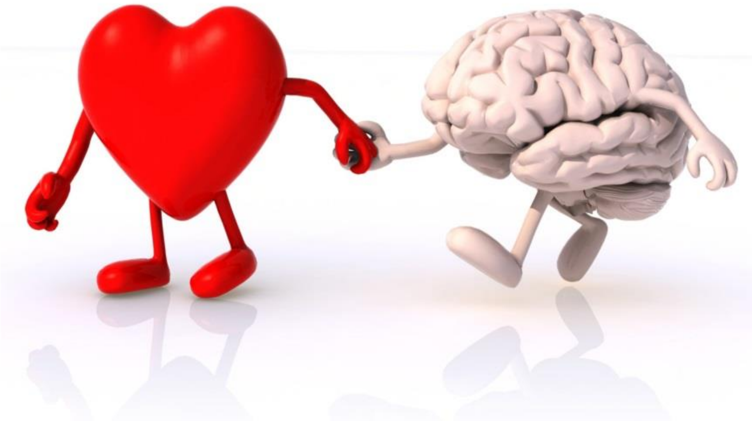
به نام خدا



Heart-Brain Axis

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مغز یا قلب

- قلب مهربان
- قلب پاک
- قلب عاشق
- قضاوت بر اساس رفتار
- مرکز احساس، درک و شناخت و همچنین کنترل رفتار مغز است.

- در عهد باستان ارسطو معتقد بود قلب جایگاه تمامی احساسات است.

- در نیمه دوم قرن ۱۳ میلادی، قلب به‌طور رسمی جایگاه عشق خوانده شد و در تمامی تصاویر مذهبی، قلب مکان مقدس عشق خداوندی معرفی شد.

- در قرن ۱۸ میلادی گرچه علم قلب‌شناسی در حال بال و پر گرفتن بود ولی جایگاه عشق متزلزل نشد تا آنکه سرانجام در قرن ۲۰ میلادی، انسان عشق را احساسی تولید و کنترل شده از سوی مغز دانست.
-
- تحقیقات اخیر نشان داده است که عشق نتیجه واکنش متقابل مغز (مراکز مربوط به غرایز، احساسات و منطق) و قلب است.

- ده‌ها هزار نورون، اطلاعات درونی بدن را به مغز مخابره می‌کنند و در نهایت مرکز مغری با بررسی این اطلاعات دستور بروز عکس‌العمل‌های فیزیکی اتوماتیک یا ارادی را صادر می‌کند.

Heart-Brain Axis

- قلب مطیع دستورات صادر شده از مغز است.

- اما قلب در واقع سیگنال های بیشتری را به مغز ارسال می کند تا مغز به قلب!

- تاثیر قابل توجهی سیگنال های قلبی بر عملکرد های مغزی همچون پردازش حسی و هیجانی و قابلیت های شناختی بالاتر مانند توجه، ادراک، حافظه و حل مسئله

- به عبارت دیگر نه تنها قلب به مغز پاسخ می دهد، بلکه مغز نیز به طور مداوم به قلب پاسخ خواهد داد.

- الگوهای مختلف فعالیت قلب که البته با حالات عاطفی مختلفی نیز همراه هستند، اثرات متمایزی بر عملکرد شناختی و عاطفی دارند.

- هنگام تجربه استرس و احساسات منفی، ریتم قلب نامنظم و به نوعی آشفته می شود. این الگو با ایجاد تغییر در سیگنال های عصبی که از قلب به مغز می رسند، عملکردهای شناختی را هم دستخوش دگرگونی می کند.

- در نتیجه توانایی ما برای تفکر منطقی، به خاطر سپردن، یادگیری، استدلال و تصمیم گیری موثر محدود می شود.

- به همین دلیل است که وقتی تحت استرس هستیم، اغلب ممکن است به صورت غیرعاقلانه رفتار کنیم.

- برعکس الگوی منظم و با ثبات از سیگنال های ارسالی قلب به مغز اثر کاملا متفاوتی خواهد داشت.

- این الگو نه تنها عملکرد شناختی را تسهیل و احساسات مثبت و ثبات عاطفی را تقویت می‌کند، بلکه بر سطح درک، نحوه تفکر، احساس و عملکرد کلی ما نیز تاثیر می گذارد.

- کلمه قلب در قرآن و احادیث بسیار استعمال شده و از اهمیت خاصی برخوردار است؛ اما مراد از قلب، همین جسم صنوبری شکل که در طرف چپ بدن قرار گرفته نیست؛
- زیرا در قرآن چیزهایی به قلب نسبت داده شده که با این جسم صنوبری تناسب ندارد.مثلاً:
۱. علم و تعقل
در قرآن می‌فرماید:«چرا در زمین سیر نمی‌کنید تا قلب‌هایی داشته باشید که با آنها تعقل کنید».(سوره حج، ایه ۴۶)
-
۲. عدم فهم و تعقل
در قرآن می‌فرماید:«آنها قلب‌هایی دارند که با آنها نمی‌فهمند و چشم‌هایی که با آنها نمی‌بینند».(سوره اعراف، ایه ۱۷۹) و می‌فرماید:«بر قلب آنها مهر نهاده شده، پس نمی‌فهمند».(سوره توبه،ایه ۷۸)
-
۳. ایمان
در قرآن می‌فرماید:«خدا در قلب این مردم ایمان را ثبت کرده و با روحی از جانب خودش تاییدشان نموده است».(سوره مجادله، ایه ۲۲)

- کارهایی از قبیل:ایمان، کفر، نفاق، تعقل، فهم، عدم تعقل، تقوا، حسرت، آرامش، تکبر، حسد، عصیان و...، به قلب نسبت داده شده است.

Little Brain

- In many cultures, such as Hebrew, Christian, Chinese, Hindu and Islamic, the heart is considered the source of emotions, desire, and wisdom.

- Dr. J. Andrew Armour, in 1991, first introduced the concept of “heart brain,” “little brain,” or “intrinsic cardiac nervous system.”

- This “heart brain” is composed of approximately 40,000 neurons that are able to sense, feel, learn, and even remember.

- These neurons in the heart are alike the neurons in the brain.

Nerve cells (yellow) that make up a heart's "brain" cluster around the top of this reconstructed rat heart, near where blood vessels enter and exit the organ. Other colors show the contours of distinct heart areas, such as the left atrium (green), right atrium (teal), left ventricle (blue) and right ventricle (purple).
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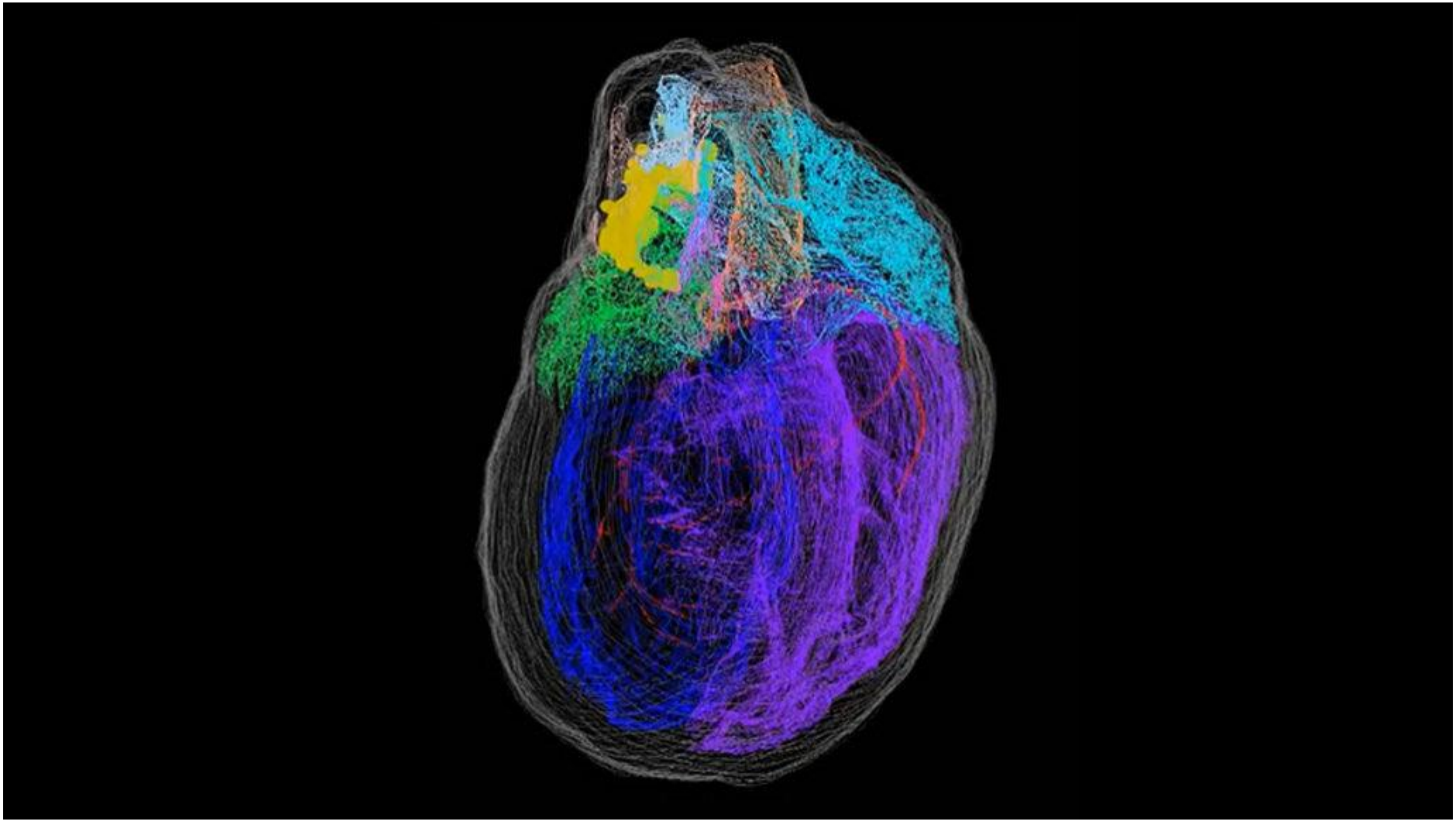


- The intrinsic cardiac neurons can generate spontaneous activity independent of inputs from central and other intrathoracic neurons.

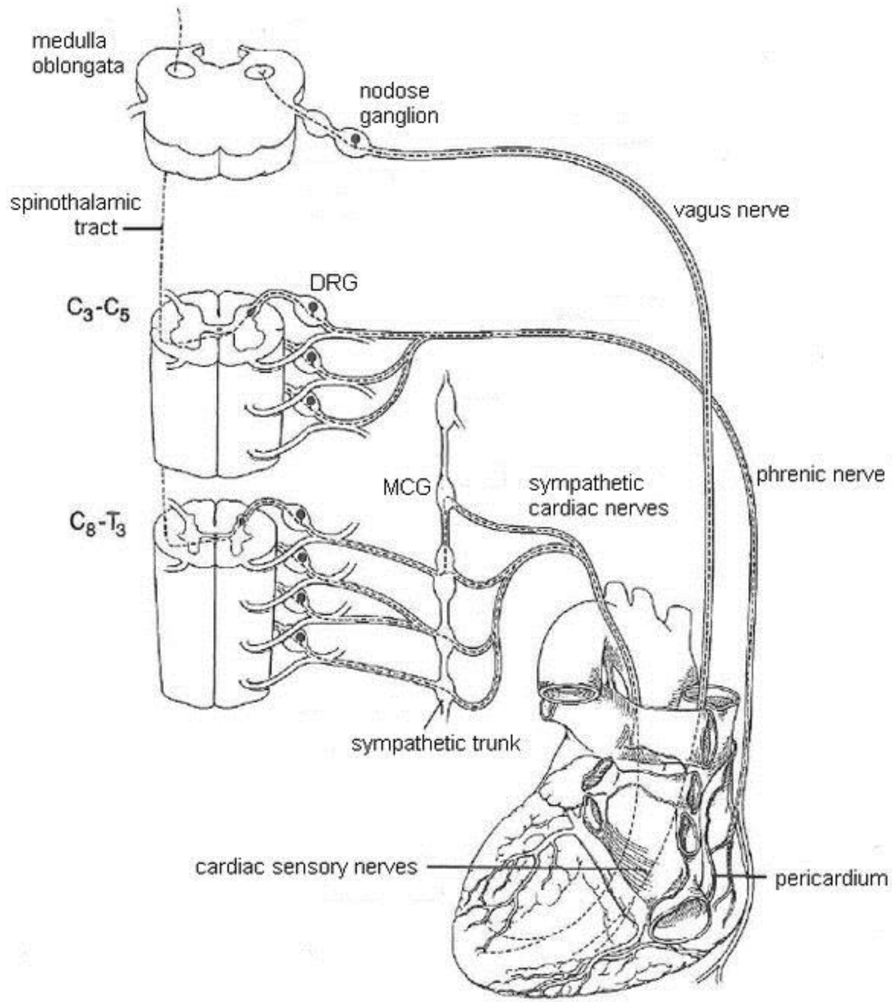
- Thus, the heart has its own nervous system.

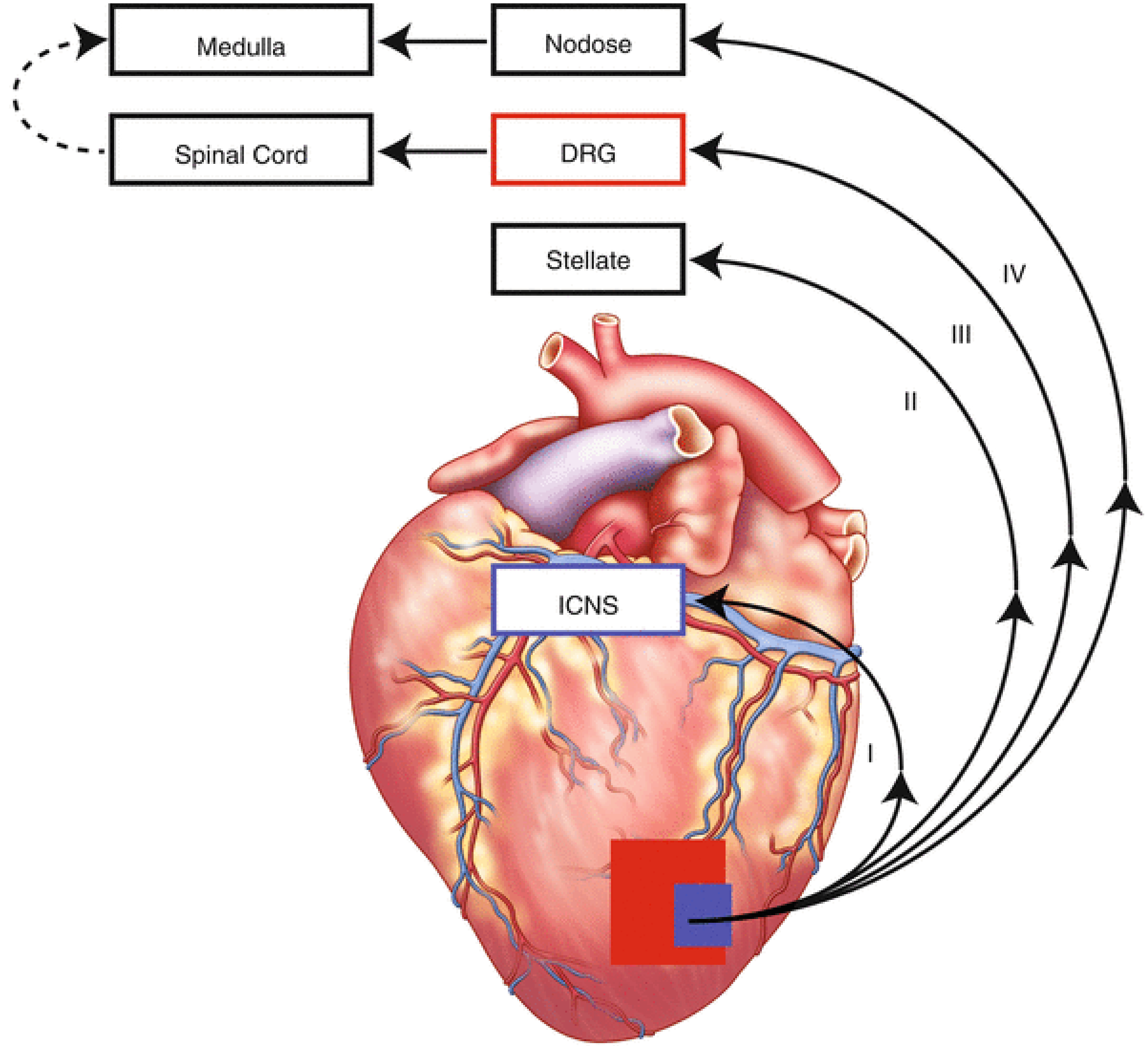
- In this perspective, the heart is a system that is complex and self organized.

- It maintains a constant two-way communication with the brain and the whole body.

Cardiac afferent neurons

- Cardiac afferent neurons are distributed relatively evenly throughout the nodose ganglia and the C7 to T4 dorsal root ganglia bilaterally.
- They are also located in intrathoracic ganglia, including those intrinsic to the heart.

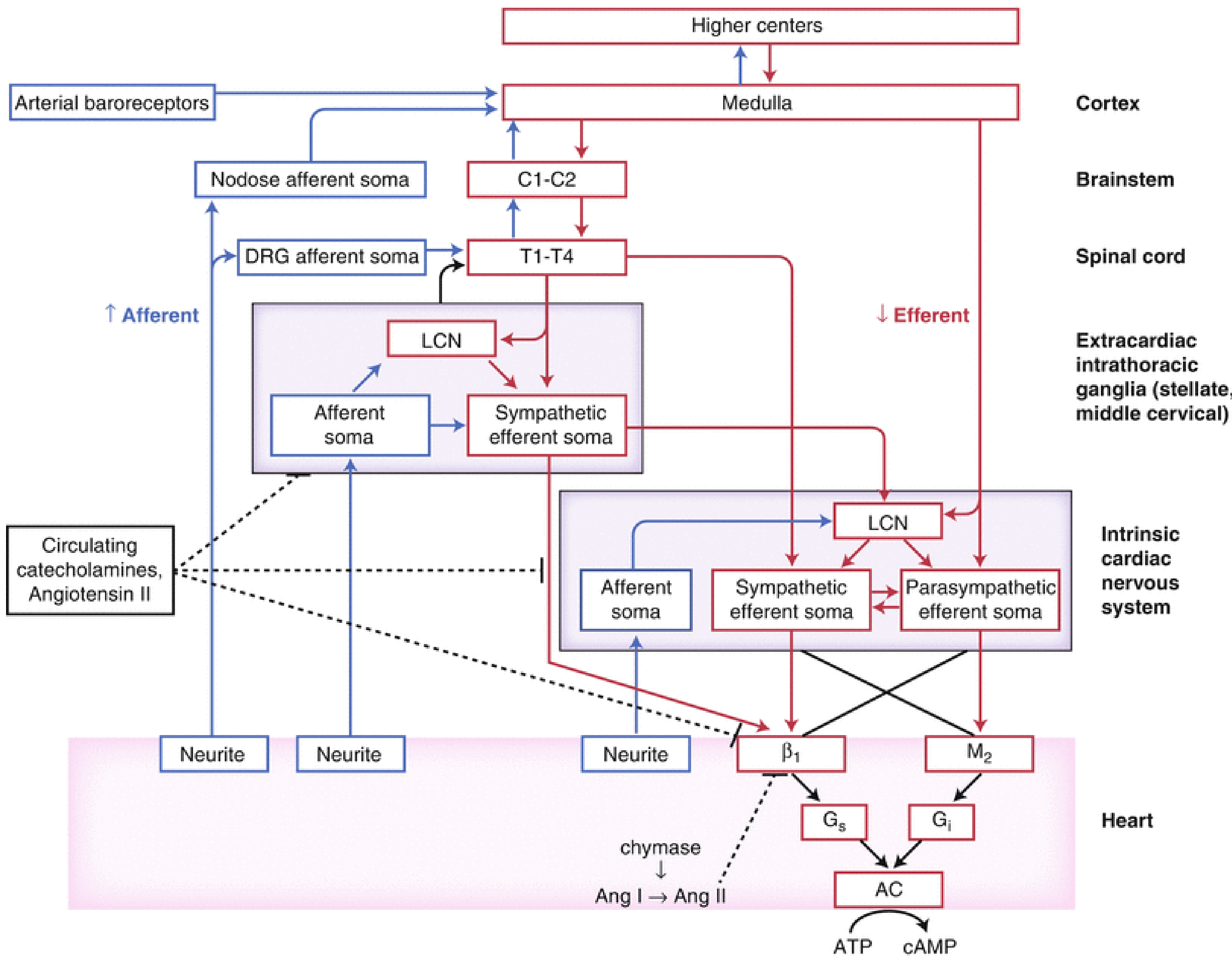




Path	SYNAPSE
I	ICNS
II	Stellate
III	Spinal cord (via DRG)
IV	Medulla (via Nodose)

Cardiac afferents provide beat-to-beat sensory information about cardiac muscle activity to the cardiac autonomic nervous system.

The processing of these afferent neural signals at multiple levels of the hierarchy provides a mechanism for fine-tuned regulation of efferent neural signals in normal and stressed states



Physiology of Cardiac afferent neurons

- The constantly changing cardiac milieu is transduced to neurons distributed throughout the cardiac neuroaxis via a rich variety of cardiac sensory neurons that are located in nodose, dorsal root, and intrathoracic extracardiac and intrinsic cardiac ganglia.

- The activity generated by the sensory neurites (nerve endings) of some neurons depends on regional cardiac or major vascular wall mechanics;

- others transduce the cardiac regional chemical milieu.

- The vast majority of cardiac afferent neurons transduce regional dynamics and/or the local chemical milieu of their neurites.

Physiology of Cardiac afferent neurons

- For instance, about 75% of nodose ganglion cardiac afferent neurons transduce chemical stimuli; fewer (about 35%) display mechanosensory capabilities.

- On the other hand, most dorsal root ganglion cardiac afferent neurons display multimodal (mechanical and chemical) transduction.

- The varied transduction capabilities displayed by these different cardiac afferent neuronal populations results in a regional specific local dynamic and chemical milieu being transduced to second-order neurons throughout the neuroaxis.

- The majority of cardiac sensory neurites associated with afferent neuronal somata in intrathoracic extracardiac and intrinsic cardiac ganglia express multimodal properties.

Physiology of Cardiac afferent neurons

- Apparently, the multimodal transduction capacity displayed by individual dorsal root ganglion cardiac afferent neurons permits this relatively limited population of sensory neurons to transduce multiple cardiovascular signals simultaneously to second-order neurons in the central nervous system.

- Adenosine is released in increasing quantities by the ischemic myocardium.

- Adenosine activates sensory neurites associated with many ischemia-sensitive cardiac afferent neuronal somata.

- In fact, it has been proposed that purinergic dorsal root ganglion cardiac afferent neurons are involved in the genesis of ischemic ventricle symptoms.

- Mechanosensory neurites associated with a significant population of intrathoracic afferent neuronal somata are also present on major intrathoracic vessels, especially along the inner arch of the aorta.

- The latter transduce constantly changing aortic wall dynamics that occur throughout each cardiac cycle, as do carotid artery baroceptor neurons that project to nucleus solitarius neurons.

- These data indicate that multiple populations of intrathoracic and cervical afferent neurons transduce regional vascular dynamics to second-order neurons throughout the neuroaxis, along with the different cardiac afferent neuronal populations described above.

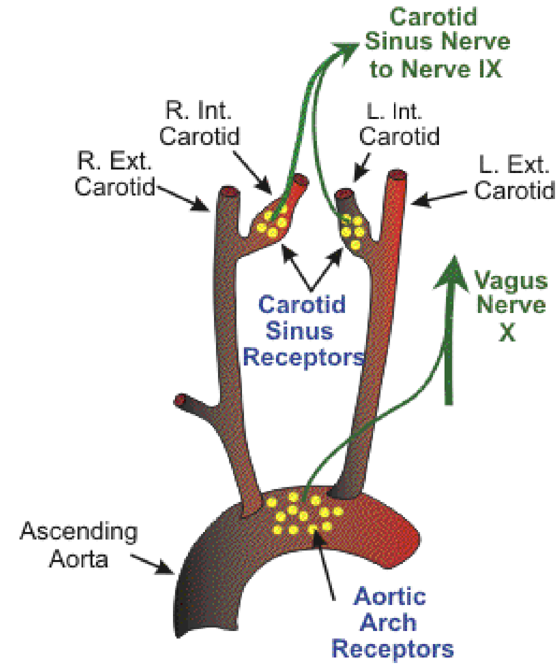


Figure 1. Location and innervation of arterial baroreceptors.

Cardiac efferent neurons

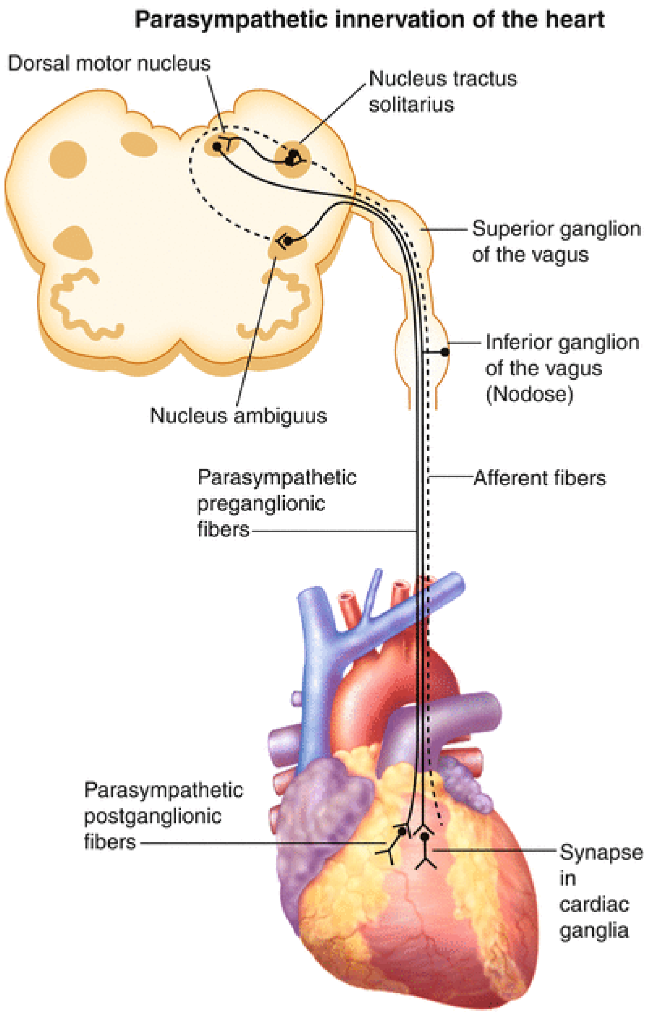
- **Cholinergic neurons.**
- The somata of parasympathetic efferent preganglionic neurons that synapse with cholinergic efferent postganglionic neurons on the heart are located

✓ primarily in the ventral lateral region of the nucleus ambiguous of the medulla;

✓ fewer are found in its dorsal motor nucleus and the zone intermediate between these two medullary nuclei.

- Cardiac preganglionic motor neurons in individual medullary loci project axons to parasympathetic efferent postganglionic neurons distributed throughout each major atrial and ventricular ganglionated plexus.

Cardiac Motor Neurons: Efferent Control of Cardiac Function



- This diagram illustrates the path of parasympathetic nerve fibers to the heart (*solid line*). Parasympathetic preganglionic neurons innervating the heart originate in the nucleus ambiguus and dorsal motor nucleus of the medulla oblongata in the brainstem.

- In contrast to sympathetic preganglionic neurons, parasympathetic preganglionic neurons have long axons and synapse near the target organ.

- Cardiac parasympathetic preganglionic neurons synapse on postganglionic neurons contained within intrinsic cardiac ganglia .
- Postganglionic neurons from these ganglia project axons to widespread regions of the heart .

- Although most efferent nerve fibers contained within the vagus nerve are parasympathetic, sympathetic nerve fibers also have been reported .
- Preganglionic neurons release acetylcholine, which binds to nicotinic acetylcholine receptors on postganglionic neurons.
- Postganglionic neurons in turn release acetylcholine, which binds to muscarinic receptors on cardiac myocytes and the coronary vasculature .
- The vagus nerve is also an important path for sensory information from visceral organs, including the heart, to the central nervous system.
- In fact, approximately 80 % of the fibers contained within the vagus nerve are afferent, being made up of A, B, and C fibers.
- Cardiac-related bipolar neurons with cell bodies in the nodose ganglia have peripheral axons projecting to the heart and central axons projecting to the nucleus tractus solitarius of the medulla (*dashed line*).
- Thus, the vagus nerve contains both ascending afferent and descending efferent nerve fibers.

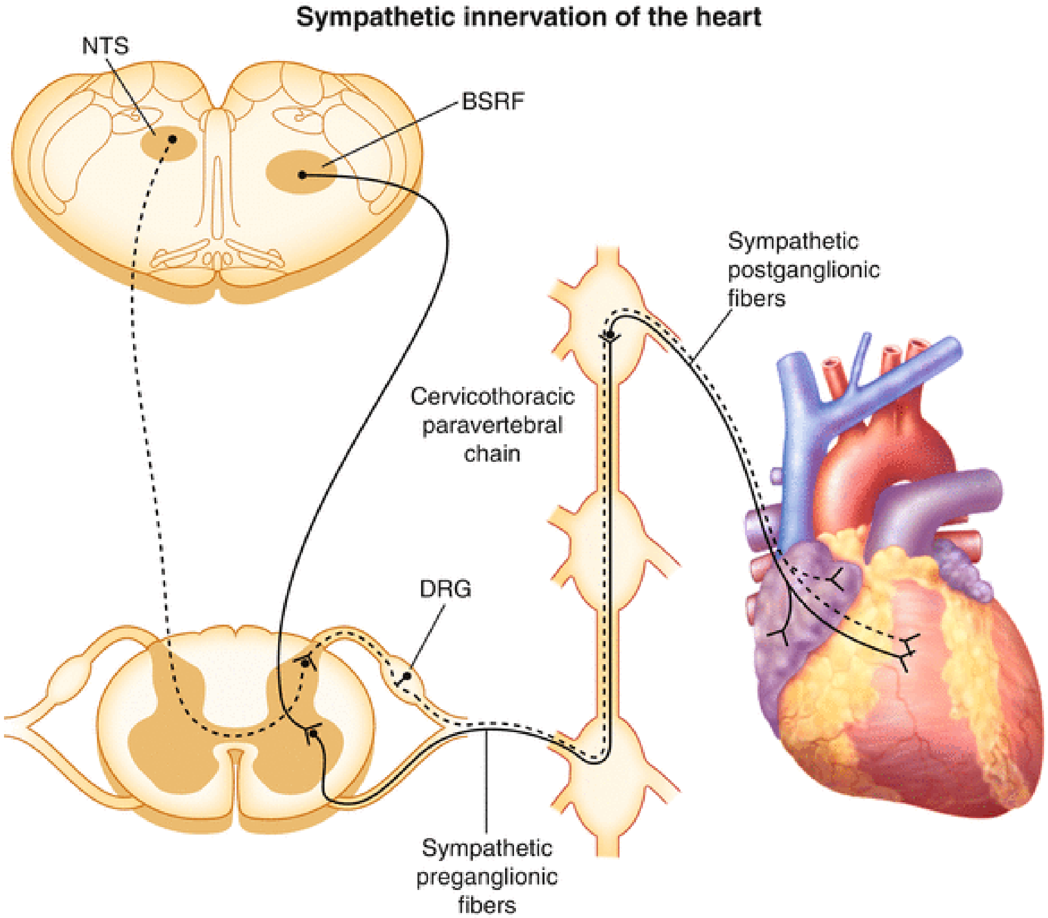
Cardiac efferent neurons

- **Adrenergic neurons.**
- Cardiac sympathetic efferent preganglionic neurons in the spinal cord project axons via the T1 to T5 rami

- to synapse with cardiac sympathetic efferent postganglionic neurons located in the cranial poles of the stellate ganglia, throughout the right and left middle and superior cervical ganglia and mediastinal ganglia adjacent to the heart.

- They also project to adrenergic neurons in each intrinsic cardiac ganglionated plexus.

Cardiac Motor Neurons: Efferent Control of Cardiac Function



- Sympathetic preganglionic neurons innervating the heart originate in the intermediolateral cell column between the first and fourth thoracic segments of the spinal cord .
- These preganglionic neurons receive inputs from glutamatergic neurons of the brainstem reticular formation (*BSRF*), which includes the rostral ventrolateral medulla .
- Preganglionic neurons course through the ventral rami and synapse on postganglionic neurons contained primarily within extracardiac intrathoracic ganglia.
- Traditionally, it was thought that cell bodies of cardiac sympathetic postganglionic neurons were restricted to the stellate ganglia ;
- however, more recent data demonstrate that they also are found in the superior, middle cervical , mediastinal, and even intrinsic cardiac ganglia .
- Postganglionic neurons from these ganglia innervate the atrial and ventricular myocardium, as well as the coronary vasculature.

- Preganglionic neurons release acetylcholine, which binds to nicotinic acetylcholine receptors on postganglionic neurons.

- Postganglionic neurons in turn release norepinephrine, which binds to α- and β-adrenergic receptors on cardiac myocytes and the coronary vasculature.

- This initiates a signal transduction cascade that involves G proteins, cyclic adenosine monophosphate, and protein kinase A, resulting in changes in chronotropy, dromotropy, inotropy, and lusitropy.

Physiology of Cardiac motor neurons

- **Parasympathetic efferent neurons.**
- When activated, cholinergic motor neurons suppress not only atrial rate and force, but also atrioventricular nodal conduction and regional ventricular contractile force.

- **Sympathetic efferent neurons.** Sympathetic efferent postganglionic neurons in each intrathoracic ganglion receive inputs from sympathetic efferent preganglionic neurons in the caudal cervical and cranial thoracic spinal cord.

- Cardiac sympathetic efferent postganglionic neurons are also influenced by cardiac and major intrathoracic vascular sensory neurons.

- These data indicate that adrenergic motor control of cardiac chronotropism, dromotropism, and regional inotropism ultimately depends on the integration of multiple cardiovascular sensory and central neuronal inputs within the intrathoracic neuroaxis.

- Intrathoracic local circuit neurons play a key role in such integration.

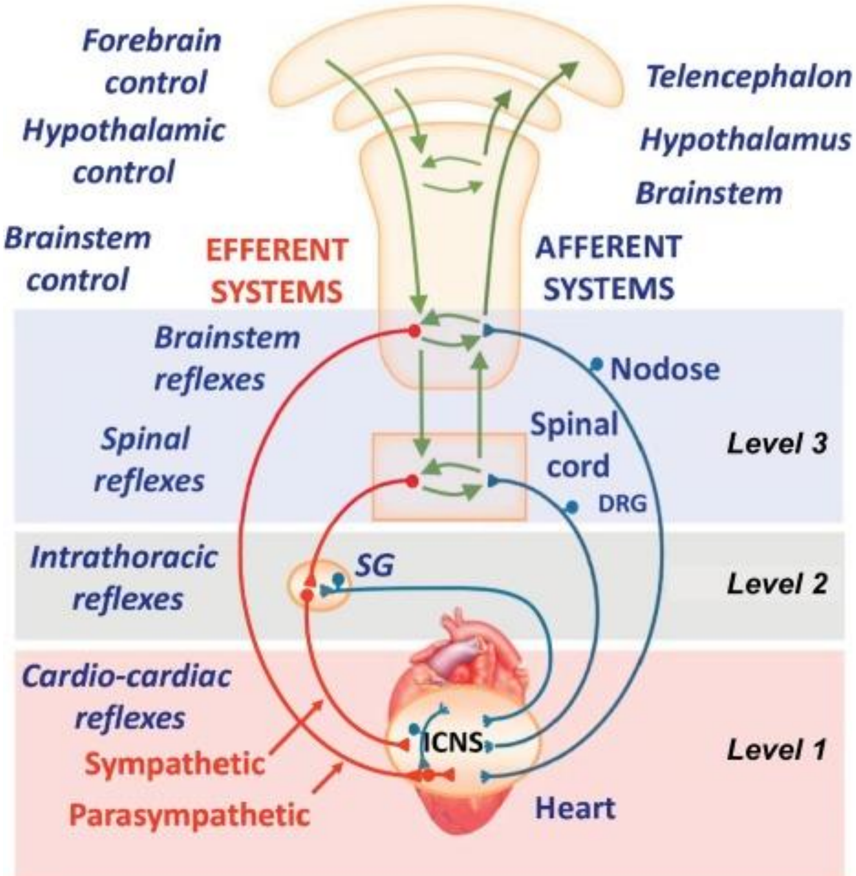
Local circuit neurons

- Interposed between cardiac afferent and efferent neurons are local circuit neurons.
- Their presence permits information exchange among neurons located not only in one intrathoracic ganglion (including those intrinsic to the heart) but also among neurons in different intrathoracic ganglia.
- Neurons of the target organ nervous system are constantly interacting with those in intrathoracic extracardiac ganglia, as well as with central neurons, to influence cardiac motor outputs.
- Some intrinsic cardiac local circuit neurons even receive inputs from sympathetic and parasympathetic efferent preganglionic neurons, indicating that some neurons process inputs from both efferent limbs of the autonomic nervous system, and not necessarily in a reciprocal fashion.

- Intrathoracic local circuit neurons also receive indirect inputs via the spinal cord neurons derived from sensory neurites in extrathoracic tissues.

- Thus, alterations in the extrathoracic milieu can also influence the intrinsic cardiac nervous system, doing so in an indirect manner.

NEURAL CONTROL OF THE HEART



- This schematic shows the four paths through which sensory information from the heart travels to the central nervous system.
- Cardiac sensory (afferent) neurons are located at multiple levels of the cardiac autonomic nervous system, including intrinsic cardiac, stellate, middle cervical, mediastinal, nodose, and dorsal root ganglia (DRG)
- (Bipolar neurons with cell bodies in the nodose ganglia have peripheral axons that project to the heart and central axons that synapse on second-order neurons contained in the nucleus tractus solitarius of the medulla .
- Similarly, bipolar neurons with cell bodies in the DRG have peripheral axons that project to the heart and central axons that synapse on second-order neurons contained in the dorsal horn of the spinal cord .
- Spinal cord neurons project to and interact with neurons in higher centers such as the medulla .
- These afferent neurons transduce the local mechanical and chemical milieu of the myocardium and coronary vasculature .
- Further, it has been shown that these neurons have multimodal transduction capabilities .

Heart-Brain Communication

- Literature has demonstrated that the heart communicates with the brain in many methods:
- Through nerve impulses (neurologically),
- Via hormones (biochemically),
- Through pulse waves (biophysically),
- Through electromagnetic fields (energetically)

- In comparison to the brain, the heart produces 40–60 times more electrical power and 5000 times more electromagnetic power.

- Consequently, the heart can align and synchronize all body systems to create physiological coherence.

- The heart produces and secretes several hormones.

- For example, atrial peptide or atrial natriuretic peptide, which inhibits the release of stress hormones, reduces sympathetic outflow and influences motivation and behavior.

- Moreover, the main source of the brain natriuretic peptide is the cardiac ventricle rather than the brain.

- The heart also manufactures and secretes oxytocin, the so-called “love” or “social bonding” hormone, which is involved in cognition, tolerance, trust, etc..

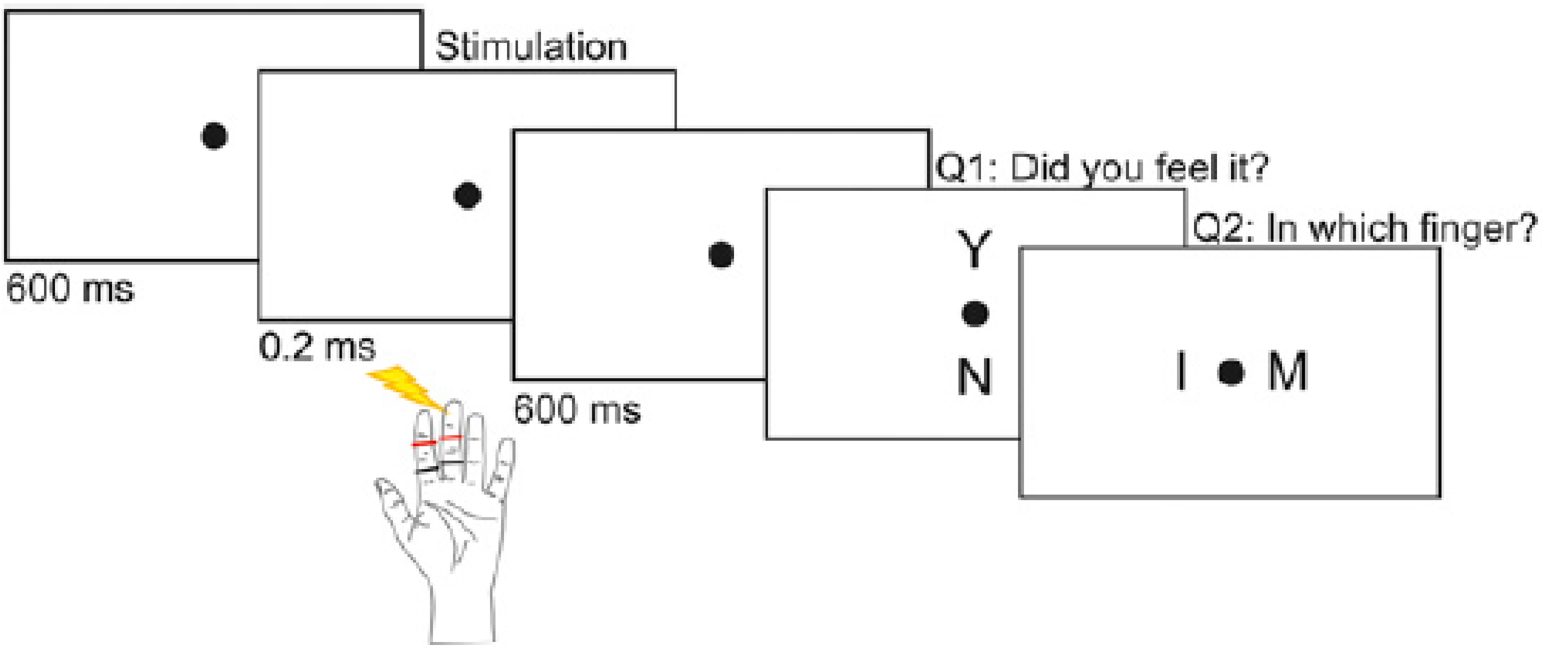
- The vagus nerve is the tenth cranial nerve, which carries information from the heart and other internal organs to the brain.
- It terminates in the brainstem, particularly in the medulla, and solitary nucleus .
- The vast majority (80%) of the vagus nerve fibers are afferent (ascending).
- This means, as previously mentioned, that the heart sends more signals to the brain than vice versa.
- Interestingly, signals from the "heart brain" transmit to the head brain via afferent neurons in the spine as well as the vagus nerve, where the signals redirect to the medulla, hypothalamus, thalamus, amygdala, and then to the cerebral cortex .
- There is evidence that a pathway from the dorsal vagal complex and cardiovascular afferent signals travels directly to the frontal cortex.

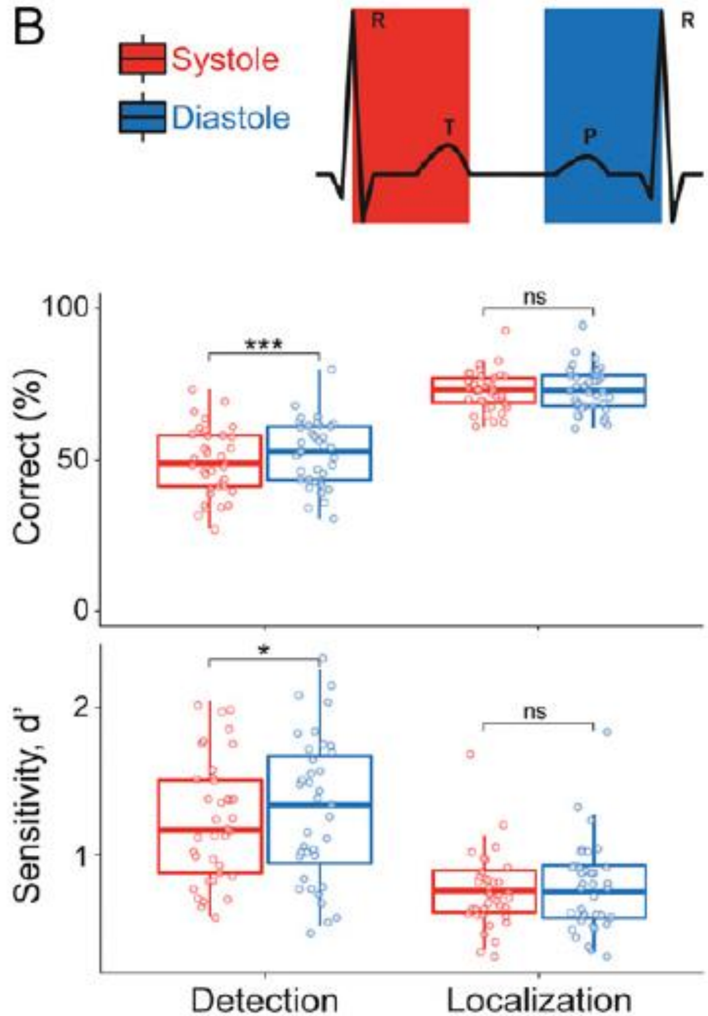
Importance of Heart-Bran axis

- The neural response to an external stimulus and its access to consciousness depend on stimulus features as well as the state of the brain.
- Interestingly, functional states of other bodily organs, such as the heart, can also influence the perception of external stimuli.
- For example, several studies have reported that timing along the cardiac cycle (e.g., systole vs. diastole) impacts the perception of visual or auditory stimuli.

Experimental paradigm.

Thirty-seven subjects received a weak electrical pulse to the left index or the middle finger in 800 out of 960 trials over eight experimental blocks. Subjects were told that every trial contained a stimulus; however, in 160 pseudorandomized trials no stimulus was actually presented. In every trial, participants were asked to first perform a yes/no detection task and then a location discrimination task.





Correct detection and localization percentages during systole and diastole. Participants had more correct detections in diastole (t36 = −3.95, P = 3·10−4). No statistically significant difference between systole and diastole was found for correct localization (P = 0.54). (B, Bottom) Detection and localization sensitivity (d’) between systole and diastole. Detection sensitivity was significantly higher in diastole than systole (t36 = −2.38, P = 0.008), and localization sensitivity did not differ significantly between the two cardiac phases (P = 0.38).

Importance of Heart-Bran axis

- For the somatosensory system, increased detection during diastole similar to the other sensory domains.
- Similar to perception, neural responses to visual and auditory stimuli are modulated across the cardiac cycle.
- Most often they have been reported to be higher during diastole than systole .
- Our brain continuously receives signals from the body and the environment.
- Although we are mostly unaware of internal bodily processes, such as our heartbeats, they can affect our perception.

- The internal state of the body is continuously monitored by interoceptive regions and networks in the brain .

- visceral signals have been argued to contribute to a wide range of psychological phenomena, including emotions , empathy, time perception, and decision making.

- The cardiac cycle from one heartbeat to the next can be divided into two phases:
- systole, when the heart contracts and ejects blood into the arteries—leading to activation of pressure-sensitive baroreceptors in arterial vessel walls—

- diastole, when the cardiac muscle relaxes, the heart refills with blood, and baroreceptors remain quiescent.

- Baroreceptor activity signals the strength and timing of each heartbeat to the nuclei in the lower brain stem, where the signal is relayed to subcortical and cortical brain regions

- Baroreceptor firing is thought to underlie cardiac cycle effects on behavior and cognition

- Baroreceptor firing is thought to underlie cardiac cycle effects on behavior and cognition like

- decreased intensity ratings for acoustic or painful stimulation
- higher reaction times to stimuli

- during early (i.e., at systole) compared to later phases (i.e., at diastole) of the cardiac cycle.

The Body in Emotion and Cognition

- Within biological psychology and cognitive neuroscience there is currently a surge of interest in interactions between body and brain, and the embodied mechanisms that support feelings and thoughts.

- Ultimately, emotional science has led this field, with theories dating back to James and Lange emphasizing the effects of the physiological state of the body upon mental processes.

- However, there has been a shift towards understanding what determines how, when, and in whom interoceptive (see Glossary) signals impact on affective and cognitive functions.

- Interoception refers to the sensing of the internal physiological state of the body.
- Interoceptive representations in the brain are informed by distinct neural and humoral channels.
- Neural (ascending spinal and cranial nerve) pathways communicate the filling and stretching of the visceral organs, their cellular integrity, and their inflammatory state.
- The brain also directly samples the contents of blood to index oxygen and carbon dioxide levels as well as the hormonal, metabolic, inflammatory, and nutritional status of the body.

- The effects of ventral prefrontal damage on emotion and decision-making led to pioneering investigations into brain mechanisms through which bodily feedback might influence brain and bias emotion and cognition, as encapsulated by Damasio's 'somatic marker hypothesis' [19,20].

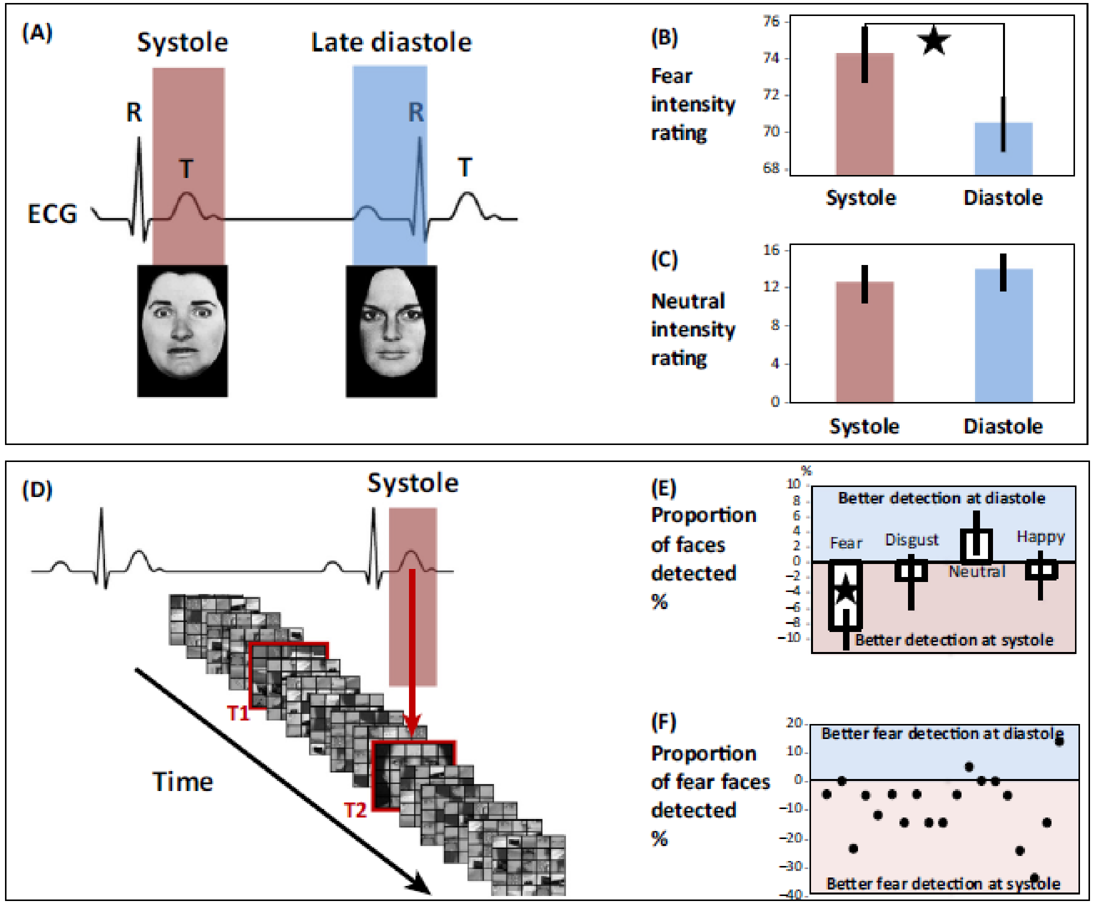
- Subsequent neuroimaging research particularly implicates insular cortex, within a wider set of brain networks, in the neural representation of physiological arousal, mediating the impact of interoceptive signals on feelings and thoughts.

- Posterior and mid-insular regions map viscerosensory state, while anterior insular cortex draws interoceptive representations into cross-modal processing to influence perceptual and conceptual representations, through interaction with cingulate and prefrontal cortices, as well as subcortical centres including amygdala and ventral striatum .

- What has been lacking is a detailed mechanistic account of how bodily arousal states can shape behaviour and determine individual differences in emotion response.

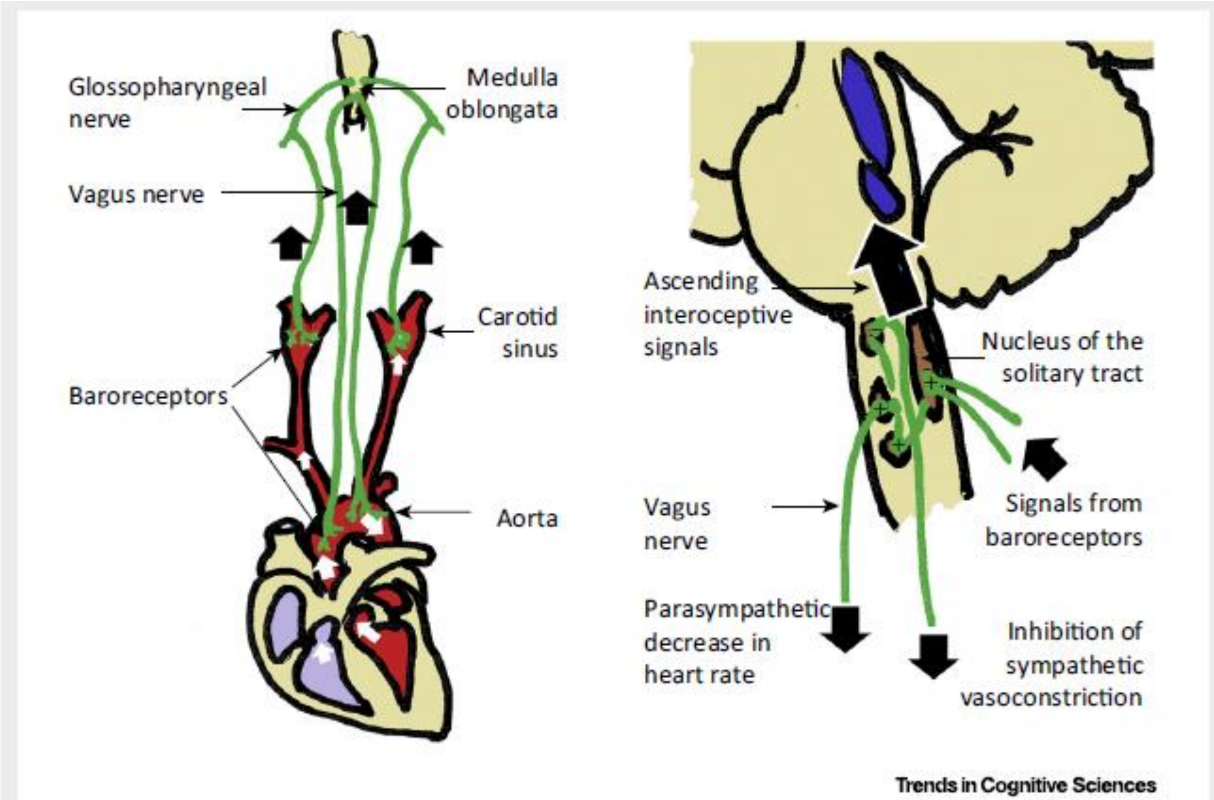
- Recent progress has been made with the recognition and characterization of selective effects of cardiac afferent signals on the processing of fear stimuli.

Enhanced Processing and Detection of Fear at Systole



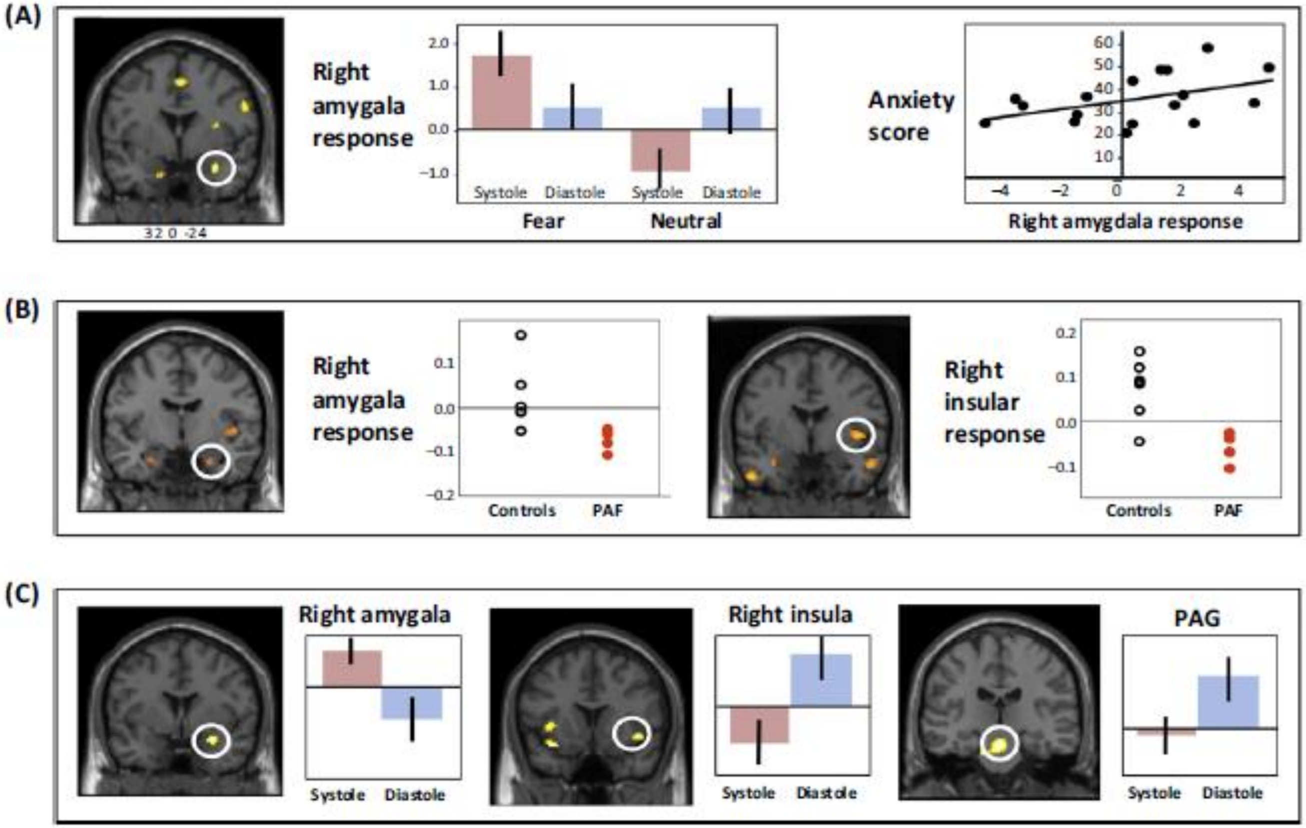
(A) In an experimental task pictures depicting emotional facial expressions were presented briefly, but supraliminally (100 ms), at either systole (to coincide with arterial baroreceptor signalling to brain) or at late diastole (when arterial baroreceptors are quiescent). Participants then rated the emotional intensity of the faces. (B) The reported intensity of fearful faces is significantly enhanced at systole relative to diastole. (C) Subjective intensity ratings of faces with neutral facial expressions were not significantly modulated by phase of cardiac cycle. (D) Systole enhances the detection of very brief fear faces compared to other emotions. In a stream of distracting scrambled images, detecting a face is difficult, particularly if it follows (at T2) closely after a previous target stimulus (T1), in other words during an 'attentional blink' [66,67]. In this type of task, emotional faces at T2 are detected better than neutral faces. (E) Across participants the detection of fearful faces at this border of awareness is better at systole, but this effect is not observed for other emotions [9]. (F) The majority of people show this specific cardiac enhancement of fear detection.

Interoceptive Relays from the Heart to the Brain. The left panel illustrates how, when the heart contracts at systole, the ejection of blood stimulates baroreceptors in aortic arch and carotid sinus to fire. This signal is relayed to the medulla oblongata via glossopharyngeal and vagus nerves. The right panel illustrates the input of these signals within medulla to the nucleus of the solitary tract which projects to the nucleus ambiguous (vagus efferent nucleus) to stimulate parasympathetic slowing of heart rate. In addition, projections via ventrolateral medullary nuclei inhibit descending sympathetic nerve traffic to muscle vascular beds. Thus a strong baroreceptor input triggers slowing of next heartbeat and peripheral vasodilatation, lowering blood pressure.



- The baroreflex maintains heart rate and blood pressure in response to postural and internal physiological changes. Emotions, cognitions, and behaviour can suppress the sensitivity of the baroreflex, via descending pathways from forebrain, to permit heart rate and blood pressure to rise together and provide the extra cardiovascular support for actual or anticipated physical demand .

- Interoceptive signals from each heartbeat are also projected to forebrain regions, measurable, for example, as heartbeat evoked potentials. These signals enable a central representation of cardiovascular arousal within viscerosensory cortices and influence on ascending neuromodulator systems, as well as striatal and limbic function, implicated in emotional and motivational behaviour .



Trends in Cognitive Sciences

- Amygdala Activity and the Interaction of Cardiac Signals with Fear, Threat, and Shock Processing. (A) Brain correlates of cardiac enhancement of fear processing at systole. Group data are presented on a coronal section of a template brain illustrating (bilateral) amygdala activity which significantly represents the interaction of cardiac timing on emotion processing. Parameter estimates for right amygdala activity (circled) are presented in the next bar plot. This activity correlates with individual differences in state anxiety, plotted in the third graph. (B) Neuroimaging observations of the interaction between autonomic arousal and threat processing. Patients with pure autonomic failure (PAF) are unable to generate changes in heart rate and blood pressure. In a fear conditioning experiment [29], right amygdala (circled) and right insula responses (circled) to conditioned threat stimuli are attenuated in this absence of autonomic response and its feedback. Group effects are plotted on a coronal image, alongside amygdala parameter estimates [29]. (C) Brain responses to brief pain (shock to skin) stimuli at different phases of cardiac cycle. Systole (not diastole) inhibits blood pressure responses to shock [56], evoking an enhancement of amygdala activity [56], and an opposite effect in mid insular and in dorsal pontine responses. Group data are presented on coronal template images alongside plots of parameter estimates for amygdala, insula, pons, and periaqueductal grey (PAG).

- when fearful faces are presented at systole, the perceived emotional intensity of the face increases compared to presentation at diastole.
- This effect of the heart on the perception of fear is associated with enhanced amygdala activity, which also correlates with individual differences in anxiety levels.
- Thus, natural arterial baroreceptor activation, encoding the timing and strength of individual heartbeats, enhances the processing of fear.
- These findings enrich our understanding of the impact of heart signals by showing a selective effect on the detection of a specific class of emotional stimuli, indicating how interoceptive signals might differentially gate access to perceptual consciousness.
- This contributes to evidence showing that the ascending signals from cardiac baroreceptors directly influence amygdala function.

Potential Mechanisms for Cardiac Enhancement of Fear Processing

- Neuromodulator systems (notably noradrenaline and acetyl choline pathways that regulate diffuse neuronal populations across the brain) are also likely to mediate the effect of phasic cardiac afferent signals on fear processing and amygdala function.

- Within the brainstem, neural activity in the locus coeruleus is influenced by baroreceptor signals relayed through the nucleus of the solitary tract.

- These noradrenergic projections ascend to influence amygdala function, and also modulate basal forebrain cholinergic projections to cortex, tuning the processing of anxiety-related information and the flow of information to cortex.

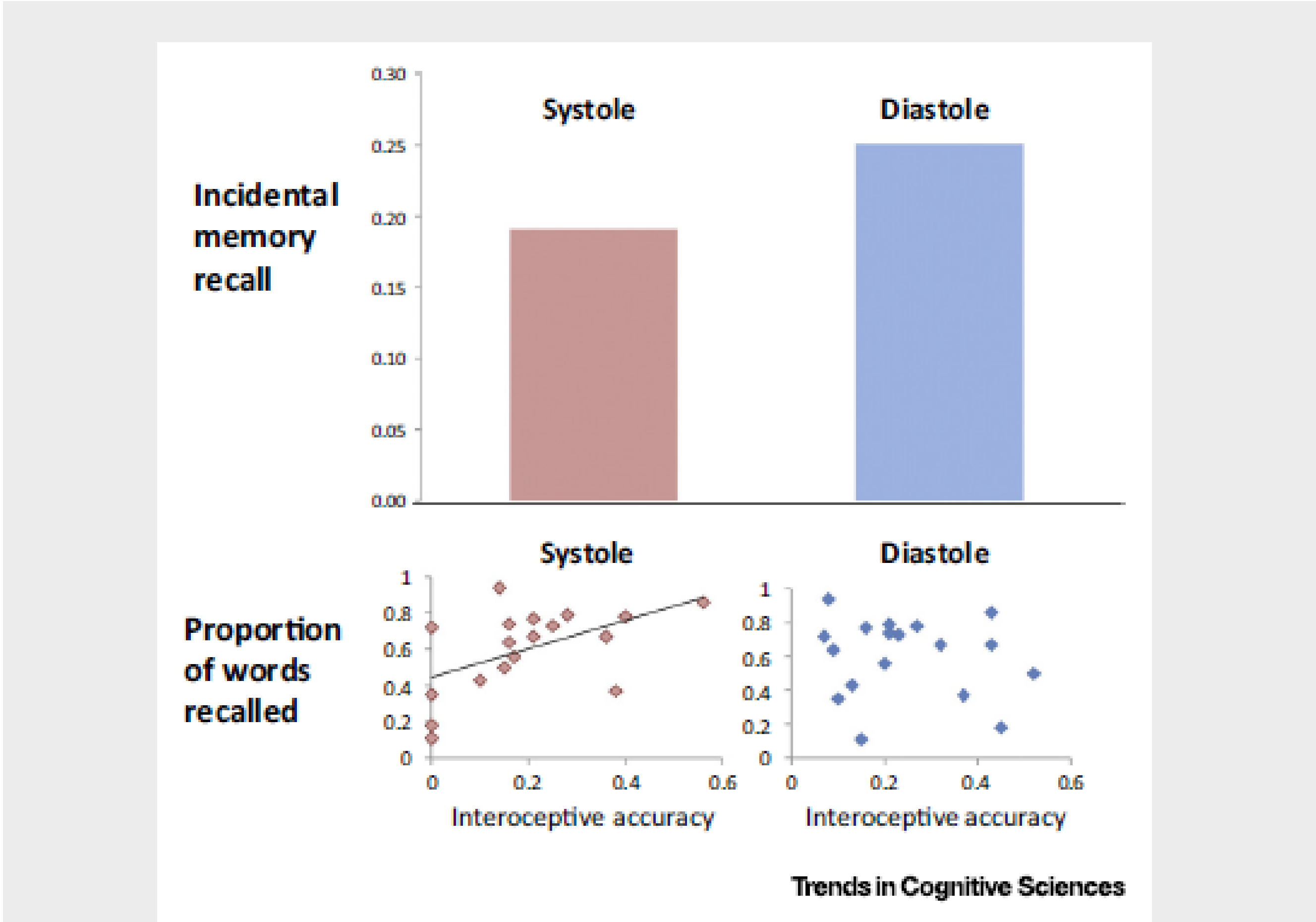
Cardiac Influences on Memory and Cognition

- Interoception can guide cognitive processes.

- Physiological arousal can facilitate memory encoding, such that arousing material usually has an advantage in memory.

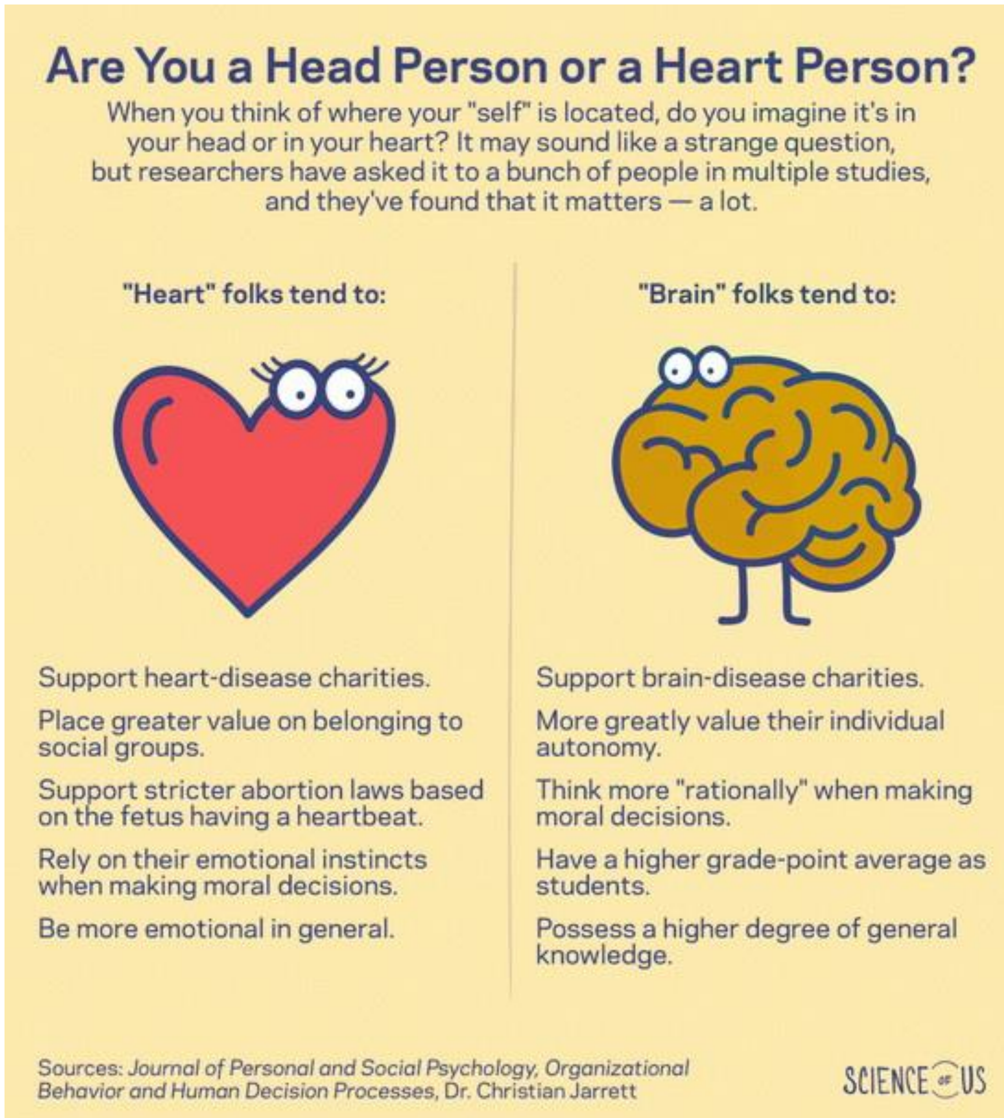
- This effect can be mediated through monoamine-enhanced coupling between amygdala and hippocampus.

- Experimentally, an individual has poorer recollection of words if presented synchronously with the heartbeat (at systole, during baroreceptor discharge) than if the words are presented between heartbeats (at diastole, when baroreceptors are quiescent).



Word Memory as a Function of the Cardiac Cycle. Memory for words was impaired if they were initially presented (i.e., encoded) at systole relative to diastole (upper bar plot). However, enhanced interoceptive accuracy (capacity to perceive one's heartbeats at rest) mitigated this detrimental effect of baroreceptor afferent signals on encoding at systole (left lower plot), but there was no correlation between interoceptive accuracy and memory for stimuli presented at diastole (lower right plot). Figure derived from [8] with permission from Society for Psychophysiological Research.

Concluding Remarks



منابع

- Threat and the Body: How the Heart Supports Fear Processing Sarah N. Garfinkel, and Hugo D. Critchley, Trends in Cognitive Sciences, 2016.

- Interactions between cardiac activity and conscious somatosensory perception, Paweł Motyka, Martin Grund, Norman Forschack, Esra, Arno Villringer, Michael Gaebler, psychophysiology, 2019

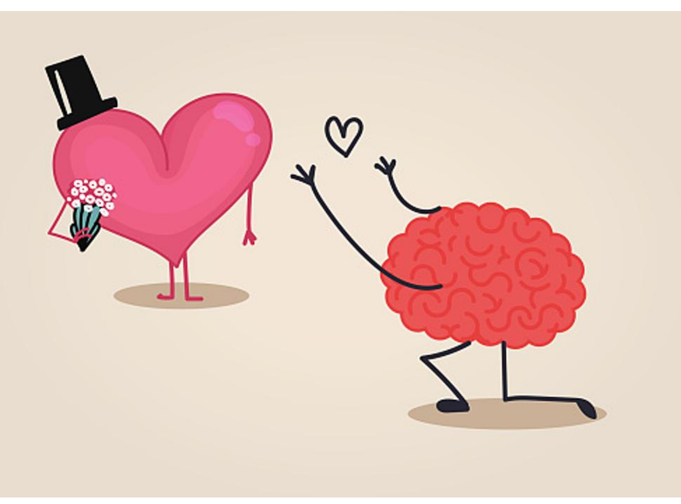
- The little brain on the heart, J. ANDREW ARMOUR, CLEVELAND CLINIC JOURNAL OF MEDICINE,2007

- Pain: Is It All in the Brain or the Heart? Ali M. Alshami, Current Pain and Headache Reports 2019

با سپاس از توجه شما

هرگز نفسی پاک نیاید ز دلت بر
تا جان تو فرمانبر این نفس پلید است

یارب به کرم کن نظری در دل عطار
کز دست دل خویش دل او بپزیده است



عطار نیشابوری