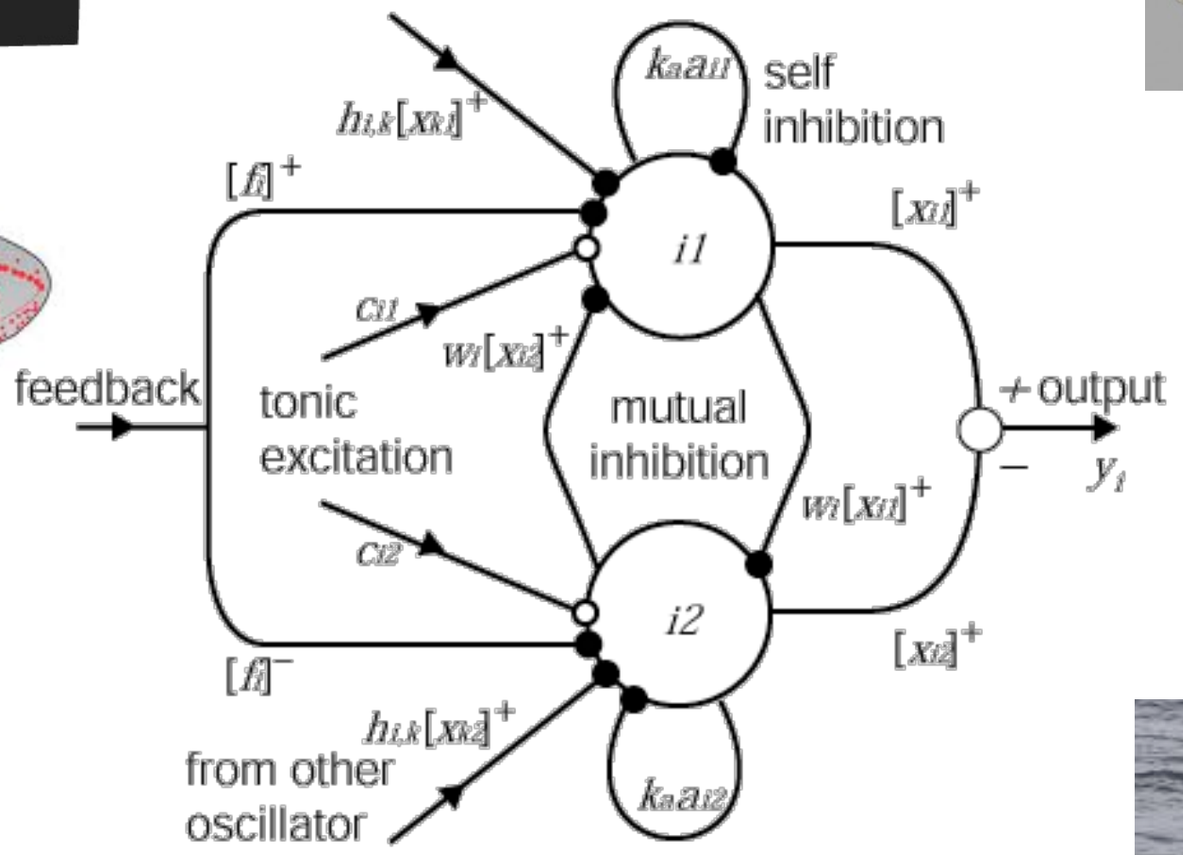
○ Acetylcholine
⊘ Serotonin
● FMRFamide-like peptide
◍ CCK-like peptide

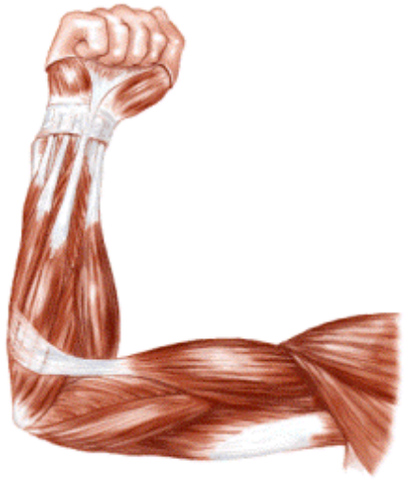
Katz 1991

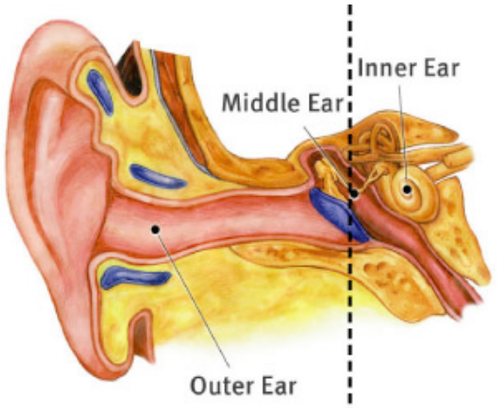
Change can occur within circuits but may occur more readily within sensory/motor appendages



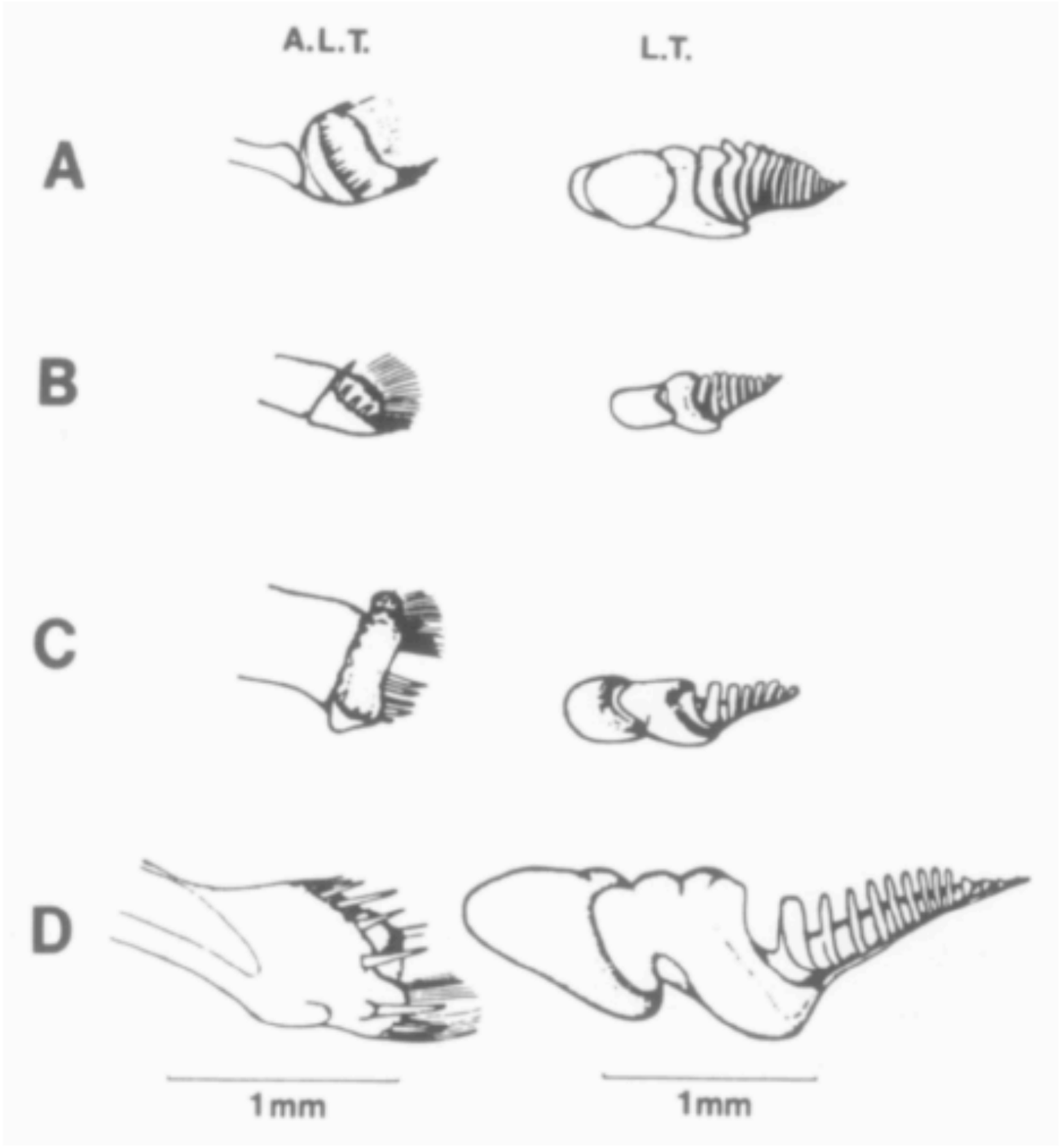








4 species of hermit crab - far more adaptation evident in teeth than pyloric circuit



Katz 1991

CPGs in mammals

White tailed deer (Odocoileus Verginianus)

Sprinting

Mule deer (Odocoileus Hemionus)

Stotting

Hindlimb head scratching