Central Regulation of Autonomic Reactions to Stress: *A Polyvagal Perspective*

Stephen W. Porges, Ph.D.
Brain-Body Center
University of Illinois at Chicago
sporges@uic.edu

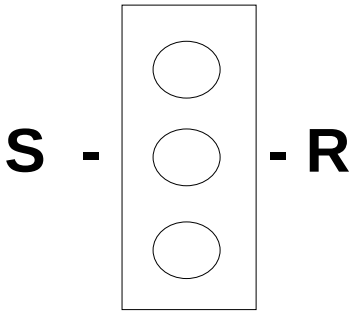
Acknowledgments

❖ **Special thanks to:**
- » C. Sue Carter, PhD
- » John Denver, PhD
- » Keri Heilman, PhD
- » Olga Bazhenova, PhD
- » Elgiz Bal, MA
- » Emily Harden, BA
- » Mika Handelman, BA
- » Senta Furman, BS
- » Greg Lewis, BA

❖ **Funding provided by:**
- » NIMH Grant MH-60625, MH-67446
- » NLMF Family Foundation
- » Unicorn Children's Foundation
- » Cure Autism Now

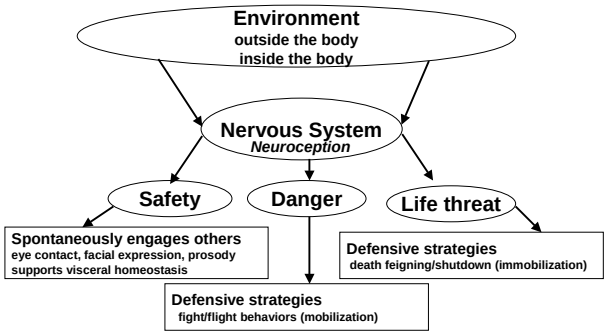
❖**Metaphor**

Physiological State Colors our Perception



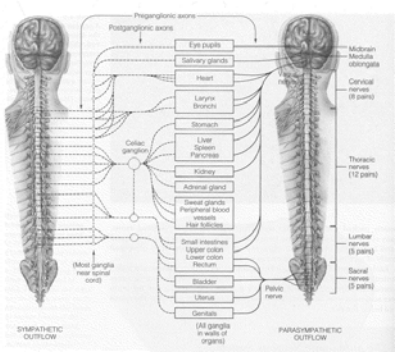
Physiological State

The Quest for Safety:
Emergent Properties and Adaptive Functions of Autonomic States



Limitations of a 2-D Perspective in a 3-D World

The Autonomic Nervous System:
A paired antagonism perspective



The Autonomic Nervous System:
A paired antagonism perspective

Gaskell (1916) *The involuntary nervous system*

Langley (1921) *The autonomic nervous system*

Meyer & Gottlieb (1926) *Experimental Pharmacology as a basis for therapeutics.*

The Autonomic Nervous System:
Integrative Perspectives

Emphasis on the features of a "system"

- Feedback
- Efferents
- Afferents
- Central regulation
  - Source nuclei in the brainstem
  - Relation with other cranial nerves
  - Influence on and mediation by CNS structures

The Autonomic Nervous System:
Integrative Perspectives

Hess (1949) *The central control of the activity of internal organs.*

Benarroch (1993) *The central autonomic network: functional organization, dysfunction, and perspective.*

Porges (1995) *Orienting in a defensive world: Mammalian modifications of our evolutionary heritage. A Polyvagal Theory.*

Thayer & Lane (2000) *A model of neurovisceral integration in emotion regulation and dysregulation.*

❖**Polyvagal Perspective – Levels of inquiry**

Polyvagal Perspective:
Levels of Inquiry

1. ANS responses as behavior (biofeedback) - conditioning & learning

2. ANS responses as peripheral physiology (traditional physiology, medicine) - autonomic balance

Polyvagal Perspective:
Levels of Inquiry

3. ANS as regulated or influenced by CNS

   a. ANS responses as correlates of psychological processes and psychiatric disorders (behavioral medicine, psychophysiology, psychosomatic medicine) – heart rate reactions, rhythms

   b. ANS responses regulated (bidirectional) by CNS (neuroanatomy, neurophysiology) - brainstem source nuclei

4. ANS reactivity as **adaptive** and dependent on the phylogeny of the neural circuits (polyvagal theory)

❖**Theory**

» **Phylogenetic shifts in the neural regulation of the vertebrate ANS**

Overview: The Polyvagal Theory

1. Evolution provides an *organizing principle* to understand neural regulation of the human autonomic nervous system.
2. Three neural circuits form a phylogenetically-ordered response hierarchy that regulate behavioral and physiological adaptation to safe, dangerous, and life threatening environments.
3. The development of these circuits parallels the phylogenetic sequence observed in vertebrates.
4. *"*Neuroception*"* of danger or safety or life threat trigger these adaptive neural circuits.
5. New models relating neural regulation to health, learning, and social behavior may be reversed- engineered into treatments.

Evolution

Neural Regulation of the Heart in Vertebrates

	CHM	DMX	SNS	AD/m	NA
Cyclostomes	X+				
Elasmobranchs	X+	X-			
Teleosts	X+	X-	X+		
Amphibians	X+	X-	X+		
Reptiles	X+	X-	X+	X+	
Mammals	X+	X-	X+	X+	X-

Polyvagal Theory:
Phylogenetic Stages of Neural Control

Stage	ANS Component	Emergent Behavioral Functions
III	Myelinated vagus ***(VVC – ventral vagal complex)***	Social communication, self-soothing and calming, inhibit sympathetic-adrenal influences
II	Sympathetic-adrenal system ***(SNS – sympathetic nervous system)***	Mobilization (active avoidance)
I	Unmeyelinated vagus ***(DVC – dorsal vagal complex)***	Immobilization (death feigning, passive avoidance)

Polyvagal Theory:
Emergent "Emotion" Subsystems

	VVC	SNS	DVC
heart rate	+ / -	+	-
bronchi	+ / -	+	-
gastrointestinal		-	+
vasoconstriction		+	
sweat		+	
adrenal medulla		+	
tears	+ / -		
vocalization	+ / -		
facial muscles	+ / -		
eyelids	+ / -		
middle ear muscles	+ / -		

The Polyvagal Theory

1. Phylogenetic changes in the neural regulation of the vertebrate ANS
2. Two vagal circuits
   a. Unmyelinated vagal pathways originating in the dorsal nucleus of the vagus, muscarinic preganglionic
   b. Myelinated vagal pathways originating in the nucleus ambiguus, nicotinic preganglionic
3. A face-heart connection
   a. Interaction between the regulation of the myelinated vagus and the striated muscles of the face and head forming an integrated "social engagement system"
   b. Activation of the "social engagement system" can calm and trigger states associated with "growth, health, and restoration."

❖**Theory**

» Phylogenetic shifts in the neural regulation of the vertebrate ANS

» **Dissolution – phylogenetically organized response hierarchy**

Dissolution: Definition

The higher nervous arrangements inhibit (or control) the lower, and thus, when the higher are suddenly rendered functionless, the lower rise in activity

John Hughlings Jackson

Dissolution: Hierarchical Model

- ❖ **Disease**
- ❖ **Trauma**
- ❖ ***Behavioral* Strategies**

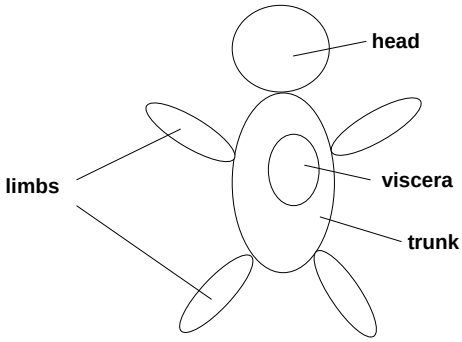
Dissolution: Polyvagal Response Strategies

- Removal of a safety circuit ("new" vagus and muscles of the face and head) to promote a precautionary hypervigilance in preparation of danger (i.e., predator).
- Stimulation of the mobilization circuit (increases in sympathetic tone) to facilitate fight/flight behaviors.
- Adaptive surge in the immobilization circuit ("old" vagus) to raise pain thresholds, conserve metabolic resources, and to prepare for death.

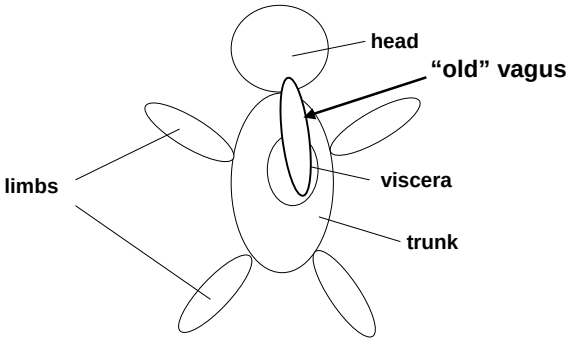
Polyvagal Theory:
A Phylogenetic Hierarchy of Response Strategies

Structure	Function	VVC	SNS	DVC
Head	Communication	+		
Limbs	Mobilization		+	
Viscera	Immobilization			+

Phylogenetic Organization of the ANS: The Polyvagal Theory



Phylogenetic Organization of the ANS: The Polyvagal Theory

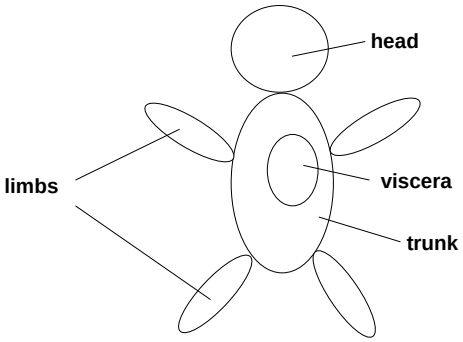


Vasovagal Syncope

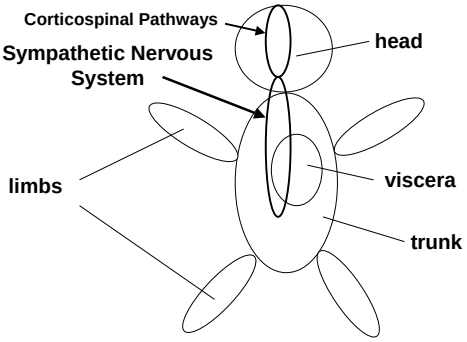
Apnea/Bradycardia

Bush Following Fainting Spell: "Chew your food"

Phylogenetic Organization of the ANS: The Polyvagal Theory

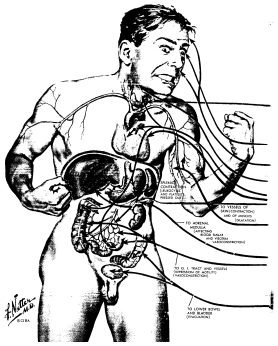


Phylogenetic Organization of the ANS: The Polyvagal Theory



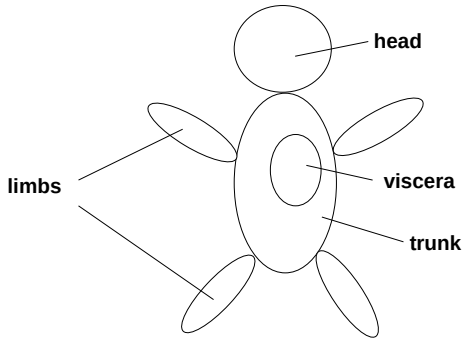
Mobilization: Flight Behaviors

Mobilization: Fight Behaviors

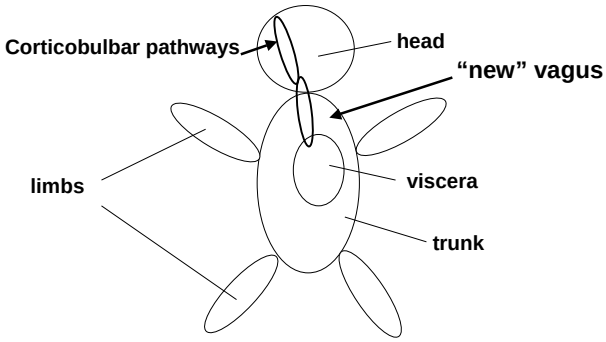


Mobilization: Fight/Flight Behaviors

Phylogenetic Organization of the ANS: The Polyvagal Theory



Phylogenetic Organization of the ANS: The Polyvagal Theory



Social Engagement

© Jeff Hunter/ The Image Bank

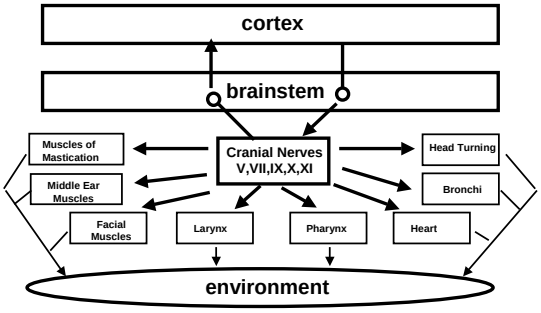
People Need People:
A Biological Basis for Social Behavior

Regulators of physiology are "embedded" in relationships

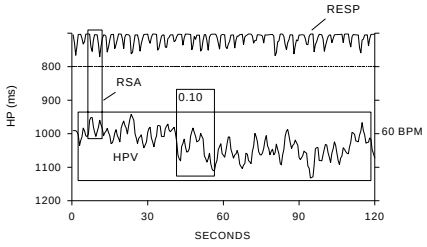
❖**Theory**

- » Phylogenetic shifts in the neural regulation of the vertebrate ANS
- » Dissolution – phylogenetically organized response hierarchy
- » **Social Engagement System**

The "*Mammalian*" Vagus is Linked to the Neural Regulation of the Face:
Forming a Social Engagement System



Heart Rate Rhythms: A Method to Quantify NA (Myelinated) Vagal Influences



The Heart-Face Connection:
A Critical Component of a Social Engagement System

• At birth the mammalian nervous system needs a "caregiver" to survive and signals the caregiver via the muscles of the face and head.

• At term the corticobulbar pathways that regulate the striated muscles of the face are myelinated.

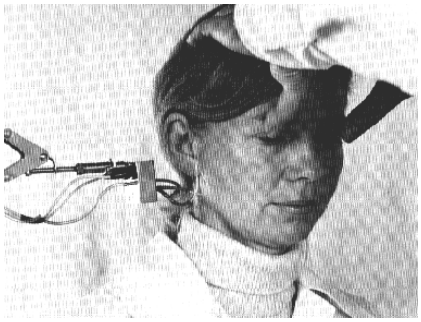
• The face is "hardwired" to the neural regulation of visceral state via a mammalian "neural circuit."

• Metabolic demands, stress, trauma and illness retract the "mammalian" neural circuit with the resultant symptoms of a face that does not work and social engagement behaviors are absent.

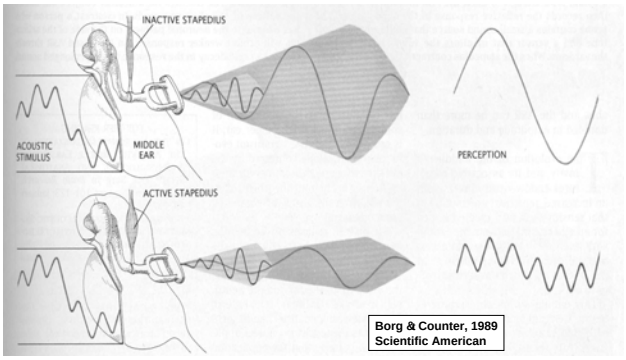
Social Engagement System:
Emergent Behaviors at Birth

Social Engagement System:
Self Regulation

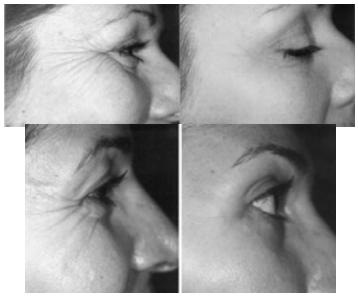
Looking and Listening: Common Neurophysiological Mechanisms



Middle Ear Muscles:
Role in Extracting Human Voice



When the Nervous System Fails Try Botox!



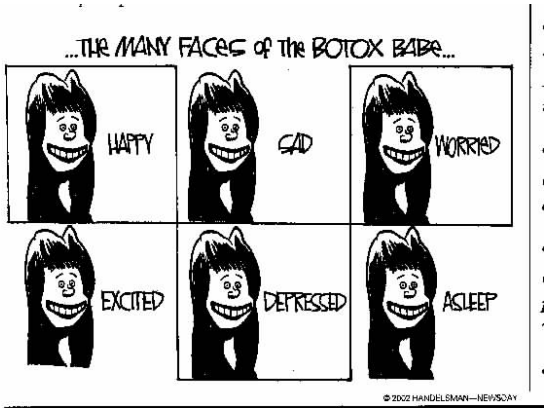
Autism

Social Engagement System:
Observable Deficits in Several Psychiatric and Behavioral Disorders

- Prosody
- Gaze
- Facial expressivity
- Mood and affect
- Posture during social engagement
- State regulation

My Child's Face Does Not Work!

When Other Faces Do Not Work!



❖Metaphor

❖**Theory**

» Phylogenetic shifts in the neural regulation of the vertebrate ANS

» Dissolution – phylogenetically organized response hierarchy

» Social Engagement System

» **<u>Neuroception</u>**

Neuroception

How are the adaptive defensive systems (flight, fight, and freeze), mediated by the amygdala and other limbic structures, inhibited to promote the positive spontaneous social behavior associated with the *Social Engagement System*?

Where in the nervous system are the <u>feature detectors</u> that determine safety?

Neuroception

The important interaction among ***context***, physiological and behavioral state, and mental and physical health.

What are the features that calm our nervous system and promote states of health, growth, and restoration?

Are these the same states that promote social behavior?

Does the media get it right?

The importance of the face-to-face interactions

How do we “feel” when there is a violation of the face-to-face interactions?

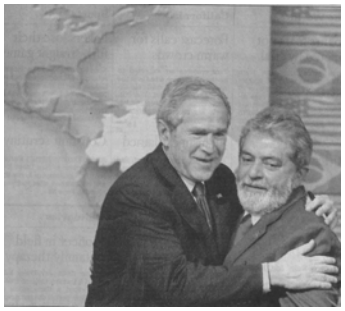
The Lovers I (1928)

Rene Magritte 1898-1967

A Violation of Social Engagement

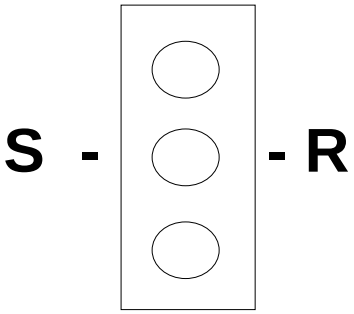
http://www.babyreference.com/nutritionconsultations.htm

President Bush hugs Brazil's Luiz Inacio Lula de Silva

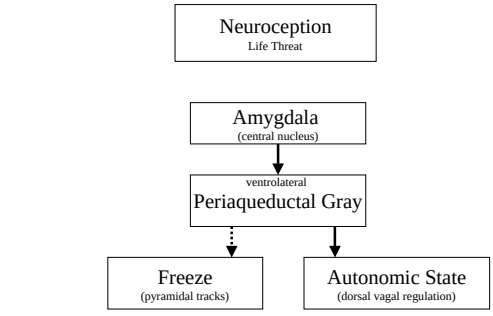


Survivors of Hurricane Katrina were five high in cots yesterday before evacuation from New Orleans.

Physiological State Colors our Perception

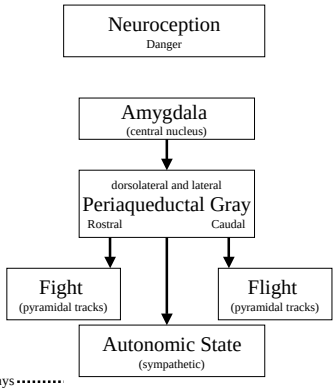


Physiological State



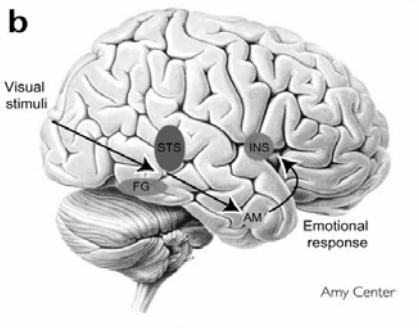
Inhibitory pathways
Excitatory pathways

Vasovagal Syncope

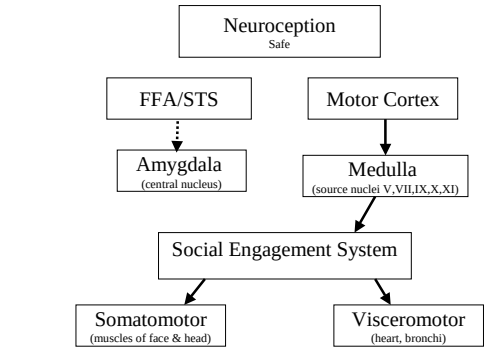


Inhibitory pathways
Excitatory pathways

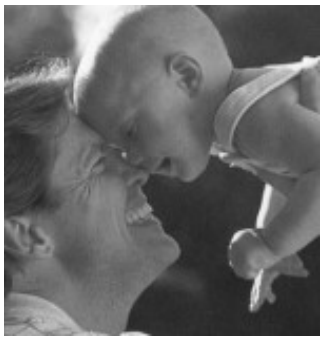
The Trustworthiness of Faces



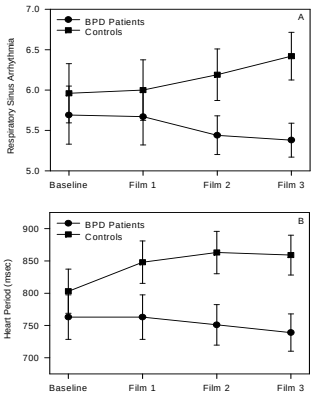
R. Adolphs, 2002



Social Engagement

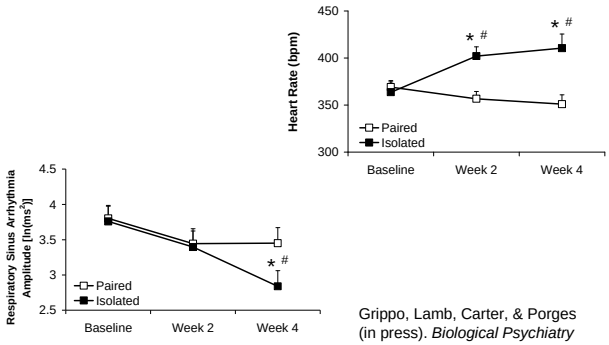


© Jeff Hunter/ The Image Bank



Austin, Riniolo, & Porges, 2007
Brain and Cognition, 65, 69-76.

Isolation Decreases Vagal Influences on the Heart



Grippo, Lamb, Carter, & Porges (in press). *Biological Psychiatry*

Immobilization With Fear

Voodoo Death: Insights into PTSD

- Voodoo Death was defined as death due not disease or injury, but do to emotional stress.
- Cannon assumed that even this "immobilized" response would be associated with increased sympathetic nervous system excitation.
- "If in the future, however, any observer has opportunity to see an instance of *voodoo death*, it is to be hoped that he will conduct the simpler tests before the victim's last gasp."

Cannon, W.B. (1942) "Voodoo" death. Amer. Anthropol., **44**: 169.

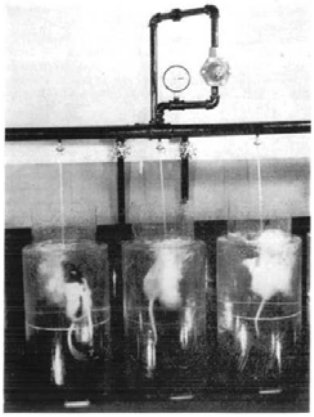


Fig. 1. Glass swimming jars, water jets, cold and hot water faucets, pressure gauge, and pressure regulator.

Hopelessness: Vagal or Sympathetic Mechanisms?

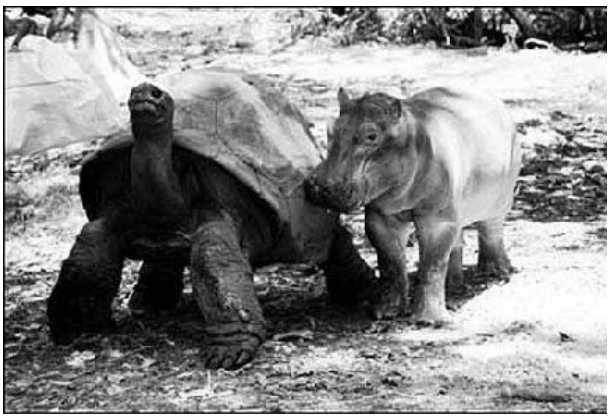
"...we believe that human victims, like our rats, may well die a parasympathetic rather than a sympathico-adrenal death, as Cannon postulated"

C.P. Richter (1957)

Mobilization Without Fear

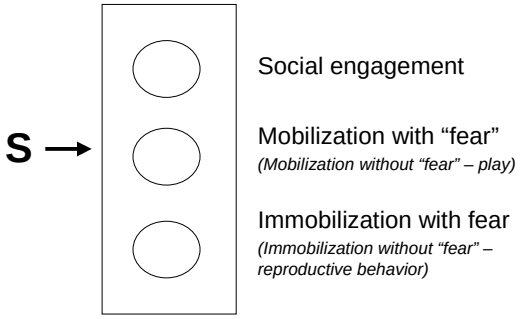
Immobilization Without Fear

Mammal-Reptile Interactions: Immobilization without fear



Neuroception:

Physiological States and Emergent Behaviors



Summary

- Autonomic reactions to challenges are organized in a phylogenetically-determined hierarchy.
- "*Neuroception*" of safety or danger or life threat trigger adaptive autonomic reactions.
- The phylogenetically recent mammalian vagus is neurophysiologically and neuroanatomically linked to the regulation of the striated muscles of the face and head forming an integrated Social Engagement System.
- Triggering the Social Engagement System has health benefits by dampening stress (e.g., sympathetic-adrenal) responses.