Brain Morsels: Packet 1

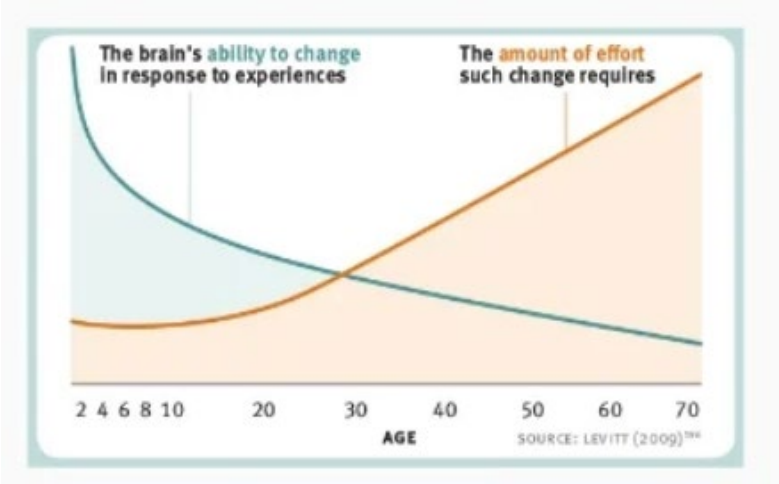
Neuroplasticity and the 5 key elements supporting brain health across the life span, but especially as you age

Also, the Neurobiology of stress

EACH BRAIN MATTERS
THE CENTER FOR NEUROSCIENCES FOUNDATION

We begin with a comforting concept called "neuroplasticity." Neuroplasticity is the *lifelong* ability of the brain to respond to stimuli by reorganizing its structure and function. It is the key to the brain's capacity to learn, to remember, and to adapt to our ever-changing experiences. New connections are made between neurons and old ones are modified, allowing change in the circuitry connecting neurons in our brain. Without neuroplasticity, we would have in our heads only a simple computer, one that could manage only the functions it had when it was created.

In thinking about what it takes to support optimal brain function - those key elements that we'll describe shortly, we really are talking about maximizing neuroplasticity. The graph below shows several important features of neuroplasticity. The green line shows, not surprisingly, that the brains of the youngest humans display an enormous amount of plasticity. Their brains are learning to interpret the world, to understand the meaning of the sensory input it receives, to manage increasingly complex motor tasks, to speak and understand language. Yes, the degree of plasticity declines with age, but notice that it never goes to zero! What *does* change is illustrated by the gold line, which is the amount of effort required to elicit changes in the brain. A simple example: consider what it takes for a child to learn a language (or two) compared to the effort a 70-year-old adult would have to put in to accomplish the same task.



What are these key elements or pillars that support optimal brain function?

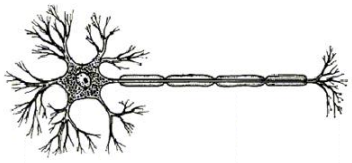
Throughout our lifespan, our brains need:

- Adequate sleep
- Physical exercise
- Appropriate nutrition
- Intellectually challenging and interesting activities
- Social engagement

In upcoming packets, we will address each in some detail, beginning with sleep. For the first two months, however, we'll begin our series with a discussion of the *neurobiology of stress* because certain kinds of stress complicate our efforts to optimize brain health. Understanding what happens in our brains when we are stressed will help in the next step, which is understanding how to build resilience, especially to chronic stress. In the next packet then, we will spend a bit of time describing what happens to the brain when it is chronically stressed.

Chronic stress becomes a part of life for many elders – loss of friends and partners, poor health, isolation, financial concerns, and so forth. Stress can cause loss of connections between neurons and even death of neurons, so finding ways to deal with it is critical. Also, medical disorders, especially atherosclerosis, heart disease, high blood pressure, obesity, diabetes, need to be controlled as well as possible. We have at least some control over things like weight, lifestyle (active or sedentary), blood pressure, control of glucose levels in diabetes, smoking, alcohol intake, diet, level of social interaction, and so forth. All those medical disorders listed affect energy production in the brain. Controlling them is critical to maintaining good brain health.

Importantly, everyone ages differently! There is huge variability and no one way to age successfully, so don't waste time comparing yourself with others, and don't get discouraged. Let us show you some things you can do to sustain your brain's health.



The Neurobiology of Stress

Many years ago, a guy named Hans Selye was a new faculty member in search of a good research area. His colleagues offered him an extract from ovaries to see what its role might be. Selye thought there were some interesting possibilities and so devised a protocol to test it. That protocol involved injecting the extract into the tail vein of rats (a very common and easily accessible injection site). The problem for Selye was that he was a very inexperienced rat handler. As he tried to get them out of their cages, he often dropped them as they twisted around trying either to escape his grasp or bite him. Most escaped and then he would chase

them around his lab with a broom or whatever else he might use to catch them. He did this every day for something like 2 weeks, then anesthetized them, euthanized them, and did autopsies and blood work.

He was astonished to find that all the rats showed symptoms like stomach and intestinal ulcers, heart disease, changes in joints, and diabetes. Well, those were surprising effects of ovarian extract! To his credit though, Selye had also included a control group that received a saline injection instead of the extract. *That group had the same symptoms*, so clearly the effects were *not* related to the ovarian extract.
Selye went on to explore what he eventually determined was a consequence of the awful struggle the rats faced each day; his research led to what he described as the *General Adaptation Syndrome*, what today we call Chronic Stress. What he was studying was the effort of the body to respond to ongoing stressful circumstances. What we know now is that those body responses are directed by the brain!

The word "stress" certainly has entered the mainstream and many of us use the word broadly – "Oh, it was a stressful day" or "I think I am so tired and sad because of all the stress in my life." But from the standpoint of the brain, which determines the existence of a threat and orchestrates the brain's and the body's response, what do we know?

First, we need to distinguish between acute and chronic stress. Acute stress is usually sudden in onset and is a difficult or unwanted situation that is severe or intense for the individual experiencing it; it is not necessarily due to a negative situation. Think the holidays, or a wedding! Chronic stress is longer lasting and is accompanied by a sense of feeling pressured and overwhelmed, either psychologically or physically.

Here are some examples of acute stress:



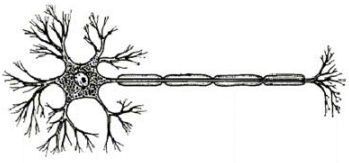



The situations in the last two images, showing natural disasters, will become for most people a chronically stressful situation, but at their onset, they elicit an acute stress response.

Activity Think back to a time when you faced a situation that was acutely stressful for you. What was the response in your body?

You likely said, well, my heart sped up; my breathing did, too, and it was more shallow. There are a host of other effects that you may not be directly aware of but that nevertheless are important in preparing you to respond effectively to the stressor. These include:

- Adrenaline is released from the adrenal glands.
- Delivery of oxygen and glucose is increased because adrenaline increases heart rate, cardiac (heart) output, and blood pressure, as well as breathing rate and widening of the bronchi of the lungs.
- Energy stores are mobilized from the liver and more insulin is released from the pancreas, both making energy (glucose) available to the cells that need it, especially muscle, heart, and brain.
- Non-emergency activities, like blood flow to the skin and like activity of the gut are decreased.
- Sensory ability is sharpened, but perception of pain is decreased. As our pupils widen, for example, we take in information about the threat more easily. Decreased awareness of pain makes it possible to fight or run despite injury. Soldiers often discover serious wounds only after an intense fire fight.
- Memory of short-term emotional events increases.
- Calcium increases in neurons, which makes them more easily excited.



And now for a little bit of neuroscience – **What's going on in the brain?** These responses are the result of interaction among several elements of the nervous system, which we'll explain shortly. These are the main elements (see figure on the next page):

(1) a network called the HPA axis, which stands for the hypothalamus-pituitary-adrenal axis;

(2) the emotional circuitry of the brain plus the prefrontal cortex; and

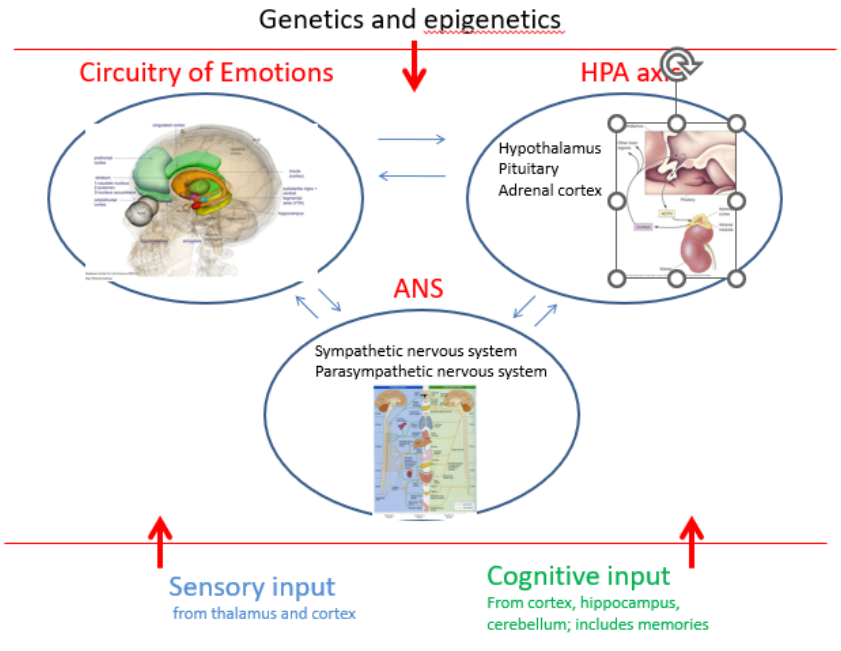
(3) the autonomic nervous system.

Briefly, when a structure deep in the brain called the **H**ypothalamus is activated, it causes the **P**ituitary gland to release a hormone that in turn leads to the release of the hormone cortisol from the **A**drenal cortex, the outer part of the adrenal gland that sits atop the kidneys. Cortisol mobilizes energy stores and helps to increase memory.

The hypothalamus also causes activation of the sympathetic nervous system, which is one part of the autonomic nervous system. That results in the release of adrenaline from the adrenal medulla (the interior of the adrenal gland). Adrenaline causes that increase in heart rate, cardiac output, breathing rate, and blood pressure mentioned earlier. At the same time, activity of the other part of the autonomic nervous system, the parasympathetic system, is reduced. That leads to less gut activity, for example. Who needs digestion when you are trying to run from a threatening situation?

But what initiates all these effects? The hypothalamus gets information from many areas of the brain, including the emotional circuitry, the prefrontal cortex, and memory areas. When these networks of neurons "determine" that something is stressful, signals are sent to the hypothalamus, which then sets the HPA axis and the sympathetic nervous system in motion. This complex choreography does not just play out on a set trajectory though. Most wonderfully, how each element functions is continuously modified by incoming sensory input from the ears, eyes, nose and skin and by input from "cognitive" regions of the brain. So, as the situation develops, so too does the response.

On top of that, any of these elements can be affected by the genetics the person carries. Some people are high responders (some people would say these are the mountains-out-of-molehills people), while others have much lower responses to the same level of applied stress (sheesh, that woman is unflappable). The offset of the stress response can be affected by your genetics, too, with some settling slowly and others quickly. We're also learning that situations that occurred long ago to an individual can change the way certain of their genes are read out. There are a number of mechanisms that normally regulate the read-out of our genes without affecting the structure of the genes. Alterations in those regulatory processes can cause a gene that should be active to be silenced and vice versa, often with serious consequences. Those changes can be passed on to their children and grandchildren. This is called epigenetics and can happen to genes affecting the stress response.



From: Bear et al., *Neuroscience: Exploring the Brain.* 2020.

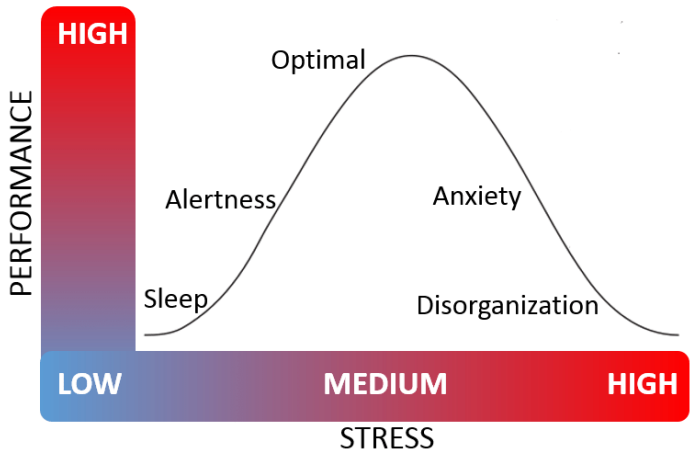
There is one more important bit to understand about acute stress. The prefrontal cortex, which resides just behind our foreheads, is responsible for what we call executive functioning. This is the part of the brain that has a major role in helping us to take reasoned approaches to various situations. One part of that responsibility is regulating the activity of the emotional circuitry. Usually that means actually restricting or inhibiting that circuitry. In doing so, we are saved from out-of-control behavior that we might deeply regret. Or at least the behavior that happens may not be as bad as it might be! *But*, when faced with a threatening situation, especially a highly threatening one to which we need to respond quickly, we want to do just that – respond quickly, and not dither around about which response might be best. Under these circumstances, the connection between the prefrontal cortex and the emotional circuitry is reduced. That, in turn, ends up meaning that we can be flying by the seat of our pants and be operating emotionally rather than rationally.

Despite this caveat, the brain and body response to acute stress is powerful and for the most part protective. It gives us the power to fight or flee. BUT, that same set of responses when engaged chronically can be devastatingly destructive. More on that in the next packet!

<u>Everyday stress</u>

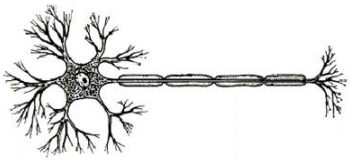
All those common situations that arise that make demands on us but that wouldn't qualify as acute or chronic stress fall in the category of everyday or garden-variety stress. For example, a nearing deadline for a project at work, a dinner party for 8, a troublesome client, a broken appliance, a bad cold, or even bad weather as you are driving home.

More than a century ago (1908), Yerkes and Dodson published a paper with a figure that showed the relationship between performance and level of stress. Performance is highest at the peak of the curve, at a moderate level of stress. According to their data, too little stress will find you bored, sleepy, not very productive, unmotivated, and less able to marshal the internal resources you need to perform. Too much stress will do the opposite; you become anxious, distressed, fatigued, disorganized, have trouble maintaining attention and remembering things. You become prone to poor decision-making and poor problem-solving, and you don't regulate emotions well either. This is the outcome of acute stress as described earlier. On the other hand, just enough stress gets us enough cortisol and enough adrenaline to optimize functioning.



Gjoreski, Martin. (2016). Continuous stress monitoring using a wrist device and a smartphone. Department of Intelligent Systems, Jožef Stefan Institute, Ljubljana, Slovenia (Graph based on Yerkes, R.M., & Dodson, J.D. (1908). The Relation of Strength of Stimulus to Rapidity of Habit Formation. *Journal of Comparative Neurology & Psychology, 18,* 459–482. https://doi.org/10.1002/cne.920180503)

Activity Chronic stress is stress that lasts for weeks or months and generates a strong sense of being overwhelmed or pressured. Gather, or draw, 5-8 pictures that convey conditions that would likely induce chronic stress. Looking at the set, write down the elements that seem common to most or all the conditions. What are the key conditions creating chronic stress?

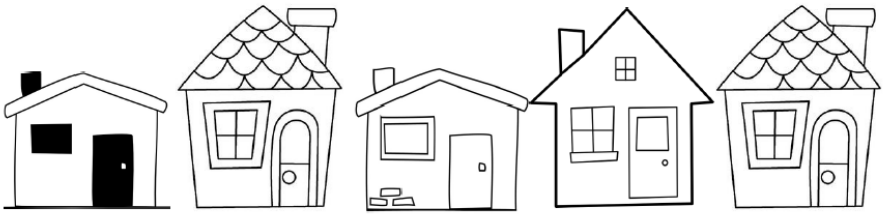


Puzzles

The puzzles you will find in these packets vary in their level of difficulty. Find ones to try that will challenge you AND also be fun.

Puzzle 1 [www.tefllemon.com]

Here's one that Einstein is supposed to have created. There are 5 houses. Each one is a different color. Each house has a family from a different country. Each family drinks a different drink, plays different sports and own a different pet. Fill in the table using the clues on the next page to figure out which family keeps a fish as a pet. All the clues are needed to solve the puzzle.

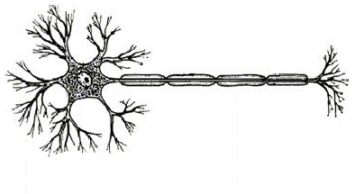


	House 1	House 2	House 3	House 4	House 5
Colour					
Nationality					
Drink					
Sport					
Pet					

Fill in the table and find out which house keeps fish as pets!

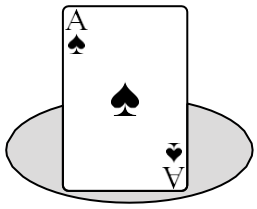
Clues:

The person who drinks milk only has one neighbor.
The American man lives in a yellow house.
The birds live next to the blue house.
The Chinese family keep dogs as pets.
The British family lives in the first house.
The person who goes to the gym lives next door to the house with the dogs.
The French family goes running.
The cat lives at the end of the road.
The British family lives next to the blue house.
The person in the red house drinks tea.
The family that likes swimming have a cat.
The Canadian woman drinks juice.
The red house is on the left of the orange house.
The American man doesn't like birds.
The family in the white house lives next door to the family that goes running.
The person living in the middle house drinks coffee.
The person who has horses lives next door to the family that goes running.
The family that likes walking drinks water.
The family that plays football has a neighbor who drinks tea.



Puzzle 2

BUSINE...



INmotherLAW

TNMN^2

BD $_{ii}$

eeee

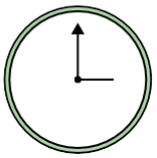
Punishment

house
PRAIRIE

MY1111LIFE

Point Shortest Distance Point

G N I K A M LOST LOST LOST LOST

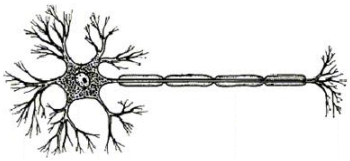


mil1lion

ni4ni

S T ONE

T O W N



Puzzle 3

Sudoku rules.

Each row, column and square (9 spaces each) needs to be filled out with the numbers 1-9, without repeating any numbers within the row, column or square.

	7			2			4	6
	6					8	9	
2			8			7	1	5
	8	4		9	7			
7	1						5	9
			1	3		4	8	
6	9	7			2			8
	5	8					6	
4	3			8			7	

Answers

Puzzle 1

House 4 has the fish.

Puzzle 2
Row 1 – Unfinished business, Ace in the hole, Mother-in-law
Row 2 – Tiananmen Square, Beady eyes, At ease
Row 3 – Capital punishment, Little House on the Prairie, For once in my life
Row 4 – Shortest distance between two points, Making up for lost time, One in a million
Row 5 – An eye for an eye, Cornerstone, Downtown

Puzzle 3

8	7	5	9	2	1	3	4	6
3	6	1	7	5	4	8	9	2
2	4	9	8	6	3	7	1	5
5	8	4	6	9	7	1	2	3
7	1	3	2	4	8	6	5	9
9	2	6	1	3	5	4	8	7
6	9	7	4	1	2	5	3	8
1	5	8	3	7	9	2	6	4
4	3	2	5	8	6	9	7	1