PORGES AND THE POLYVAGAL THEORY

Reflections on clinical and therapeutic significance

This polyvagal theory deals with complexities of the Autonomic Nervous System that are not yet fully understood – and are in the process of being further researched. This paper gives a brief (and therefore simplified) introduction to some of the main concepts.
The next webpage – A8 ("The Polyvagal Theory *and a more sympathetic awareness of the ANS"*) gives a further perspective.

Contents

1. Preamble

The polyvagal theory links the evolution of the neural regulation of the heart to affective experience, emotional expression, facial gestures, vocal communication, and social behaviour that is responsive to the behaviour of others. The theory points out that the neural control of the heart is neuro-anatomically linked to the neural control of the muscles of the face and head.

Porges 2011 p 16

The physiological model of the Autonomic Nervous System (ANS) during the last one hundred years or so has been that of its division into the Sympathetic Nervous System (SNS) and the Para-sympathetic Nervous System (PSNS). The SNS has been seen as the part of the ANS to do with Fight and Flight, and the PSNS to do with Rest, Repair, and Recuperation. The Freeze response has been deemed to be part of the Fight and Flight Response – or at least, that was my understanding.

In terms of Autogenic Training and Schultz's "psycho-physiological shift" (Schultz & Luthe 1969), this overall model has served us well in that it has clearly distinguished between the Stress Response (SNS) and the Relaxation Response (PSNS) (Benson 1975).

However, it is not entirely accurate. If we look at the development of physiological responses that adapt the organism appropriately to what is going on in the environment, we come up with a subtly different model. In humans, in the reverse order of their evolutionary development, we have:

i. **The fast acting (myelinated – PSNS) vagal system** that embraces social engagement and, when the environment is safe, can over-rule the
ii. **Sympathetic System of Fight and Flight Response**; if this fails, we fall back on the oldest system
iii. **The slow acting (un-myelinated – PSNS) vagal system of immobilisation and the Freeze Response**, with an associated reduction in metabolic activity.

So this means that the vagal system is in two fundamental parts: the ancient vertebral un-myelinated system that results in freezing and immobilisation; and the much newer myelinated[1] system that can embrace cortical (conscious and unconscious) inputs in the face of danger to over-ride the classic Fight and Flight Response of the SNS. Furthermore, in general terms, when faced with a threat, mammals / humans respond to it using the above three systems in reverse order to that of evolutionary development – i.e. in the order i. to iii. given above (Porges 2009 pp 35-36; Porges 2011 p 16).

This paper's introduction to the polyvagal theory of Porges tends to the non-linear rather than linear to emphasise its interconnected origins and influences.

<u>2. Perception and neuroception from the perspective of the Polyvagal theory</u> (Porges 2011 pp 11-19)

In evolutionary terms, the most important matter for an organism was to survive and reproduce; vertebrates and mammals developed very sophisticated systems for defending themselves against external threats. The Fight and Flight responses that evolved to deal with, say, a predator, do so at a stimulus–response level that does not rely on conscious awareness (LeDoux 1998; 1999). Perception can be regarded as conscious awareness – say of danger. In the context of survival repertoires, unconscious awareness (neuroception) monitors what is going on and then puts the Fight / Flight response into action when appropriate (see also B10 Figure 1 – which discusses our unconscious response to danger – such as a snake – which is based on LeDoux 1998).

The fight and flight response thus evolved to deal with threatening / dangerous situations – that were not life threatening – by mobilising the SNS system. In life threatening situations[2], the Freeze Response was activated through the ancient (PSNS) un-myelinated vagal nerve (originating in the Dorsal Vagal Complex – sometimes referred to as the Dorsal [motor] Nucleus); this worked well in reptiles in whom a near total shut down of all systems was not a threat to the organism – as they could survive with

[1] Myelinated neurones transmit neural signals much faster than un-myelinated systems; these newer (mammalian) myelinated vagal PSNS fibres include those going specifically to the heart and lungs (Porges 2011 pp 28-29; Porges 2008).

[2] Panksepp has a somewhat different perspective (in the context of Emotional Operating Neuro Circuits / Systems – B3), and suggests that the Freeze response can (initially) be activated before the Flight response. "Activity of this system [i.e. FEAR] is the unconditional response that mediates classical conditioning of fear, with frozen postures when arousal of the system is modest, and with intense flight when the arousal is stronger" (Panksepp 2009 p 10).

a very low metabolic rate. The system works less well in mammals and humans who normally require a relatively high metabolic rate to ensure cell survival – especially in the brain.

Note that this means that the Freeze response is not part of the SNS system; it is distinct from the SNS based Fight / Flight Response.

Co-option of un-myelinated vagus for other immobilisation activities not associated with fear or threat

The un-myelinated vagus system was later co-opted (in evolutionary terms) to facilitate, for example: the posture of nursing mothers; childbirth; sexual intercourse; and for digestion, rest & repair (Porges 2009 p 53; Porges 2011 Chapter 11). In these situations, immobilisation without fear can occur as a result of the action of oxytocin (Porges 2011 p 14).

The threshold at which the Fight / Flight system comes into force is crucial. Minimal / insignificant threats can normally be over-ridden by the "smart" myelinated vagus system, which fosters social engagement and at the same time down regulates the SNS system. If the threshold of the (flight / fight) systems is set very low, then FEAR and RAGE neural circuits may be set off inappropriately. This may be the basis for various anxiety states and phobias.

Mental Training / Autogenic Training will help to facilitate activation of the myelinated (and unmyelinated) vagal system and down regulate the FEAR / RAGE circuits of the amygdala. These benefits are brought about by the psycho-physiological shift, which is unconsciously mediated through the Standard Exercises – and perhaps later partly mediated by increased awareness in terms of mindfulness (D1).

3. Polyvagal System

The Vagus nerve is the tenth Cranial Nerve (out of a total of twelve). Originally, the vagal system was regarded as a unitary aspect of the PSNS[3]. However, Porges suggests that this can no longer be regarded as correct, in view of the two systems (i. and iii) highlighted in the preamble – hence *poly*-vagal.

Now the fast acting myelinated vagal system (originating in the Nucleus Ambiguus, part of the Ventral Vagal) encompasses various modalities including:

- Regulation of calm states that facilitate:
  - i. Spontaneous social engagement and health,
  - ii. Growth and
  - iii. Restoration (Porges 2009 p 36).

This means that the myelinated vagus is, amongst other things, crucial for interactions with others – and hence our overall Well-Being. For this reason it is sometimes called the "smart vagus" (Wikipedia 2012). In terms of spontaneous social interactions, it will be intimately connected with basic emotional systems such as CARE, SEEKING and PLAY (Panksepp 1998; and B3 Part ll).

Social engagement with others will not be facilitated, normally, with a pounding heart. To this end, the activated myelinated vagus puts a brake on the heart (rate), and at the same time facilitates pro-social activities including:

- Making eye contact;
- Vocalising with an appealing inflection and rhythm;
- Displaying appropriate facial expression;
- Modulating middle ear muscle to distinguish the human voice from other environmental sounds.

(above bulleted points from / paraphrased from: Porges 2011 p 15)

Anatomically, the unmyelinated and myelinated vagal systems are somewhat distinct, and Figure 1 schematically represents these in a simplified form, together with the SNS fight / flight system.

[3] Note that the PSNS manifests itself not just in the Vagal (X) nerve but also in the following cranial nerves: lll; Vll; lX; and the sacral spinal nerves: S2, S3, and S4.

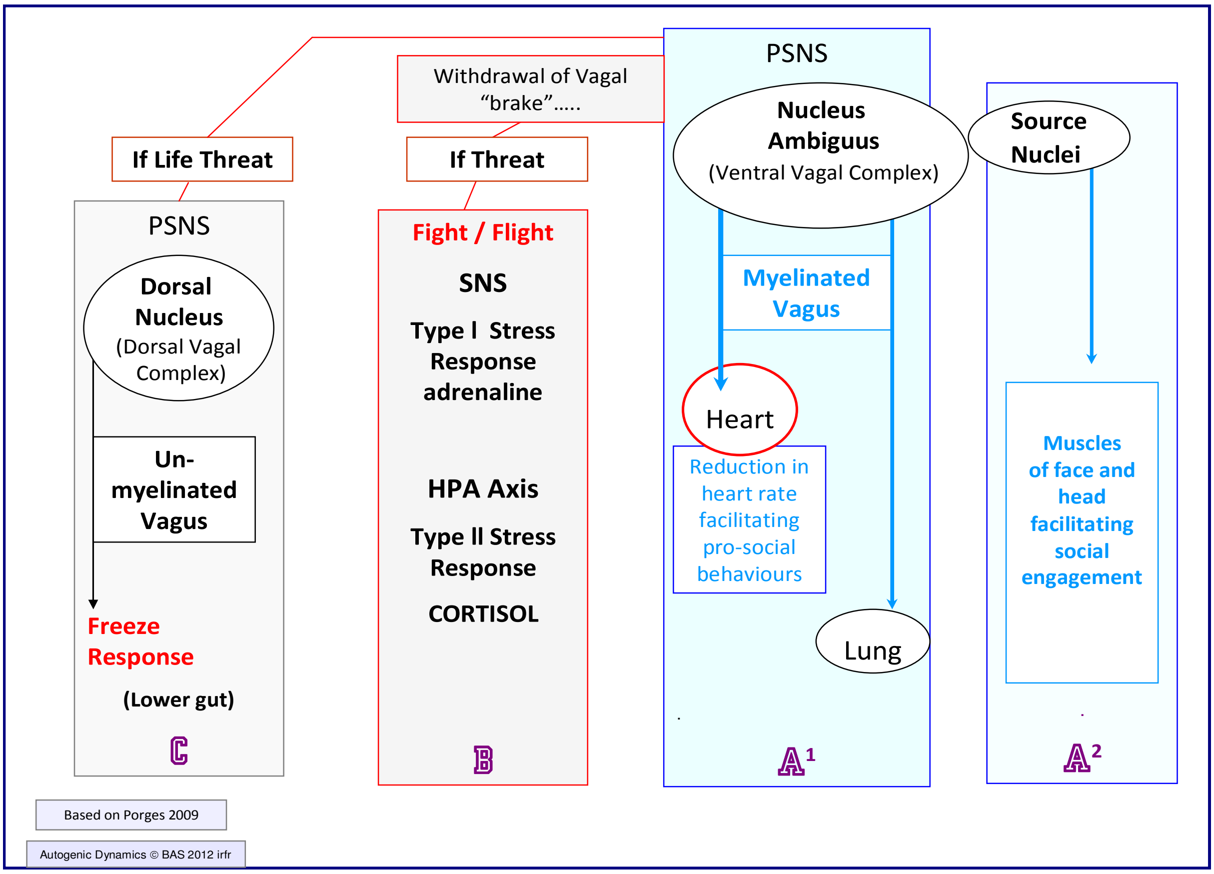

Figure 1
Four overlapping systems embraced by the Polyvagal Theory
(extrapolated from Porges 2009; 2011)

Comments on Figure 1

- Four linked systems are shown.
- In our normal social interactive state, the myelinated vagus is active [𝔸1] in bringing about a slowing of the intrinsic heart rate (see below), and facilitating pro-social behaviours and interactions – including facial (non-verbal) communications [𝔸2].
- The myelinated vagus [𝔸1] thus acts as a vagal brake on heart rate.
- If there is an external or internal threat, one of two systems comes into play:
  - i. A significant (but not life-threatening) threat: here the myelinated vagal brake is withdrawn, with activation of the SNS flight / fight system [𝔹]; or
  - ii. Life Threatening: where there is potentially catastrophic threat, then the ancient unmyelinated vagal system [ℂ] comes into play (the Freeze Response).

- The Stress Response (SNS component) is complex, and involves two distinct parts:
  - i. Type I SNS response involving the Adrenal Medulla and the adrenaline / nor adrenaline system.
  - ii. Type II Hypothalamic Pituitary Adrenal axis response. ACTH, released from the Pituitary gland, stimulates the Adrenal Cortex to release Cortisol. [Types I & II as described in Ross 2010].
- Cortisol, when secreted over prolonged periods (as a result of on-going stressors), is a major cause of damaging stress (Benson 1975), Allostatic Load (McEwen 2003; 2004), and possibly depression (see, for example, Burke et al 2005).

The intrinsic heart rate /

The intrinsic heart rate is regulated by the sino-atrial node. This is faster than our resting pulse, because at rest the myelinated vagus to the heart reduces the heart rate during expiration[4] (as does slow diaphragmatic breathing). This also means that mammals and humans can prepare for mobilisation (and potential fight and flight) by inhibiting this vagal-induced-bradycardia (slowing of the heart), so that the heart speeds up without activating the SNS flight / fight system: the organism is thus able to assess the situation to see if mobilisation of the SNS is required. If not, reactivation of the vagal-heart system[5] brings about a rapid slowing of the heart (Porges 2009).

4. The central trio of the polyvagal theory – *Engagement, Mobilisation, and Immobilisation*.

We can conceive the polyvagal theory in terms of three distinct systems that have evolved during the course of evolution to give us three distinct behavioural possibilities in responding to external (and internal) events in our environment. These are:

1. Social engagement with other humans / animals (Myelinated). [The bio-behavioural quest for Safety – Porges 2009 pp 36-38; including cranial nerves V (trigeminal), Vll (Facial), lX, X (Vagus) & Xl.]
2. Mobilisation in preparation for Fight and Flight (SNS) [Bio-behavioural quest for Survival.]
3. Immobilisation when confronted with a life threatening event (Unmyelinated Vagus)[6].

Note that the Fight and Flight response is not always the appropriate response in the face of danger. The myelinated vagal system of social engagement embraces the Tend and Befriend Response to danger discussed in "The Stress Response, the Relaxation Response, and the Tend-and-Befriend Response" (A1 in this series). In other words, the appropriate response for women and their children (in evolutionary terms) when faced with danger may not be that of flight or fight – but rather one associated with "tend and befriend" (see webpage A1 in this series for further discussion; note also of course that this Tend-and-Befriend Response may often be appropriate for men in our modern world).

In primates the use of facial expression to monitor and gauge appropriate responses becomes increasingly important, especially in us humans. The myelinated vagal system allows us to over-ride a SNS induced tachycardia (increased heart rate) in the face of danger where social engagement may actually be more appropriate. "In general, phylogenetic development results in increased neural control of the heart via the myelinated mammalian vagal system that is paralleled by an increase in the neural regulation of facial muscles" (Porges 2009 p 37) involved in facial expression.

> Note that other cranial nerves are involved in sensory and motor aspects of facial expression / behaviour – i.e. V (Trigeminal), Vll (Facial); lX (Glossopharyngeal), X (Vagal myelinated – including control of the muscles of the voice and resonance of the palate).

The following gives a good summary of Porges' central tenets of his polyvagal theory:

---

[4] During inspiration, there is maximum oxygen in the alveoli to saturate the blood in the alveolar arterioles with oxygen if the blood is flowing fast (i.e. increased heart rate); during expiration, there is less oxygen in the alveoli, and less need for a fast heart rate. The bradycardia related to expiration may in part be an energy conserving device (Yasuma et al 2004; Pöyhönen M et al 2004). A respiratory rate of around six breaths a minute is associated with maximum Heart Rate Variability, and thus maximal myelinated vagal tone to the heart (AED communication).

[5] Note: inhibition of the myelinated vagal brake speeds the heart more quickly than the SNS would alone.

[6] Porges implies that such life threatening immobilisation can, in the final analysis, be linked to the bio-behavioural quest for "a painless death" (Porges 2009 p 36). What would be the evolutionary significance of such a quest?

> First, there are three response systems proposed in the Polyvagal Theory:
> 1. cranial nerves to regulate the face and to mediate calm autonomic behaviour states;
> 2. sympathetic-adrenal system to increase metabolic output, and
> 3. an inhibitory vagal system to decrease metabolic output and promote freezing and defecation.
>
> These three response strategies are the products of distinct neuro-physiological systems.
>
> Second, these distinct neuro-physiological systems represent a phylogenetically dependent hierarchy, with the use of cranial nerves to regulate facial expression emerging in mammals (well developed in primates); the sympathetic-adrenal system shared with other vertebrates, including reptiles; and the inhibitory vagal system shared with more primitive vertebrates, including bony fish, and cartilaginous fish (see Porges 1997, 1998)
>
> Porges 2009 p 39

5. Affect, the Social Engagement System, and caring

The Polyvagal Theory is intimately linked with our neuro-physiological social engagement systems. That is, the myelinated vagus system allows us to become calm and settled as the heart rate is reduced (from its intrinsic sino-atrial rate), and this allows us to interact in a calm and social way with others. The Social Engagement System embraces the myelinated vagus and other crucial cranial nerves that allow us to express our feelings – not just through words and intonation, but also through facial expressions. This includes eye and eyelid movement, facial expressions, prosody ("patterns of stress & intonation in a language" (CED 2011), and head turning – for example, orientation and gestures (Porges 2009). So in a safe environment, we can understand each other in many different ways.

Our affect and mood is crucial to social engagement; as too is the autonomic nervous system. When we are safe, the myelinated vagal system (PSNS) will be active and suppressing SNS activity.

> The Social Engagement System is an integrated system with both a somatomotor component regulating the striated muscles of the face and a visceromotor component regulating the heart via a myelinated vagus. The system is capable of dampening activation of the sympathetic nervous system and the HPA[7] axis. By calming the viscera and regulating facial muscles, this system enables and promotes positive social interactions in safe contexts.
>
> Porges 2009 p 41

If our Social Engagement System malfunctions, the calming effect of the myelinated vagus system will of course be lost, and this can then lead to anxiety and hyper-vigilant states, which have been incriminated in Medically Unexplained Symptoms; such a disturbed state can lead to a negative interpretation bias (e.g. seeing a neutral face as an angry or threatening face) and low / disturbed mood (see Dobbin and Ross[8] 2012; and see B10 & B11 in this web series).

On the other hand, meditative type practices will activate the myelinated vagal system (PSNS) and hence slowing of the heart rate (see e.g. Miu et al 2009) – and facilitate the Social Engagement System and the calming effect it can have. In addition, these various dynamics can activate the Self Soothing system (see A8 pp 10-11 including Figure 7) and the associated CARE circuits (Panksepp 1998) – with the release of oxytocin. Sunderland emphasises that gentle caring and close interactions with our children are crucial for their social development, affect regulation, and overall Well-Being (Sunderland 2007).

[7] Hypothalamic-Pituitary-Adrenal axis that results in the release of cortisol from the adrenal cortex.
[8] No relation to Ian Ross

6. Interactive play (PLAY) and Social Engagement

Play in childhood is also crucial to the wholesome development of our neuro-circuits (Panksepp 1998; 2009; Sunderland 2007), and thus to our subsequent well being. Real PLAY in adults – i.e. fun play, as opposed to professional play which can degenerate into a craving and determination to win at all costs – remains important for adult health as well.

Play involves the mobilisation of the SNS (Porges 2009 p 50) for the activity that is required – e.g. basketball; badminton. However, in contrast to the SNS arousal in the Fight and / or Flight response, PLAY circuits also embrace the Social Engagement system[9] (Porges 2011 pp 275-277). So, for example, if we accidentally knock into someone during a game, then our subsequent immediate response is crucial: if we apologise and express this with caring gestures then the incident is usually quickly forgotten. If, on the other hand, we totally ignore the person we have just bumped into, then the outcome may be very different – and their FEAR / RAGE circuits may become automatically activated.

> Play is different from fight / flight behaviours. Although fight / flight behaviours often require an awareness of others, they do not require reciprocal interactions and an ability to restrain mobilisations. Play recruits another circuit that enables aggressive and defensive behaviours to be contained. The rapid recruitment of the Social Engagement System results in an immediate face-to-face evaluation of whether there is intentionality in the event that provoked the painful response………
> The superior temporal sulcus has been proposed to evaluate biological movement and intentionality. Thus, it is through this area of the brain that familiar voices, calming gestures, and appropriate facial expression can rapidly defuse a possible physical conflict.
>
> Porges 2009 p 51

So appropriate facial and bodily gestures – which may include a verbal apology – can indicate that our intention was not to harm.

Play is like a bio-dance between two or more people, in which the neuro-circuitry of those involved alternates between mobilisation / SNS activity, and inhibition of this via the PSNS myelinated vagal system that puts a brake on the SNS (especially the heart rate), while at the same time mobilising the Social Engagement System. This intra neuro-circuitry aspect of the bio-dance is always at work in play. Figure 2 illustrates schematically some neuro-physiological interactions when one player inadvertently bumps into, or hurts, another.

[9] Figure 3 in the associated webpage A8 has a further refinement of our conceptualisation of the SNS; PLAY can be seen to be associated with the reward and SEEKING system (and hence dopamine); this is a quite different modality from the Fight / Flight / RAGE / FEAR SNS modality (Schore 2009; Panksepp 1998 & 2009; Porges 2011; Lynch 2011).

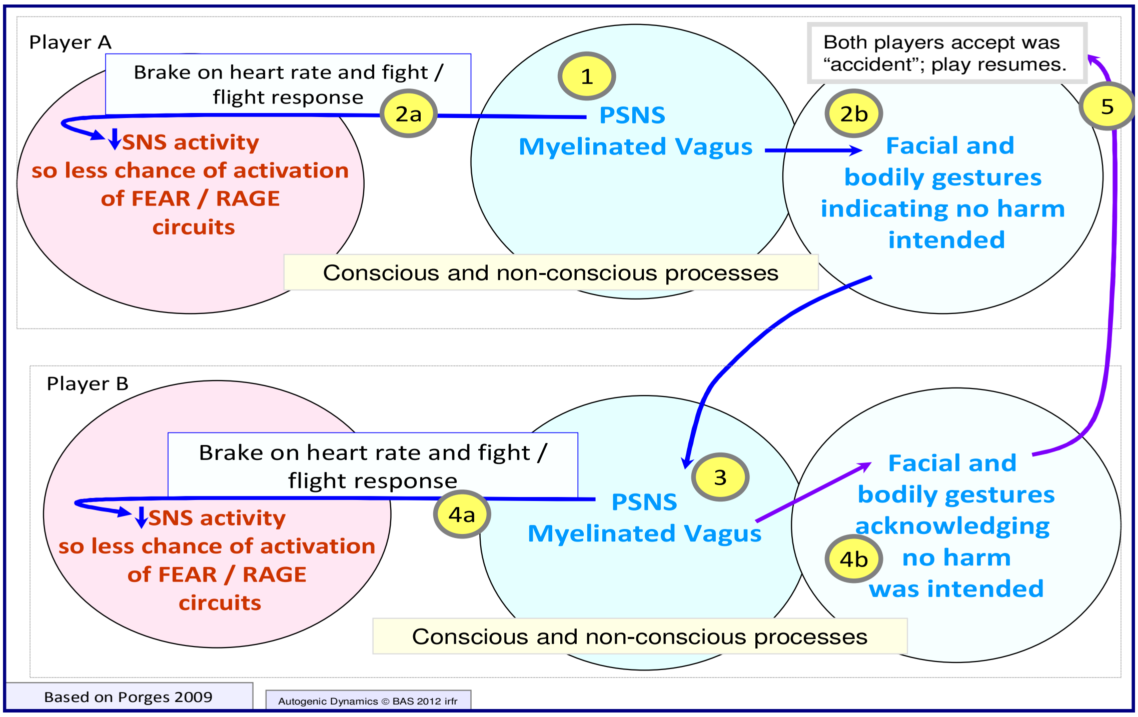

Figure 2
Schematic and highly simplified bio-dance of neuro-circuits involved in harmonious play – just after player A has inadvertently bumped into player B
[Based on Porges 2009 pp 50-55; 2011]
(essentially a pictorialisation of Porges' text)

Comments on Figure 2

The figure depicts the type of neuro-physiological events that occur when one player accidentally bumps into or hurts another player, here represented by Player A who bumps into Player B.

1. Player A realises (consciously and unconsciously) that she / he has inadvertently bumped into Player B. The myelinated vagus comes into action and……

2a. ….. dampens down SNS activity which includes putting the vagal brake on the heart rate. [Note that reduced SNS activity will also tend to dampen down the RAGE / FEAR circuits.]

2b. At the same time, the myelinated vagus system activates Player A's Social Engagement System that communicates in gestures, glances, looks (and possibly words) that this was an error / mistake.

3. This information is then communicated to Player B at both an unconscious and conscious level, resulting in:

4a. a dampening down of Player B's SNS response by the myelinated vagal brake system (so the FEAR and/ or RAGE systems are not activated), and, simultaneously……

4b. ……. the activation of B's own Social Engagement System which with positive gestures and looks etc ………

5. ……. communicate back to A that her / his "apology" (whether non-verbal and / or verbal) has been accepted.

As a result, PLAY can now continue in a playful way.

It is suggested that SNS activity that is stimulated in PLAY is interlinked with our SEEKING system, and is thus a distinct subset of the SNS; i.e. it is distinct from the SNS flight / fight (FEAR / RAGE) system (Panksepp 1998; 2009; Panksepp & Biven 2012 e.g. pp 351-355; and see also A8 in this series – Figure 3).

Play is enhanced when we feel secure. If we feel insecure or socially isolated, then play will be inhibited (see also B3 in this series). In addition, if, during play, we begin to feel excluded, we will feel the pain of rejection (Eisenberger & Lieberman 2004A; 2004B).

The mini Off-Loading Exercise and the OLE-CROE exercise in Autogenic Training can activate our PLAY circuits (see Ross 2010 p 268).

7. Summary

This paper has attempted to introduce some of the basic concepts of Porges' Polyvagal Theory. The theory is rooted in an understanding of some fundamental divisions within the Autonomic Nervous System. So we have, in simplified form:

1. **PSNS Myelinated Ventral Vagal System**[10] – the most recent to develop in evolutionary terms. This embraces:
    - Social Engagement System including Facial Expression;
    - Myelinated Ventral Vagus's ability to down regulate the SNS flight / response (including a brake on the heart rate[11]);
    - Rest, repair and digestion…..

2. **SNS system** that is associated with flight (FEAR) and fight (RAGE), which embraces:
    - Type l Stress Response of SNS and Adrenal Medulla releasing catecholamines – i.e. adrenaline and nor-adrenaline.
    - Type ll Stress Response of the Hypothalamic (CRF) – Pituitary (ACTH) – Adrenal Cortex Axis releasing Cortisol.

> In certain circumstances the SNS response may also lead to:
> - Dissociated rage
> - Dissociated panic (Schore 2009 p 131)
> - We may also get dissociated fear (see webpage A8 Figure 3).

3. **PSNS Un-myelinated Dorsal Vagal System**
    - Freezing (death feigning)
    - Defaecation
    - Dissociation

Now in practice, as already discussed, the autonomic nervous system in its entirety leads to five distinct types / groups of behaviour derived from the above three, which we will now summarise – Figure 3 below is based on, and extrapolated from, Porges 2009 page 53.

[10] The myelinated vagal system discussed in this paper is more precisely the *ventral* vagal system; the un-myelinated includes the *dorsal* vagal system; see also A-8 in this series for further details.

[11] Note that while this paper has focused on the vagal effects on the heart, the control of the heart and heart rate is complex and involves many factors, such as: exercise, blood pressure, feedback from baroreceptors in the transverse aortic arc and the internal carotid arteries; and carbon dioxide levels pCO_2 (see, for example Pöyhönen et al 2004; Yasuma and Hayano 2004; Francis et al 2000).

The Polyvagal Theory, Bodily States and Five Domains of Behaviour
Based on Porges 2009 (especially pp 52-54)**; 2011**

Behaviour system • Anatomical / physiological underpinnings	<u>*Comments on system*</u>
1. Social Engagement • PSNS Myelinated Ventral Vagal system	The myelinated (ventral) vagal system is closely linked in with the muscles of the face and the head that facilitate non verbal communication. This Social Engagement System: • "Promotes positive social interactions" • "Reduces psychological distance" • "Promotes a sense of safety between people" Porges 2009 p 53
2. Mobilisation – *fight / flight* • SNS	Mobilisation and the fight / flight mode is underpinned by the SNS and the adrenal medulla (adrenaline / nor-adrenaline) system. This allows for increased heart rate and increased respiration rate to facilitate in getting more oxygen to the relevant organs and tissues for the required increase in bodily needs for flight / fight (i.e. bodily metabolism). At the same time, the Hypothalamic-Pituitary-Adrenal Cortex axis is activated with the release of Cortisol.
3. Play and foreplay • SNS; Vagal Myelinated (PSNS); Social Engagement system.	In PLAY we combine and integrate the mobilisation of the SNS with the Social Engagement system. In this way our movements, tones of voice, facial expressions and our overall gestures join in an intertwining dance. Our myelinated vagal system acts as the bridge and harmoniser between SNS activity and our Social Engagement system. Foreplay involves activation of the SNS in close conjunction with the myelinated vagal and Social Engagement System.
4. Immobilisation *Life-threat* • Un-myelinated Dorsal Vagal (PSNS)	Reptiles deal with Life-Threatening situations by activating the ancient non-myelinated vagal (PSNS) that results in a shut down of systems, with the animal becoming "frozen" and so appearing dead. Heart rate and respiration are reduced to a minimum. In reptiles this works well as they could survive with low metabolism. This becomes less and less appropriate in mammals, primates, and especially humans,[12] where very low metabolic rates may be associated with tissue / brain damage.
5. Immobilisation *without fear –* *pro-social behaviours* *(mediated by oxytocin)* • Un-myelinated Dorsal Vagal (PSNS)	The ancient un-myelinated vagal system[13] has also been co-opted for vital behavioural activities in mammals – including of course humans. These circuits are utilised, for example, in the following: • Nursing mothers (kyphosis reflex – Porges 2009 p 49); • Childbirth; • Reproduction (i.e. sexual union); • Sleep: enabling humans to sleep safely with each other (and their babies / small children – Porges 2009 p 49; Sunderland 2009[14]); • Digestive and restorative processes. In these situations, oxytocin is released, and so the mobilisation of the un-myelinated vagal system is not associated with fear (Porges 2011 p 17); oxytocin is an antidote to fear (Panksepp 1998 – and see webpage B3 Part ll).

Figure 3
The extended varieties of behaviours / activities associated with the Polyvagal Theory

[12] "Although the brain represents only 2% of the body weight, it receives 15% of the cardiac output, 20% of total body oxygen consumption, and 25% of total body glucose utilization." Magistretti et al 2000.

[13] This system is closely interlinked with the kyphosis reflex and lordosis reflex, utilised in nursing mothers and during intercourse respectively.

[14] Note that in Asian countries where younglings still sleep with their parents, cot death is almost unknown (Sunderland 2009 pp 70-77); especially note Key Facts on p 73 regarding crucial safety aspects of co-sleeping.

A somewhat different – and complementary – perspective of the Polyvagal Theory (PVT) can be found in the next paper in this series – A8: The Polyvagal Theory *and a more sympathetic awareness of the ANS*. Appendix I and II (below) give some further details of the neuro-physiology of the PVT, including aspects that may be of relevance in bronchospasm and asthma.

Appendix I

Some further aspects of the neuro-anatomy and physiology of the polyvagal theory.

As indicated at the start of this article, the polyvagal theory covers complex matters that are still being investigated and worked out. The outline given above is a general overview with inevitable simplifications for the sake of clarity. This Appendix deals at a basic level with some of the complexities in terms of the neuro-anatomy and physiology of the vagal systems, the ANS, affect and emotions.

1. 80% of vagal fibres are afferents (Agostoni et al 1957; Porges 2011 p 27) – i.e. they take messages from the body (e.g. organs such as the heart) to the brain stem. This means that nature has evolved to allow massive information to be relayed to the brain concerning the state of things (i.e. physiology etc) in the different parts / organs of the body. Many of these afferent fibres terminate in the Nucleus Tractus Solitarius (NTS) of the brain stem (Figure 4).
2. Unmyelinated efferent vagal (PSNS) fibres from the Dorso *Motor*[15] Nucleus (DMNX – in the dorsal medial medulla of the brain stem) innervate sub-diaphragmatic organs such as the stomach and intestines – Figure 5 (Porges 2011 p 28). The Vagus is the tenth (X) cranial nerve – so DMNX means that part of the DMN dealing with cranial nerve X.
    - Note that some unmyelinated vagal fibres also go to the heart and bronchi; these fibres can be activated in "life threatening situations" causing, in mammals and humans, cardiac arrest (Porges 2011 p 32) and possibly bronchospasm (Porges 2011 p 45). (In a freeze situation, bronchospasm would reduce oxygen perfusion – fine for reptiles with much lower metabolic rates.)
3. The newer vagal system (PSNS) efferents leave the brain stem from the Nucleus Ambiguus (NA)[16] to structures mainly above the diaphragm – supra-diaphragmatic (Figure 6). These include:
    - The myelinated fast B fibre to the heart and lungs. Specifically, these slow the heart and constrict the bronchi (McAllen & Spyer 1976; 1978).
    - The slowing of the otherwise fast heart rate by these myelinated vagal fibres is crucial for many forms of Social Engagement (the "vagal brake").
    - Efferent fibres to the larynx, pharynx, soft palate, and oesophagus – many of which are crucial for effective Social Engagement.
4. In addition, the rostral (i.e. toward the head / nose) portion of the NA has fibres innervating sub-diaphragmatic structures (Kalia & Mesulam 1980; Porges 2011 p 28) (Figure 6 still).
5. Many of the afferent vagal fibres, as mentioned in 1 above, go to the Nucleus Tractus Solitarius (NTS). The NTS has direct connections to both the DMNX and the NA (see Figure 7).
6. However, there does not appear to be any direct communication between the DMNX and the NA, suggesting that they are evolutionarily distinct parts of the PSNS.
7. Note that the DMNX and the NA both receive direct fibres from:
    - Amygdala (central nucleus);
    - Hypothalamus (Hopkins 1987; Leslie et al 1992; quoted by Porges 2011 p 28);
    - ……in addition to those from the NTS mentioned in 5 above (Figure 7).

Figure 4, 5, 6 and 7 illustrate some aspects of the above.

[15] This is technically a misnomer as afferent fibres terminate in the DMNX which are axiomatically not *motor*; a better name would be "Dorsal Nucleus of the Vagus Nerve" – Porges 2011 p 46 quoting the suggestion of Nara, Goto & Hamano 1991.

[16] So named because of the initial difficulties in determining its borders / connections (Porges 2011 p 27).

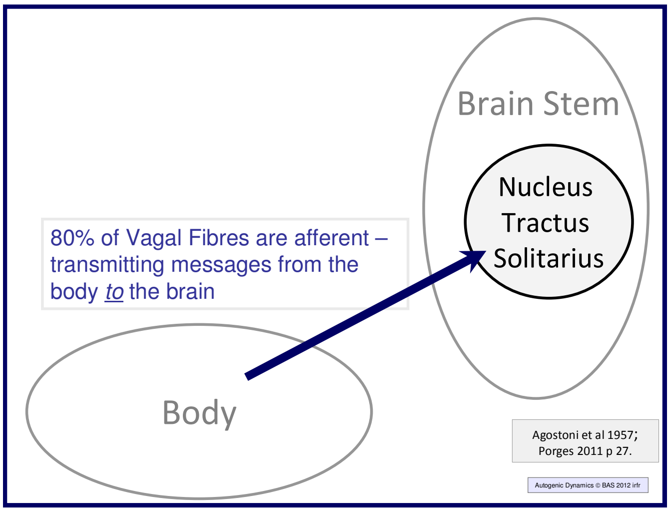

Figure 4
Afferent PSNS Vagal Fibres

- 80% of Vagal Fibres are afferent fibres; most terminating in the Nucleus Tractus Solitarius (NTS).

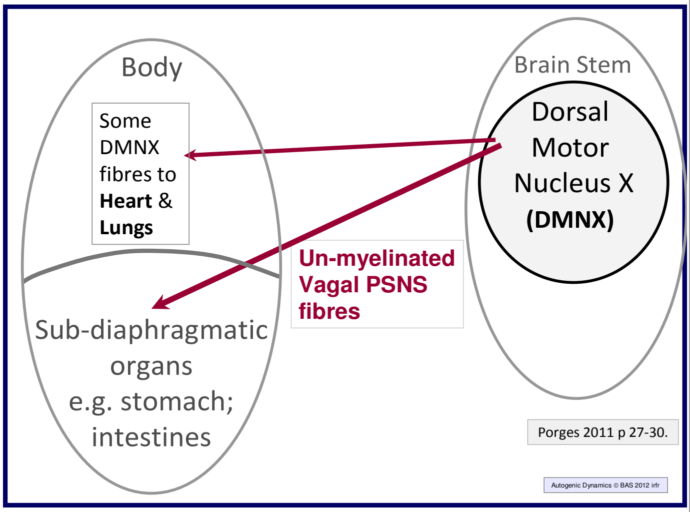

Figure 5
Our ancient (i.e. Reptilian) **PSNS** (un-myelinated)
Vagal Efferents innervate organs mainly below the diaphragm

- Some efferents go to supra-diaphragm structures such as the heart / bronchi.
- Activation of these (in life threatening situations) can be dangerous in humans – with the potential for fatal bradycardia (slowing of the heart).
- (DMNX / Dorsal Vagal Complex)

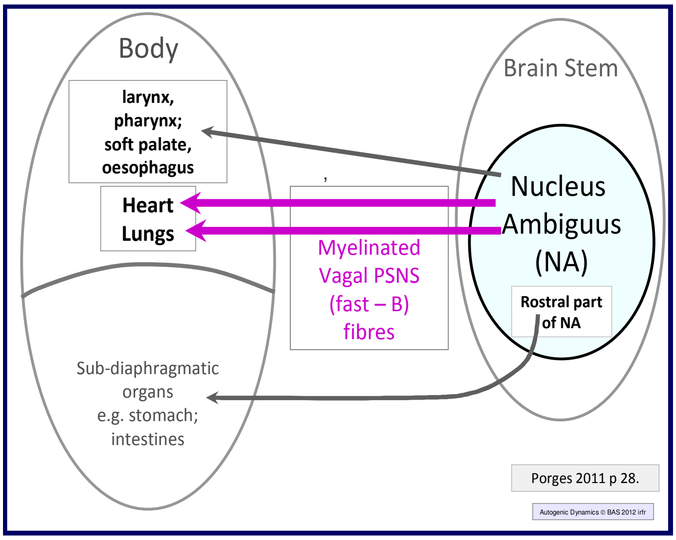

Figure 6
Myelinated ("smart") PSNS Vagal Efferents

- The (newer) mammalian Vagal PSNS efferents start in the Nucleus Ambiguus.
- The thick fast conducting myelinated fibres to the heart (and lungs) are also linked in with Social Engagement (and play) and facial expression.
- (Nucleus Ambiguus is within the Ventral Vagal Complex.)

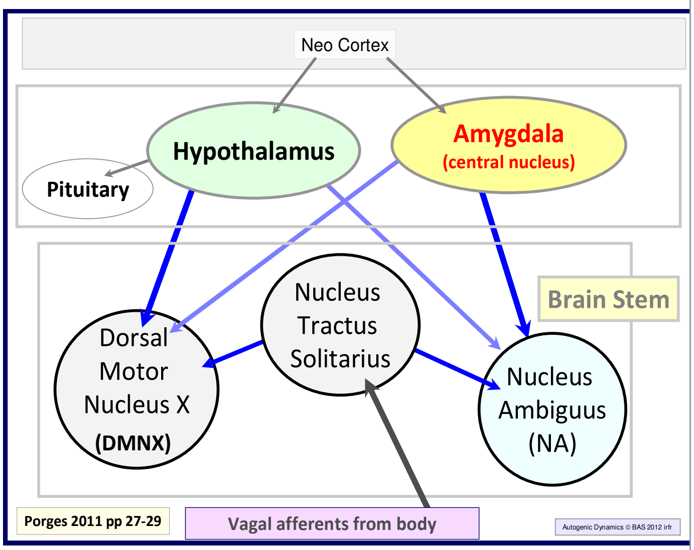

Figure 7
Some brain stem connections with Body, Limbic System and Cortex

- Note: there do not appear to be any direct connections between the DMNX and the Nucleus Ambiguus (Porges 2011 p 28).

All Figures highly schematic

Appendix II
A reflection on asthma in terms of the Vagal Competition Hypothesis
(Porges 2011 p 46)

The bronchi receive PSNS fibres from both the old reptilian un-myelinated vagus and the mammalian myelinated (fast) fibres. These myelinated fibres have a similar rhythmic action as the equivalent fibres do on the heart – where it produces Sinus Arrhythmia (i.e. the cyclical slowing of the heart rate with each expiration – due to increased vagal activity during expiration).

This means that on the in-breath, the broncho-spasmic tendency of the myelinated vagus is relaxed as neural impulses are inhibited. This can to some extent act as an anti-dote to asthma, as each inspiration will be associated with bronchial relaxation. Figure 8 summarises these dynamics.

Breath cycle	Vagal impulses	HEART Rate	LUNGS
IN	↓	No / little effect	Bronchial Relaxation
OUT	↑	Slowing (Bradycardia)	Bronchial Constriction

Based on Porges 2011 p 45-46.

Autogenic Dynamics © BAS 2012 irfr

Figure 8
Effects of breath cycle on heart rate and bronchial tubes

However, there is no such waxing and waning (with respiration) of the un-myelinated efferents from the DMNX to the bronchi. This means that it is possible that bronchi can become vulnerable to DMNX vagal efferent surges that would produce excessive broncho-spasm if the cyclic myelinated vagal impulses are for any reason compromised – such a situation, according to the Vagal Competition Hypothesis, can be potentially lethal in mammals / humans, just as un-myelinated vagal neurogenic bradycardia can be. Note that in this bronchospasmic DMNX reflex afferents from the bronchi terminate in the DMNX and not the NTS (Figure 9B).

Contrast this with the normal healthy situation where:

- vagal afferents from the bronchi that end in the NTS (Figure 9A) will relay information to the NA to provide a "fail safe feedback system" (Porges 2011 p 46) in which the rhythmic reduction in NA efferent (myelinated) impulses to the bronchi – during inspiration – will prevent serious bronchospasm (i.e. asthma)].

These various dynamics are illustrated schematically in Figure 9A and 9B.

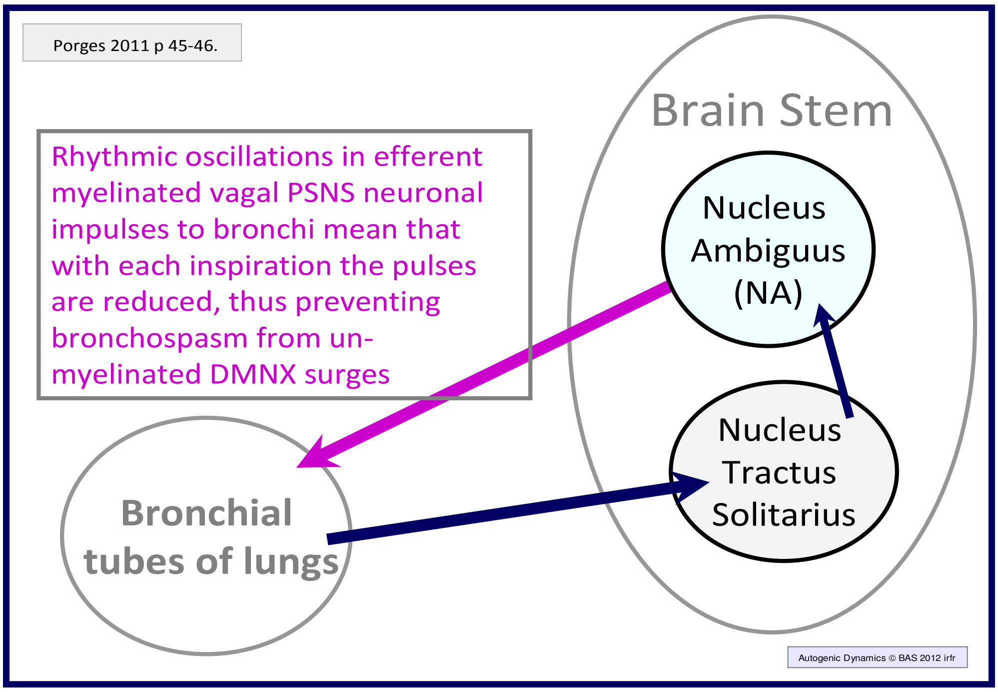

Figure 9A
The effect of Rhythmic Oscillations of myelinated vagal efferents to the bronchi

Comments on Figure 9A.

In primates and humans, the myelinated efferent impulses to the lungs / bronchi are rhythmic – just as they are to the heart where this produces Sinus Arrhythmias: the slowing of the heart with each out breath as a result of an increase in the vagal brake on the heart rate.

So with each expiration, the myelinated efferents to the bronchi will tend towards broncho-constriction, but this is off-set with each inspiration when there will be a relaxation of the bronchi.

Autogenic Training will tend to facilitate such rhythmic myelinated impulses, and thus easy breathing.

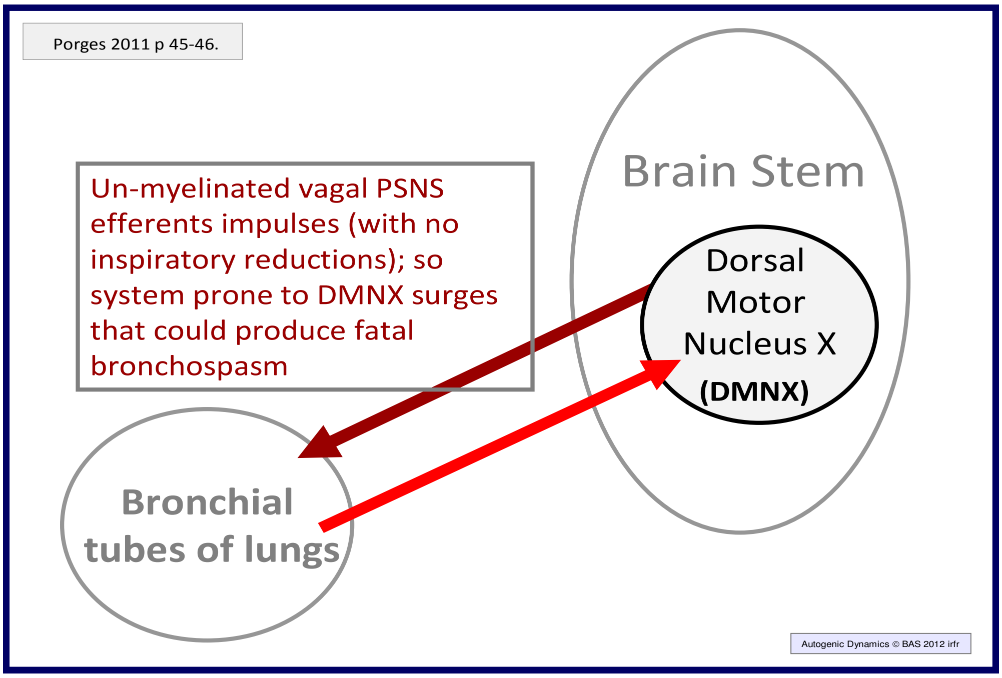

Figure 9B
Potential toxic effects of un-myelinated vagal efferents on bronchial tubes

comments of Figure 9B on next page

Comments on Figure 9B.

Un-myelinated vagal efferents from the DMNX have no such rhythmic oscillations as described in 8A. Furthermore, afferents from the lungs / bronchi are not relayed via the Nucleus Tractus Solitarius but go direct to the DMNX.

If for any reason the myelinated mammalian vagal system is out of action, this means that unopposed un-myelinated efferents can induce broncho-spasm which may be aided by the potentially toxic mono-synaptic afferents direct to the DMNX (Porges 2011 p 46).

In health, the Nucleus Ambiguus plays a vital role in allowing safe rhythmic impulses to go both to the heart and the bronchi, and other visceral organs. These tonic influences "promote health, growth, and restoration" (Porges 2011 p 46); this is known as the "Nucleus Ambiguus (vagal) protection hypothesis"[17].

It is thought that Meditative approaches such as Mediation and Autogenic Training can facilitate these mammalian PSNS rhythmic neuronal pulses.

References and sources

Agostoni, E.; **Chinnock**, I.E.; **DeBurg Daly**, M.; & **Murray** I.G. **1957. Functional and histological studies of the vagus nerve and its branches to the heart, lungs and abdominal viscera in the cat.** Journal of Physiology, 135, 182-205.
Benson, Herbert; and Klipper, Miriam Z; 1975. **The Relaxation Response**; ISBN 0-00-626148-5
Burke, H.M.; **Davis, M.C.**.; **Otte,** C.; **Mohr, D.C. 2005.** Depression and cortisol responses to psychological stress: *a meta-analysis.* Psychoneuroendocrinology. 2005; Oct; 30(9):846-56.
Dobbin, Alastair D and ***Ross***[18], Sheila. **2012. Resilience and Recovery –** *Dumping Dualism* Contemporary Hypnosis and Integrative Therapy pp 136-155
Eisenberger, Naomi I.; & **Liberman**, Matthew D; **2004A. Why it hurts to be left out:** *the neuro-cognitive overlap between physical and social pain*. IN The Social Outcast: Ostracism, Social Exclusion, Rejection and Bullying. (Williams, K.D. et al., eds.), Cambridge University Press.
Eisenberger, Naomi I.; & **Lieberman**, Matthew D.: **2004B: Why rejection hurts: a common neural alarm system for physical and social pain.** Trends in Cognitive Sciences; 2004; vol 8: (7); 294-300
Francis DA, **Coats** JS, **Ponikowski** P. **2000. Chemoreflex-Baroreflex inter- actions in cardiovascular disease.** In: Bradley TD, Floras JS (eds) Sleep Apnoea
Hopkins, D.A. **1987**. **The dorsal motor nucleus of the vagus nerve and the nucleus ambiguus:** *Structure, and connection*. IN: R. Hainsworth, P.N. Williams & D.A.G.G. Many (Eds), Cardiogenic reflexes: Report of the international symposium (pp 185-203; Oxford: Oxford University Press.
Kalia, M; & **Mesulam**, M. M. 1980**. Brain stem projections of sensory and motor components of the vagus complex in the cat. ll. Laryngeal, tracheobronchial, pulmonary, and gastrointestinal branches.** Journal of Comparative Neurology, 193, 467-508.
LeDoux, Joseph. 1998: Emotion, The Memory and the Brain. Scientific American pp 62-71. Updated version (2002) available in PDF on: http://people.brandeis.edu/~teuber/emotion.pdf
LeDoux's illustration from Scientific American 1994: http://www.cns.nyu.edu/home/ledoux/
LeDoux, Joseph. 1999. **The Emotional Brain.** ISBN 798-0-7538-0670-8
Leslie, R.A.; **Reynolds,** D.J.M. & **Lawes,** I.N.C. 1992. **Central connections of the nuclei of the vagus nerve.** IN: S. Ritter, R.C. Ritter, and C.D. Barnes (Eds.): Neuroanatomy and physiology of the abdominal vagal afferents (pp 81-98). Boca Raton, FL: CRC Press.
Lynch, Prof. Thomas R. **"New Thinking in Treatment-Resistant Depression".** Oxford two day workshop 12 & 13th September, 2011 (organised by Grayrock / Stanton Psychological Services).
Magistretti, Pierre J.; **Pellerin,** Luc; and **Martin,** Jean-Luc Brain. **2000. Energy Metabolism:** *An Integrated Cellular Perspective* • [P. J. Magistretti, L. Pellerin, and J.-L. Martin: Institut de Physiologie, Faculté de Médecine, Université de Lausanne, CH 1005 Lausanne, Switzerland; accessed via www on 30.iv.2012: *http://www.acnp.org/g4/gn401000064/ch064.html*
McAllen, R.M.; & **Spyer,** K.M. 1976**. The location of cardiac vagal preganglionic motor-neurones in the medulla of the cat.** Journal of Physiology, 258, pp 187-294.
McAllen, R.M.; & Spyer, K.M. /

[17] Note that inhibition of the Nucleus Ambiguus for short periods of time will remove the vagal brake – to allow for fast movements / locomotion etc by increasing metabolic output; this will be adaptive to the individual. However, prolonged withdrawal of the NA resulting in no rhythmic vagal impulses can put organs and the organism at risk – this is knows as the "Nucleus Ambiguus (vagal) withdrawal hypothesis" (Porges 2011 p 46).

[18] No relation to Ian Ross

References and sources *continued*

McAllen, R.M.; & **Spyer,** K.M. 1978 The **location of cardiac vagal preganglionic motor-neurones projecting to the heart and lungs.** Journal of Physiology, 282, pp 353-364
McEwen, Bruce; & **Lasley**, Elizabeth N: **2003**. Allostatic Load: When Protection Gives Way to Damage. Advances; in Mind-Body Medicine; Spring 2003; 19; (1); 28 - 32)]
McEwen, BS; **2004; Protective and Damaging Effects of the Mediators of Stress and Adaptation: Allostasis and Allostatic Load.** **IN:** IN J. Schulkin (Ed.): Allostasis, Homeostasis, and the costs of adaptation (pp 65-91) ISBN 0-521-81141-4
Miu A. C., Heilman R. M., Miclea M. 2009: Reduced heart rate variability and vagal tone in anxiety: trait versus state, and the effects of autogenic training *Auton. Neurosci.* 2009; 145(1-2): 99-103
Nara, T; **Goto**, N; & **Hamano**, S. **1991. Development of the human dorsal nucleus of the vagus nerve:** *A morphometric study.* Journal of the Autonomic Nervous System, 33, 267-276.
Panksepp, Jaak: **1998. Affective Neuroscience:** *The Foundation of Human and Animal Emotions;* Oxford University Press; ISBN 0-19-509673-8.
Panksepp, Jaak: **2009. Brain Emotional Systems and Qualities of Mental Life.** (pp 1-26) IN: The Healing Power of Emotion – Eds: Diana Fosha, Daniel J. Siegel, & Marion Solomon. ISBN 978-0-393-70548-5
Panksepp, Jaak; & **Biven,** Lucy. **2012. The Archaeology of Mind:** *Neuroevolutionary Origins of Human Emotions.* ISBN 13-978-0-393-70531-7
Porges Stephen W. **1997. Emotion**: *An evolutionary by-product of the neural regulation of the autonomic nervous system*. Annals of the New York Academy of Sciences, 807, 301-318**.**
Porges Stephen W. **1998. Love:** *An emergent property of the mammalian autonomic nervous system.* Psychoneuroendocrinology, 23, 837-861
Porges, Stephen W. 2001. **The polyvagal theory:** *phylogenetic substrates of a social nervous system.* International Journal of Psychophysiology 42 (2001) 123 – 146)
Porges, Stephen W. **2008 The Polyvagal Theory:** *New insights into adaptive reactions of the Autonomic Nervous System*. Cleveland Clinical Journal of Medicine. Vol 75; Suppl. X; pp S1-S5
Porges, Stephen W. **2009 Reciprocal Influences Between Body and Brain in the Perception and Expression of Affect.** IN: The Healing Power of Emotion – Eds: Diana Fosha, Daniel J. Siegel, & Marion Solomon pp 27 - 54 ISBN 978-0-393-70548-5
Porges, Stephen W. **2011. The Polyvagal Theory** – *Neuro-physiological foundations of Emotions, Attachment, Communication, Self-Regulation.* ISBN 978-0-393-70700-7
Pöyhönen M.**; Syväoja** S.**; Hartikainen** J.; **Ruokonen** E.; **, Takala** J. **The effect of carbon dioxide, respiratory rate and tidal volume on human heart rate variability. Acta Anaesthesiol Scand. 2004 Jan;48(1):93-101**
Ross, Ian R.F. 2010. **Autogenic Dynamics** – *Stress, Affect Regulation and Autogenic Therapy.* ISBN 978-0-9563993-0-4
Schore, Alan N. 2009. **Right-Brain Affect Regulation** – *An Essential Mechanism for Development, Trauma, Dissociation and Psychotherapy.* IN: D. Fosha, M. Solomon, & D. Siegel (Eds.), The healing power of emotion: Integrating relationships, body and mind. *A dialogue among scientists and clinicians* (pp. 112-144). New York: WW Norton Chapter 5
Yasuma, Fumihiko and **Hayano**, Jun-ichiro. **2004. Respiratory Sinus Arrhythmia:** *Why Does the Heartbeat Synchronize With Respiratory Rhythm?* CHEST / 125 / 2 / FEBRUARY, 2004 680-690
Wallnöfer, Heinrich. **2000. Autogenic Therapy:** *History – Development – Future.* Schultz Memorial Lecture 11.11.2000.
Wikipedia 2012: Polyvagal Theory: http://en.wikipedia.org/wiki/Polyvagal_Theory
Schultz, J.H; **Luthe,** Wolfgang; **1969. Autogenic Therapy: Volume l; Autogenic Methods**. [BAS 2001]; ISBN 0-356-22736 -7
Sunderland, Margot. **2006 / 2007 What every parent needs to know** ISBN 978-1-4053-2036-8

Linked themes in this Autogenic Dynamics section

A1	The Stress Response, the Relaxation Response, and the Tend and Befriend Response.
A3	Towards a concept of happiness and well-being
A8	The Polyvagal Theory – *And a more sympathetic awareness of the ANS*
B3	Part l: The Origins of Affect and Affective Neuroscience – *And the misplacing of Affect in the neo-cortex*
B3	Part ll: Emotional Operating Neuro Circuits – *a brief introduction to Panksepp's model*
B5	Emotions, Frontal Lobe dynamics, and Autogenic Training
B10	Snakes, Conditional Stimuli, and Equanimity – *Approaches to treating mind-body disturbances*
B11	Transforming Distressing Mind-Body-States – *from Negative Ruminations towards Well-Being*
B12	Affect Labelling, Autogenic Training, and reducing Emotional Distress
C2	Mindsight, our seventh sense – *and associated middle pre-frontal cortex functions*
C7	Being in touch with our feelings – Hemispheric Integration *(includes the concept of Affect Labelling)*
D1	Reflections on foundations for mindfulness

Thanks to Annie Sturgeon and Michael Ross for their helpful suggestions and proof reading.