

The Physiology of Connectedness

Social, Therapeutic, and Educational Practice
of Polyvagal Theory
A Learning Guide

MICHEL ACKERMANN & MARVIN MILES FERRANTE

Chapter 1 — free giveaway for conference attendees

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Theory**

A Learning Guide

Michel Ackermann & Marvin Miles Ferrante

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CHAPTER 1

The Autonomic Nervous System

... and How It Stands Up for Our Wellbeing

by Michel Ackermann

1.1 What Is a System?

To me, a system is something like a well-functioning (often also not-so-well-functioning) shared flat — a collection of "puzzle pieces" (in this case: people, things, situations, processes, etc.) that are interconnected, influence one another, and together accomplish something no single piece could manage alone. Systems exist everywhere: in nature, in our bodies, in technology, in society, and in science. The exact angle from which you view a system depends on who's looking: biologists, engineers, or nerds with diagrams. Or systemic therapists, for that matter. But a few ground rules always apply ... and a system is a fascinating thing for many reasons — for instance, when it comes to which influences support or impair the self-steering of a self-regulating system (such as the Autonomic Nervous System). Fundamentally, though, with any system we always encounter a mix of everything that needs to work together for anything to function *together* at all.

A systemic process always has a few main ingredients: first, there are the *elements* — the building blocks a system is made of. These can be objects, such as technical components like processors. But they can also be people, when we're talking about social systems. These elements don't simply hang around aimlessly; rather, they stand in *relationships* to one another. Their connections and communications determine how the system ticks. And then ... there's also something like a *structure*, which, similar to a blueprint, shows how the elements and their relationships are organized.



- ✓ Systems bring about change or maintain balance.
- ✓ Systems communicate via internal and internal-external signal pathways (with the environment).
- ✓ Systems act and react according to guidelines and rules.
- ✓ Systems react to external and internal influences.
- ✓ Systems have elements that stand in relationships and connections.
- ✓ Systems generally require a structure.

Systemic processes have a *goal* — otherwise it would hardly be a system: for example, a billiard table has a purpose, and the players around it have a

goal, but the table and its balls don't thereby become a system. They lack some fundamental properties for that.

The *function* of the system (of a functioning system) is, in a sense, the *goal* toward which everything in the system is working: whether that's a car meant to drive, or an ecosystem that has to maintain its balance, or indeed our *Autonomic Nervous System* (→ Autonomic Nervous System), which steers and balances our body so that it can function. And for everything to function "systemically" in terms of its goals, there are (systemic) *interfaces*: every system has an invisible — but sometimes very visible — line that communicates what belongs to it and what doesn't: the asphalt doesn't necessarily belong to the system "car," even though we need it in order to drive. Emotions don't belong directly to the Autonomic Nervous System. But without them, this system works a lot worse.



- ✓ Systems have a function, determined by their (goal-)task.
- ✓ Systems communicate via interfaces (and also via threshold values).
- ✓ Systems function through exchange via signal pathways.
- ✓ Systems have internal elements and external co-players and "suppliers."

Last but not least: systems are not rigid structures. Thanks to their *dynamics*, they can develop, adapt, or even fall apart when push comes to shove. Whether ecosystem, smartphone, or family — systems exist all around us. Some arise on their own, like nature and its ecosystems. Others we humans build ourselves, such as technical devices or jointly developed *social structures*. And there are "abstract" systems too, like "logic," which clever people have described. But one thing they all have in common: they can be very impressive. And sometimes they're also pretty complicated.

FIGURE 1.1 — What Is a System? The Autonomic Nervous System (ANS) as an Example

[existing English diagram — insert here]

Takeaway: As a dynamic system, the ANS continuously evaluates our safety and flexibly navigates between different states in the service of wellbeing and survival.

A balance seems to be better for systems than an imbalance ...

Systems exist almost everywhere. Take a "motor vehicle," for example (this word itself has "system" built into it, so to speak) — here, mechanical, electrical, and digital components work together like a well-rehearsed band to move the vehicle from A to B. Or a company: employees, work processes, and available (or over-used) resources throw themselves together to offer products or services. An ecosystem, where animals, plants, and microorganisms interact with their environment, can look as though they're throwing an invisible party — all so that everything stays in balance. And a

balance generally seems to be better for systems than an imbalance. More on that later.

Then there's our actual topic: the *Autonomic Nervous System* (ANS). Without you noticing much of it, it regulates, among other things, heartbeat, breathing, and digestion. It communicates hormone release in response to physiological and social needs — and, on top of that, it also regulates communication with various brain regions. It *manages* the energy balance of our whole bodily-psychological system and is thus something like the invisible assistant director for your life's vital functions. Maybe even the director herself! So ... a *system*, in this case, is not just very impressive, but also vital to life. Whether in nature, technology, or society: systems have one thing in common. It's worth understanding their functioning, their dynamics, and their interactions with their environment.

Part of how the ANS functions — no surprise — involves functioning nerve pathways. But what exactly is a nerve? Read on in the next section.

review: #system #elements #function #goal #structure #dynamics
#balance

1.2 What Is a Nerve?

A nerve isn't just some plain cable sending signals back and forth. It (the nerve) forms networks of nerve pathways together with other nerves, and is thus the communications technology of our body, plain and simple. Because the nerve *mediates* (informatively) between the outer world and our inner responses to it.

A nerve, furthermore, consists of many small conduits — the *axons* — that transport electrical impulses. These axons are wrapped in a kind of insulating layer made of connective tissue. There are also blood vessels to keep the networks of nerves running. Some axons (more precisely, about 40 to 50 percent in the body) need to be especially fast in order to transmit vital signals in time. For this, they have a so-called *myelin sheath* — a kind of "rubber coating" made of fats and proteins that provides better insulation for the nerve cables and thus less transmission loss along the line.

By the way: the *vagus nerve* is a colorful mix of myelinated and non-myelinated fibers, and that's exactly what makes it so special. The majority of its fibers — 70 to 80 percent — have no myelin sheath. These non-myelinated fibers are the long-distance runners among nerve fibers. They don't need a high-speed connection, because they take care of tasks like the relaxed "wave motion of digestion." Their motto is: a little slower, but efficient. But the vagus nerve also has its fast kids on the block:

Its myelinated fibers, making up about 20 to 30 percent, are responsible for the snappy stuff. Here we're talking about motor commands for the larynx, the cough reflex, or precise sensory feedback in coordination with other so-called *cranial nerves* (→ Cranial Nerves). Thanks to their myelin sheath, signals zip through the nerve at lightning speed — perfect for reflexes or for

the articulation of speech (the vocal organs). And why is there this mix of fast and slow nerve fibers? Quite simply: the vagus nerve is a master of efficiency. Where speed counts, it relies on myelinated fibers. Where sustained operation is called for, it trusts its energy-efficient non-myelinated colleagues. That's how it manages to deliver both high performance and sustainability. It's really a multitasking pro, with many more remarkable qualities, as we'll see.



- ✓ The vagus nerve consists of myelinated and non-myelinated fibers.
- ✓ Myelinated fibers conduct faster.
- ✓ The vagus nerve is one of the so-called cranial nerves; it is the 10th cranial nerve (cranium = skull).
- ✓ The vagus nerve is the main nerve of the parasympathetic branch of the ANS.
- ✓ It works closely with other cranial nerves.

Back to nerve fibers in general: these nerve bundles — yes, that's literally what they are! — function in two directions: on the one hand, they carry information from the outside world into the brain (for example, that the stove is hot), and on the other, they send commands back to the muscles to trigger a response (get your finger off the stove!). There are then also the "autonomic" nerves, which take on something like the facilities management of our body: breathing, digestion, heartbeat, communication of the body with our evaluation centers in the brain — all of that and more runs through them.

These nerves of the *Autonomic Nervous System* both activate and mobilize us, and are equally capable of powering down the "pulse of life" again. We speak here of a *sympathetic* (activating) and a *parasympathetic* (down-regulating) function of the Autonomic Nervous System. *Polyvagal Theory* distinguishes, within the parasympathetic functions of the *vagus nerve*, between a *ventral* (front) branch and a *dorsal* (rear) branch, referring to the point of origin of the vagus nerve in the *brainstem*.

Data highway

Neurologically speaking, nerves are, among other things, concerned with processing, relaying, and coordinating electrical and chemical signals. In our bodily system, we have a kind of "data highway" for this. There, work is done using "action potentials" — brief electrical voltage impulses — that sustain the propagation of excitation. And at so-called *synapses*, the crossing points, things get chemical: neurotransmitters shoot across and fire up the next nerve cell. When these processes are disrupted, the consequences can be severe. Take, for instance, so-called peripheral neuropathy, where nerve pathways outside the "*Central Nervous System*" (→ Central Nervous System) are damaged. It feels as though the body suddenly has dead zones. So one of your legs may suddenly stop bearing its weight. Nerves, unsurprisingly, are very, very important.

When we say ... "that gets on my nerves," we're also talking about the stimulus processing of the Autonomic Nervous System

In psychology, the term "nerve" often shows up metaphorically. But it's still closely tied to biology (or biopsychology): stress, fear, or joy — all of that influences the activity of the *Autonomic Nervous System*, but ... it also works the other way around: the Autonomic Nervous System influences whether and how we experience joy, anger, or stress.¹ When we say, for instance, "that gets on my nerves ...," we actually also mean that our stimulus processing — including that of the Autonomic Nervous System — is overloaded. No wonder, since stress can act directly on the body, from tension to pain to serious illness.

To sum up: *a nerve is a biological masterpiece* that connects us with the world, steers our life, and co-activates our emotions. Whether as an electrical signal carrier, a neurological network, or a psychological stress indicator — without nerves, nothing here works. That said ... the energy transported via nerves should somehow also be deployed and regulated in stable processes. We'll talk about that in the next sections.

review: #axon #myelinsheath #sympathetic #parasympathetic

1.3 Why Do Systems Need the Capacity for Self-Regulation?

The Autonomic Nervous System is a true masterpiece of *self-regulation* (→ Self-Regulation), and that is exactly what secures our survival in a world that constantly presents new challenges. While we're lying on the couch or rushing through the city, a highly complex interplay of autonomic processes runs in the background: the heart beats faster when danger threatens, breathing adjusts, and digestion is scaled back — all without a single conscious thought. Why? Because our body always strives toward one goal: stability and balance, or, in more scientific terms: *homeostasis*.

Self-Regulation: Inner calming from one's own resources, made possible developmentally through previously experienced co-regulation.

The systems theorist Ross Ashby would have delighted in studying the *Autonomic Nervous System*, because his "Law of Requisite Variety"² describes exactly this: the more flexibly a *system* can respond to outside influences, the better equipped it is to compensate for disturbances. The Autonomic Nervous System is a perfect example of this. Via *feedback loops* (something like a cycle of ongoing feedback), it continuously monitors our internal states and adjusts them at lightning speed — whether in response to a sudden drop in blood pressure or a surge of adrenaline.

It becomes even more fascinating when we bring in Francisco Varela, another systems thinker. His theory of *autopoiesis* (= self-production) explains how biological systems actively generate and maintain their own structures. The Autonomic Nervous System, from this autopoietic perspective, would be our tireless conductor, ensuring that the heart, lungs,

brainstem, and other organs and control centers of the body work well together ... while still preserving their own independence. It's like a dance in which every movement (as activation and calming) depends on the one before — precise, flexible, and always oriented toward the bigger picture.

review: #selfregulation #adaptation #ashby #varela

1.4 What Does the Concept of Homeostasis Describe?

Without the capacity for self-regulation via the ANS, we would not be able to adapt to the constant changes in our environment

For the *Autonomic Nervous System* (ANS), this also means that it keeps us alive without us first having to concern ourselves with it. It reacts to stress, regulates temperature and energy balance, and thereby ensures that we can function under the most varied conditions. Without this capacity for self-regulation³ (of the ANS), we would not be able to adapt to the constant changes in our environment. It is, in truth, a genuine marvel of evolution.

Stephen Porges' *Polyvagal Theory* has opened up, in both the scientific and the therapeutic community, a new and — for many — surprising perspective on the Autonomic Nervous System and its contribution to self-regulation and *co-regulation* (→ Co-Regulation) with other people. He has researched the truly remarkable ways in which the *vagus nerve* influences us in *social communication*, enabling a "safe connection" in social interaction in both an activating *and* a calming way, by dampening and practically moderating reflexive fight-or-flight responses (→ Fight-Flight) that may be mobilized by the "sympathetic" branch. In a sense, the multilayered regulatory functions of the vagus nerve thus make it possible for us to experience community with others in a relaxed and regulated way.

Stephen Porges has thereby shown that it isn't only about a bodily *self-regulation* of physiological processes, but also about a self-steering *social regulation* ... and by that he *also* means the co-regulation that happens between people. The goal of all these regulatory processes, however, is — as described above — a state of *inner and outer balance*, an equilibrium described by the concept of *homeostasis*. We'll discuss that in the next section.

review: #selfregulation #adaptation #ashby #varela

Homeostasis — that sounds at first like a *fancy* term straight out of biology, but in truth it describes something fundamental that happens in pretty much every living system. Whether plant, animal, or human ... homeostasis is a system's drive to maintain its inner equilibrium, no matter what's happening outside. It's like a constant balancing act, in which the system tries to self-regulate in order to function optimally.

And: all of this runs more or less fully automatically, without you having to give it much thought. Your body works at this *homeostasis* (→ Homeostasis)

like a high-tech thermostat that's checking around the clock whether everything is within the green zone. Too warm? Your body switches on the sweat glands so you can cool down. Too cold? It delivers goosebumps and shivering to generate warmth. Homeostasis is thus the invisible building superintendent in your body, always making sure the "technical stuff" keeps running somehow — but who also opens a window when it gets too stuffy in the hallway.

While homeostasis describes the goal (i.e., the balance), self-regulation is the reliable path to get there

The *self-regulation* discussed above is, so to speak, the *modus operandi* of homeostasis. While homeostasis describes the goal (i.e., the balance), self-regulation is the reliable path to get there.

Homeostasis: Maintenance of stable physiological (and energy-related) values. The basis for physiological balance and the felt sense of bodily safety.

These are all the processes and mechanisms that run in order to restore balance whenever it wobbles. It's a bit as though your body is continuously making little *adjustments* (compensatory micro-movements), like dancers who stay in balance even when the floor wobbles beneath them. At its core, *self-regulation* is what makes living systems into "survival professionals." They respond to changes in their environment, adapt, and make sure you keep functioning regardless. Without this capacity, life as we know it would simply be impossible.

Homeostasis, then, is not merely a biological concept — it is the fundamental principle of life itself. And our *Autonomic Nervous System* (→ Autonomic Nervous System), as we saw in Section 1.3, works in a *self-regulating* way toward ... exactly! ... toward homeostasis. What's new, from the perspective of Polyvagal Theory, is Stephen Porges' vantage point, which links these processes more explicitly with our socially oriented *behavior* and the parasympathetic *vagus nerve* (which grants us the regulatory capacity for social openness and connection), as well as with our overall *wellbeing*.



- ✓ Homeostasis and self-regulation are closely connected. Why?
- ✓ The ANS regulates neurophysiological functions — and influences psychological ones. How does it manage that?
- ✓ The ANS maintains an inner balance and needs external circumstances to do so.
- ✓ Why does the ANS "react" to emotions (even though, in a sense, it can also be seen as part of emotions)?

His perspective thus emphasizes human *salutogenesis*, which can be supported by the *feedback systems* in connection with the vagus nerve.

Our body, viewed neurophysiologically, is like a smart round-the-clock doorman at work

The concept of homeostasis describes the capacity of a *system*, particularly biological systems, to maintain a stable inner balance, and this despite often rather *nerve-wracking* (!) changes in the environment. This principle of homeostasis plays a central role also in the physiology of our body ... and in the neurophysiology of the Autonomic Nervous System as well: the body, viewed neurophysiologically, is like a smart round-the-clock doorman at work, keeping things like temperature, pH level, blood sugar, or fluid balance, our cellular respiration as well as our digestion and more (e.g., our psychological wellbeing!) within the best possible range.

The *Autonomic Nervous System* (ANS) communicates our energy budgets in these processes: does it need more energy, or can energy be saved in the household? *We* ourselves, though — meaning our self-awareness — don't pick up on much of this consciously. At the very least, no one has said much about how their ANS regulates digestion, even though that can indeed be quite palpable (via so-called *interoception* [→ Interoception], see Section 2.2). Nevertheless, we are strongly influenced by these processes of self- and co-regulation (→ Co-Regulation) with respect to our homeostasis. Because our bodily and psychological wellbeing goes hand in hand with these regulatory processes.

Here's a takeaway: *homeostasis* is indispensable for our survival, since major deviations from the necessary conditions can lead to disturbances or even to life-threatening danger. In a broader sense, the term is also used in other fields, such as psychophysiology and the Polyvagal Theory situated within it, as well as in ecology (the balance of ecosystems).

The Autonomic Nervous System is, in a sense, the MVP (most valuable player) of homeostasis, because it's the one that first ensures that vital energy can come into *balance* through a well-calibrated *activation* or *deactivation* of our energy systems. All of this also has a major influence on our *behavior* — and thus on our *psychophysiological* wellbeing. Because *we ourselves* are the ones (... yes, unfortunately it's also us!) who help determine whether the *Autonomic Nervous System*, in cooperation with our behavior, can do its job well.

review: #homeostasis #psychophysiology #selfawareness #interoception #selfregulation #coregulation

1.5 The Autonomic Nervous System Communicates with the Environment — and Thereby Indirectly with Us, Too

The Autonomic Nervous System, ANS for short, is like an invisible director who, behind the scenes, is constantly making sure our body functions smoothly — and that in close interaction with our environment. You can picture it as a sophisticated system of *feedback loops* (input-output evaluations that regulate one another), assigning two leading roles: the *sympathetic* branch and the *parasympathetic* branch. While the sympathetic

branch — besides its job of supplying activating energy in everyday life — can also send us into a "fight-or-flight" mode, driving up heart rate, for instance, so we can run or fight in an emergency, the parasympathetic branch provides relaxation (keyword: "rest and digest"). These two systems are not opponents, but a perfectly coordinated team that hits the right note in every life situation ... as long as we don't get in the way (see Section 1.6, the passage "Chronic stress damages the blood-brain barrier ..."). The parasympathetic branch also protects us in everyday situations from harmful hyper-mobilization — for example, by responding to signals of relaxation and safety in social exchange. That, of course, presupposes that we're still able to interpret such signals as "safe."

The ANS's dialogue with the environment begins with *sensory perception*. Stimuli from the environment — whether a loud noise or the sudden sight of danger, but also pleasantly activating sensory impressions — are picked up by our sense organs and relayed directly to the *diencephalon* (the deep brain region that includes the hypothalamus). There, it's decided in a flash how the body should respond. In the face of danger, the sympathetic branch triggers the release of *stress hormones* such as adrenaline, which speed up heart and breathing rate while putting the muscles on high alert. But that's only one side of it. *Effector responses* such as sweating, inhibited digestion, or elevated blood pressure are likewise part of the regulatory process; they help us respond efficiently to the environment and, in the end, survive better in a well-adjusted state of balance.

The parasympathetic branch, as already hinted at above, is the relaxed buddy of the sympathetic branch — basically the yin to the ANS's yang. It's the one saying, "Hey, let's just chill!" And it does that quite cleverly. When it comes to the heart, for example, it orders up acetylcholine via the vagus nerve — a neurotransmitter that calms the sinus node in the heart. Result: your heart rate comes down, and your heart can relax and prepare for the next round. Same story with breathing: where the sympathetic branch pumps up your bronchi so you can pull in more oxygen, the parasympathetic branch makes sure they relax again afterward. In rest mode, you don't need high-performance breathing.

Even when the sympathetic branch is at the wheel, the parasympathetic branch often still has a hand on the steering wheel

What's fascinating is how these two systems play off each other. It's like a well-rehearsed DJ duo: the sympathetic branch cranks up the party, but when things get too wild, the parasympathetic branch turns the music down and brings you back to normal level. This back-and-forth is no coincidence — it's a perfectly tuned feedback system that constantly checks what your body needs, in and with its environment, right now.

Even when the sympathetic branch is at the wheel, the parasympathetic branch often still has a hand on the steering wheel. This is called the "Vagal Brake": imagine you're stressed but not fully at your limit: the parasympathetic branch, in such situations, keeps you from completely spinning out — or even helps you enjoy strenuous physical activity, at best. That's of existential importance. Because without this collaboration, you'd

be either constantly overdriven or completely lethargic — neither of which is a good option. In short: *the parasympathetic branch is the calming genius*. Its abilities help you come back down after the action. Without it, you'd be trapped in chronic stress. It's not about hitting the gas, put plainly — it's much more about finding the right timing for *releasing* the brake! We can only tighten the vagal brake consciously in indirect ways — for example, through breathing exercises or a cold shower.

Feelings such as fear or relaxation interact with the ANS

The Autonomic Nervous System thus works within a feedback process. Via so-called *afferents*, organs send information to the brain, which then returns the appropriate commands via *efferents*. A classic example: if blood pressure drops, special sensors in the blood vessels register it and report the problem to the brain. The sympathetic branch kicks in, constricts the blood vessels, and drives the pressure back up. But it's not just physiological states that feed into these feedback mechanisms — our *emotions and thoughts* do too. Feelings like fear or relaxation influence the ANS directly — and conversely, the ANS makes itself known through bodily signals, signals that can in turn trigger emotional reactions in us.



- ✓ What does the Autonomic Nervous System respond to?
- ✓ Which "tools" does it use to keep us in balance?
- ✓ How can we understand the vagal brake?
- ✓ What role does our felt sense of the body play as the sympathetic and parasympathetic branches do their work?

It's worth adding: the signals of the *ANS* aren't only there for survival. They're equally a channel of communication with ourselves. Heartbeat, "gut feeling," or shallow breathing in stressful situations give us subtle — or sometimes very clear — feedback about our state. Feedback from the ANS is thus integrated into our *awareness* and shapes our (self-)perception. We can, in other words, learn to read the signals our Autonomic Nervous System sends as "safety signals."

Stephen Porges developed a concept in Polyvagal Theory for exactly this phenomenon: he speaks of the body's "*neuroception*" — meaning: you don't decide alone, through your thoughts, whether something is safe or not. In the background, your cooperating body is running an entirely different story: your Autonomic Nervous System is checking the situation — a process that remains *unconscious* to you. It notices when the "energy" in the room, and within you, shifts, even before your conscious mind has figured out what exactly is wrong. That sounds a bit *spooky* ... but on closer inspection, it's a brilliant protective mechanism from our evolution. Your body detects potential threats before you can even say "Boo!" (→ Neuroception, see also Section 2.3).

There's a finely tuned orchestra of detection and response deciding whether you keep strolling along, relaxed, or take cover instead

So what exactly is special about this collaborative work our body does? This *detection* doesn't just apply to external stimuli like a growling dog or an approaching car. It also picks up on internal states: heart rate, breathing pattern, muscle tension — all of it gets factored in and monitored on our behalf. It's like a high-tech security system continuously cross-checking with our body. A finely tuned orchestra of detection and response, deciding whether you keep strolling along, relaxed, or take cover instead. At its core, Polyvagal Theory shows us that this unconscious detection influences not only our behavior, but also our capacity to feel safe and connected. Your nervous system doesn't just have an eye on danger — it also checks when it's time to relax and build trust.

The Autonomic Nervous System is a multi-talent quietly doing great things for our wellbeing

Through body-based therapeutic methods such as breathing exercises or biofeedback, we can also actively influence the Autonomic Nervous System and restore our balance. All in all, the ANS is an impressively dynamic system that connects us with our environment and with ourselves. It doesn't just regulate fine-tuning within the body, but also balances the bodily foundations of our experience and behavior — it's a genuine multi-talent, quietly doing great things for our wellbeing behind the scenes. But, of course, the functioning of the Autonomic Nervous System requires effective communication with the brain and with the *Central Nervous System* there, which continues down into the spinal cord. We'll talk about that in the next section.

review: #detection #unconscious #afferents #efferents #neuroception
#behavior

1.6 How Does the Autonomic Nervous System Communicate with the Brain?

Wasn't there something like the blood-brain barrier? And how exactly does the ANS communicate with the brain? Doesn't the *Central Nervous System* (→ CNS) have full control there? And how, then, is communication with the body and its autonomic nerve team supposed to work?

Let's go step by step: the *blood-brain barrier* is something like the brain's bouncer — a control freak who decides who gets in and who doesn't. Imagine you want to get into the hottest club in town, but the bouncer first checks whether you have the right molecular size, the correct charge, and the right chemical properties on top of that. That's exactly what the blood-brain barrier does. It's so clever that it lets nutrients like glucose or oxygen through, while keeping toxins and microbes coldly locked out. *Tight junctions* (a kind of molecular handcuffs between so-called endothelial cells) make sure nothing slips through that shouldn't. Safety comes first,

especially when it's about your brain. But here's the crucial part: this barrier isn't just a shield — it's also a communication hotspot. Astrocytes, pericytes, and endothelial cells are constantly chattering with one another to keep this barrier optimally regulated.

Things get complex once the *Autonomic Nervous System* enters the picture. Because under stress, your sympathetic branch triggers the rapid transport of hormones like adrenaline and (under sustained stress) cortisol, which signal to the barrier: "Heads up, we've got a problem here!" That can be helpful in the short term, but over time it makes the barrier brittle — and you really don't want that. Adrenaline and cortisol — the stars of your stress team — talk first to the blood-brain barrier (BBB), and not without reason! The BBB, the bouncer of your brain, lets itself be influenced by these hormones. Why? So that your *Central Nervous System* (CNS), in coordination with the Autonomic Nervous System, can properly respond to whatever stressful action is happening out there, whether that's being chased or sitting an exam.

Adrenaline: the sympathetic branch's fast messenger

Adrenaline⁴ is the one sprinting onto the stage whenever there's a fire to put out. It binds at lightning speed to adrenergic receptors on the endothelial cells of the blood-brain barrier — essentially a direct line into the control center. The result? Signaling pathways are activated that make the barrier a bit more permeable for select molecules. So, for example, glucose (sugar), your brain's favorite snack, can flow through faster. At the same time, adrenaline makes sure that other messenger substances, like cytokines, get a say at the margins too. And as if that weren't enough, adrenaline also has an indirect effect: it makes sure astrocytes and pericytes, the guardians of the barrier, pitch in properly — all in service of the grand entrance the sympathetic branch has staged.



- ✓ Why do we need a blood-brain barrier?
- ✓ How does the ANS communicate with the CNS?
- ✓ What role do hormones play in this?
- ✓ When is the BBB compromised — see also the following section.

Cortisol enters the scene a bit later, but it has staying power. This hormone docks onto receptors on the (above-mentioned) endothelial cells and takes on the role of the strategist. In moderate amounts, cortisol stabilizes the barrier (BBB) like a professional site manager: it reinforces the *tight junctions* — the molecular door locks of the BBB — and keeps inflammation-promoting substances out. But be careful: when cortisol stays at the controls too long (you know — chronic stress and all that), it can become critical. The tight junctions get leaky, and suddenly the barrier to the CNS stops working reliably.

Harmful substances and inflammation then have an easier time getting through, which can become problematic for your brain. So there's real communication here — with risks and side effects. Adrenaline and cortisol are indispensable when it comes to acute stress and your brain's ability to adapt. But these two hormone specialists also show just how sensitive the system is: a bit of stress? No problem, the BBB plays along. Chronic stress? That's when it gets critical, because the ones guarding the door eventually lose control. And you definitely want to avoid that.

Cortisol also plays a decisive role in the interplay between the vagus nerve and its part-time job in the nervous system: under acute stress, activation of the so-called *HPA stress axis* (Hypothalamic-Pituitary-Adrenal axis) releases cortisol, which dampens parasympathetic activity by acting on parasympathetic functions via the brainstem. Specifically, it acts on brain regions like the *hypothalamus* and the *nucleus tractus solitarius*, which help control the vagus nerve. The result: the body is reconfigured for a rapid stress response, which facilitates "fight-or-flight" reactions (→ Fight-Flight). If cortisol remains chronically elevated, however, the suppression of vagal functions becomes habitual, impairing recovery after stress and disturbing the balance between the sympathetic and parasympathetic branches. Our capacity for *resilience* (→ Resilience) declines.

The HPA stress axis

The HPA stress axis is something like the body's rapid-response squad: right up front stands the hypothalamus, the watch commander with fine-tuned antennae. Whenever danger appears anywhere — a loud noise, a stern look, an inner unease — it immediately hits the alarm bell. This alarm is heard by the *pituitary gland*, the sharp-witted dispatch center that never sleeps. It then sends an express telegram on to the adrenal glands, with their firefighters. They rush out and pump cortisol into the bloodstream — our body's own energy booster, making us alert, focused, and ready for action. Once the emergency is over, everything scales back down. The alarm squad wipes its brow, tidies up, and restores calm. In short: the HPA stress axis is our hotline for stress, linking body and brain — a finely coordinated team switching between "all clear" and "attention, focus on!"

review: #adrenaline #cortisol #cns #bloodbrainbarrier

1.7 An Example of the Interplay Between Body (ANS) and Brain

Imagine you're hungry. Really hungry. This feeling doesn't just come out of nowhere — it's the result of an impressive communication strategy on your body's part. The chief in charge? The *hypothalamus* (HT). This small but mighty part of your brain sits roughly in the middle of your skull, in the diencephalon,⁵ just above the pituitary gland — the brain's "master gland" for important hormones. And this hypothalamus has the job of monitoring your internal state.⁶ Whether it's hunger, thirst, temperature, or sleep, the hypothalamus is your biological control center. When it notices your blood

sugar level is too low,⁷ it sounds the alarm, together with other parts of the *limbic system* (the hypothalamus belongs to this system! [→ Limbic System]) ... and the *insula* (→ Insula). This happens via specialized neurons and neurochemical receptors (docking sites) sitting in the hypothalamus that monitor your body's energy needs.

You become more alert and attentive — and may even start thinking about food

Then the *Autonomic Nervous System* takes the stage as well, joining hunger, which has already made its entrance.⁸ The hypothalamus first receives signals from the gastrointestinal tract in the brain — with (surprise, surprise!) the vagus nerve as the reliable messenger, transmitting signals to the brain about the energy balance in the digestive system. This, in turn, triggers the release of hormones and neurotransmitters, such as *ghrelin*, a hormone that tells your brain, quite clearly: "Time to go find food!" At the same time, insulin release is throttled to conserve remaining energy reserves. The result? You become more alert and attentive, and start thinking about where the next meal might come from. Attention, activation, and relaxation ... along with hormone cycles, are all very important here. Unfortunately, when it comes to food, this interplay doesn't always go so smoothly — this is where it gets a little *tricky* ...

Because when we become too stressed by feelings of hunger, or link them to fear or negative emotions, the sympathetic branch kicks in — who else? — throttling, for example, insulin release (sugar breakdown). That's fine, in a way, at first ... after all, we're hungry, and energy reserves need to be conserved. At the same time, though, the "sympatho-adrenergic" system (keyword: "fight-flight") should itself also be dialed down. Ultimately, we don't want to burn off even more activation energy and, as a result, end up even hungrier. What doesn't sit as well, on the other hand, is fear or negative emotions. Notice a pattern? ...

Eating behavior

Stress and emotion in combination with hunger can activate the sympathetic branch too strongly — the very branch that's supposed to be reined in by the vagus. Together, these can disrupt the interplay of the ANS (around the topic of hunger) and all the hormonal cycles tied to it. Add our reward system into the mix (yes, the one involving dopamine), which itself interacts with the vagus nerve, and the whole thing — meaning our eating behavior — can go seriously off the rails ...



- ✓ How does the ANS work together with the CNS?
- ✓ What happens in the hypothalamus?
- ✓ Why do we need hormones at all? Why don't the nerves regulate things on their own?

- ✓ Does our ANS influence (eating) behavior?

Generally speaking: all culinary-related signals land in the *Central Nervous System*, meaning also in your brain, where they're further processed. The hypothalamus translates this information, in sophisticated collaboration with other brain regions and the digestive organs, into the subjective feeling of hunger. And, together, they generally ensure that you're motivated to eat. Your prefrontal regions, the planning centers of your brain, then take on the task of organizing the route to your next meal.

The CNS checks the situation and, in collaboration with the ANS's parasympathetic pathways, restores the body to balance

Once you've finally eaten something, the return trip happens along the same communication loop described above. Blood sugar rises, and the hypothalamus recognizes: "mission accomplished." Via the vagus nerve, the body signals: "Digestion! ... Please switch to rest mode!"

Ghrelin production (among other things) stops. Instead, *leptin* is released, a satiety hormone that signals to your brain: "You've had enough!" The CNS checks the situation and, in collaboration with the ANS, restores the body to balance — a state of *homeostasis*. This back-and-forth between the Autonomic Nervous System and the Central Nervous System is not only a clever feedback system, but also an impressive example of how your body seamlessly interweaves physiological processes and behavior. The ANS and CNS are a dream team!

review: #homeostasis #hypothalamus #hormones #prefrontalcortex
#neuroception

1.8 The "Language" of the Autonomic Nervous System — A Summary — and Something New ...

The *Autonomic Nervous System* (ANS) speaks its own "language," one that's as fascinating as it is complex. It's a language made of signals, messenger substances, and finely tuned neurophysiological response patterns — a kind of code that shapes our inner experience and, through that, influences our behavior.

This communication is based, alongside the nerve pathways of the ANS, on various signaling molecules, including *neurotransmitters* and *hormones*. *Noradrenaline* plays a key role as the central messenger substance of the sympathetic branch, while *adrenaline* complements its activation at the hormonal level. *Acetylcholine*, in turn, is the most important neurotransmitter of the parasympathetic branch and, at the same time, the shared messenger substance of the entire Autonomic Nervous System. Autonomic *regulation* is thus based on finely tuned, context-sensitive modulation — a point Polyvagal Theory repeatedly emphasizes.

Neurotransmitters: Neurotransmitters transmit fast, precisely targeted signals between nerve cells, while hormones act more

slowly and over a broader range, setting the overarching bodily and emotional framework of state.

Added to this are further players, such as *neuropeptides* (e.g., Substance P, which is strongly associated with sympathetic activation and inflammation), as well as stress hormones like cortisol, which modulate the activity of the system via feedback loops that vary in timing and location. While such messenger substances primarily amplify alarm and strain contexts, they also indirectly influence how available vagal regulatory mechanisms remain — in the service of social safety — or whether they become restricted.

The biological "syntax" of the ANS is anything but rigid

The syntax of this language shows up in the precise patterns of signal transmission. Nerve pathways send electrical impulses, whose effects are further differentiated through chemical modulation and receptor binding. What matters here is *receptor specificity*: it determines not *whether* a signal arrives, but *how* it is interpreted at its destination. Noradrenaline, for instance — depending on the particular receptor type and context — can produce different effects, such as constriction or a functional redistribution of blood flow. The biological "syntax," then, is anything but rigid. It adapts to the body's current demands and to the given situation, enabling highly flexible steering.

But what would a language be without "meaning"? The signals of the Autonomic Nervous System give direction and weight to neurophysiological states. Noradrenaline often stands for heightened alertness and readiness to act — for example, through increases in heart rate, vascular tone, and attentional focus. Acetylcholine, by contrast, supports vagally mediated regulatory processes such as lowering heart rate and supporting digestive activity. What matters, though, isn't only *which* messenger substance is active, but *how intensely* the system is firing: high activity generates a sense of urgency. Reduced activity leaves room for relaxed self-awareness, for social connection — and, last but not least, of course, for the essential metabolic processes of our body. And yes: relationships need to be "digested," too ...

Fundamentally: *context sets the tune*. The very same neurochemical message can play out quite differently depending on the situation. In an acute stress situation, noradrenaline^[9] contributes to mobilizing the body and supports "fight-or-flight" responses (Cannon, 1915). In a state of relative calm, however, a comparable activation pattern would be disruptive or dysregulating. Target organs, therefore, respond not only to the signal itself, but also to their own physiological state, and enter into continuous exchange with the Autonomic Nervous System via a wide range of feedback loops. This is precisely where the true "linguistic artistry" of the ANS shows itself: it coordinates the dynamic interplay of the sympathetic and parasympathetic branches not linearly, but in a context-dependent, self-regulating way. In concert with other organ systems, as well as with behavior and emotions, a kind of "pre-reflexive regulatory logic of the body" emerges — one aimed at maintaining inner stability under ever-changing conditions, a process we call *homeostasis* (→ Homeostasis).

In the end, this "language" of the ANS is, of course, not a conscious expression, but a quiet, self-regulating stage direction that steers our lives from the background. And yet these interactions shape not only our *behavior*, but also how we perceive *ourselves*.



- ✓ How can the ANS respond and act with such fine-tuned precision?
- ✓ What role does our self-awareness play in ANS regulation?
- ✓ Who are the MVPs — the most valuable players — of the ANS?
- ✓ Why can we speak of a "language" of the ANS?

But what happens when the fine balance of the ANS falls out of equilibrium?

Against the backdrop of Stephen Porges' Polyvagal Theory, it becomes clear how a *dysregulation* of the Autonomic Nervous System can occur — a state that affects not only our physical health, but also our emotional experience in lasting ways. First, though: in its supportive pathways, the ANS is oriented toward flexibly mediating between various physio-psychologically mediated states: safety, exploration and activation, alarm, calming ... and protection! In *safe* moments, we're regulated by the so-called *ventral vagus* (→ Ventral Vagal Complex = VVC), a central branch of the parasympathetic system that, in coordination with other cranial nerves (→ Cranial Nerves), enables us to be relaxed and connected with the world. "Enables" here means that, through its down-regulating functions, it opens up to us, as social beings, behavioral pathways that aren't limited merely to "fight or flight." As social human beings, we're capable of responding, so to speak, within the in-between space of social attunement. And, contrary to what was long assumed, this capacity for social regulation doesn't reside solely within the domain of psychological regulatory capacities (such as conscious behavioral control, emotion regulation, etc.).

In threatening situations, by contrast, either the sympathetic branch of the ANS or the *dorsal vagus* (→ DVC) takes over energetic regulation — depending on whether the body opts for fight or flight, shuts down completely ... or moves through mixed states drawing on both sympathetic and dorsal-vagal pathways of the ANS. But chronic stress, trauma-related disorders (→ Trauma), or ongoing strain can significantly disrupt these finely tuned supportive processes. The body stays too long in a state of alarm readiness, or withdraws prematurely into a "shutdown" mode (→ Shutdown). And the system begins to calibrate itself incorrectly, becoming dysregulated.

The root of this dysregulation often lies in a kind of "miscalibration" in how signals are perceived

FIGURE 1.2 — Dorsal and Ventral Vagus: Regulation & Dysregulation

[existing English diagram — insert here]

A so-called dysregulation of the ANS often shows up as the body's overall system overreacting to harmless stimuli, as though life itself were on the line. The sympathetic branch can go into a state of chronic alarm, leading to symptoms such as a racing heart, insomnia, or persistent inner restlessness. Or the dorsal vagal complex (→ DVC) leaves us experiencing states of emotional numbness, exhaustion, and social withdrawal. Both states can impair our ability to perceive situations as safe — even when they are, in fact, safe. The root of this lies in a kind of "miscalibration" in how signals are perceived. The ANS interprets neutral or even positive signals as threatening because the communication pathways between brain and body — that is, between the CNS and the ANS — are disrupted. Such overreactions or "shutdowns" are not weaknesses, but rather *protective strategies* of the body — simply deployed, unfortunately, at the wrong time, in the wrong place.

One problem here: once dysregulation has taken hold, it tends to reinforce itself. Chronic stress or trauma leave their traces in the system. The body learns to stay in a hyper- or hypoactive state, and the capacity for effective self-regulation becomes limited. This shows just how closely our nervous system is bound up with our self-awareness, our behavior, our emotions, and even our relationships.

The good news? The Autonomic Nervous System can learn — with our help, support that stands *beside* the ANS in its own autonomy (!) — to regulate itself again. With the help of safe connections in so-called co-regulation (→ Co-Regulation), mindfulness practices, or therapeutic support, the body can gradually reinterpret the signals it receives and find its balance again. The "language" and the feedback loops of the Autonomic Nervous System remain the same throughout. But the *context* in which they're read can be changed. That way, an alarm can even become a signal of safety, or a resource for self-awareness — and our inner world reorganizes itself anew.

review: #dysregulation #protectivestrategies #ventralvagus #dorsalvagus #context #signalinterpretation #cranialnerves

-
1. Under stress, our heart beats faster and breathing quickens: everything is ready for action ... the sympathetic branch takes over, up to and including a "fight-or-flight response" (→ Fight-Flight), which we can hardly influence voluntarily. The parasympathetic branch, by contrast, regulates our energy supply back down, which we may, at best, perceive as "calming down" or inner peace. [↪](#)
 2. In German: "Gesetz über erforderliche Varietät" — variety here should be understood as "variability" and flexible range of options. [↪](#)
 3. However, we also need so-called co-regulation (→ Co-Regulation) in exchange with other people. [↪](#)

4. Generally speaking: adrenaline (epinephrine) functions mainly as a hormone, released almost exclusively from the adrenal medulla, but in the CNS it also acts as a neurotransmitter. Noradrenaline (norepinephrine) functions both as a neurotransmitter — particularly within the sympathetic nervous system — and as a hormone from the adrenal medulla, though to a lesser extent than adrenaline. [↵](#)
5. In the diencephalon, signaling pathways generally run faster than they become conscious to us in the cortex, which steers our conscious thinking. That's precisely why the body first communicates (so that it's fast) with the diencephalon. [↵](#)
6. Reminder: it's always also about homeostasis — a balance of our bodily metabolic processes and energy budgets. [↵](#)
7. This mechanism, colloquially known as "low blood sugar," isn't, however, solely responsible for our eating behavior. The latter is also steered via the orbitofrontal cortex and the limbic system. [↵](#)
8. Imagine how people feel who suffer from chronic, politically-caused hunger. How does the ANS respond? Presumably, at some point, it responds with a traumatically induced "shutdown" of the whole body (→ Shutdown). [↵](#)

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About this book

The Physiology of Connectedness (German: *Die Physiologie der Verbundenheit*) is a comprehensive learning guide to the social, therapeutic, and educational practice of Polyvagal Theory, written by Michel Ackermann and Marvin Miles Ferrante. It combines rigorous neurophysiological grounding with an accessible, engaging voice, and covers autonomic regulation, mixed states, co-regulation, embodied safety, community safety, and somatic practice across eight full chapters.

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