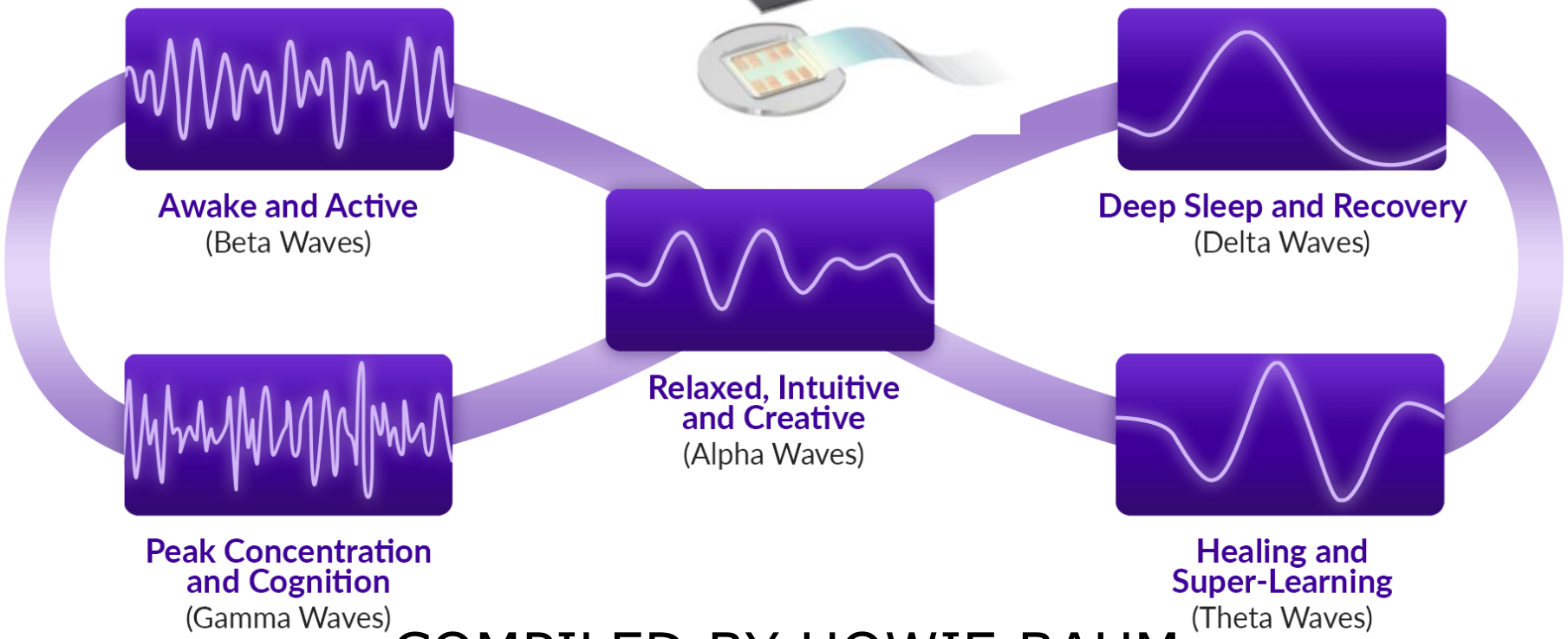
AN INTRODUCTION TO THE BRAIN-COMPUTER INTERFACE (BCI) AND COMPANIES WORKING ON IT

THE NEURALINK DEVICE



COMPILED BY HOWIE BAUM

Introduction

- A Brain-Computer Interface (BCI) is a technology which allows a human to control a computer, peripheral, or other electronic device with thought.

- It does so by using electrodes to detect electric signals in the brain which are sent to a computer.

- The computer then translates these electric signals into data which is used to control a computer or a device linked to a computer.

BRAIN-COMPUTER INTERFACES (BCI)

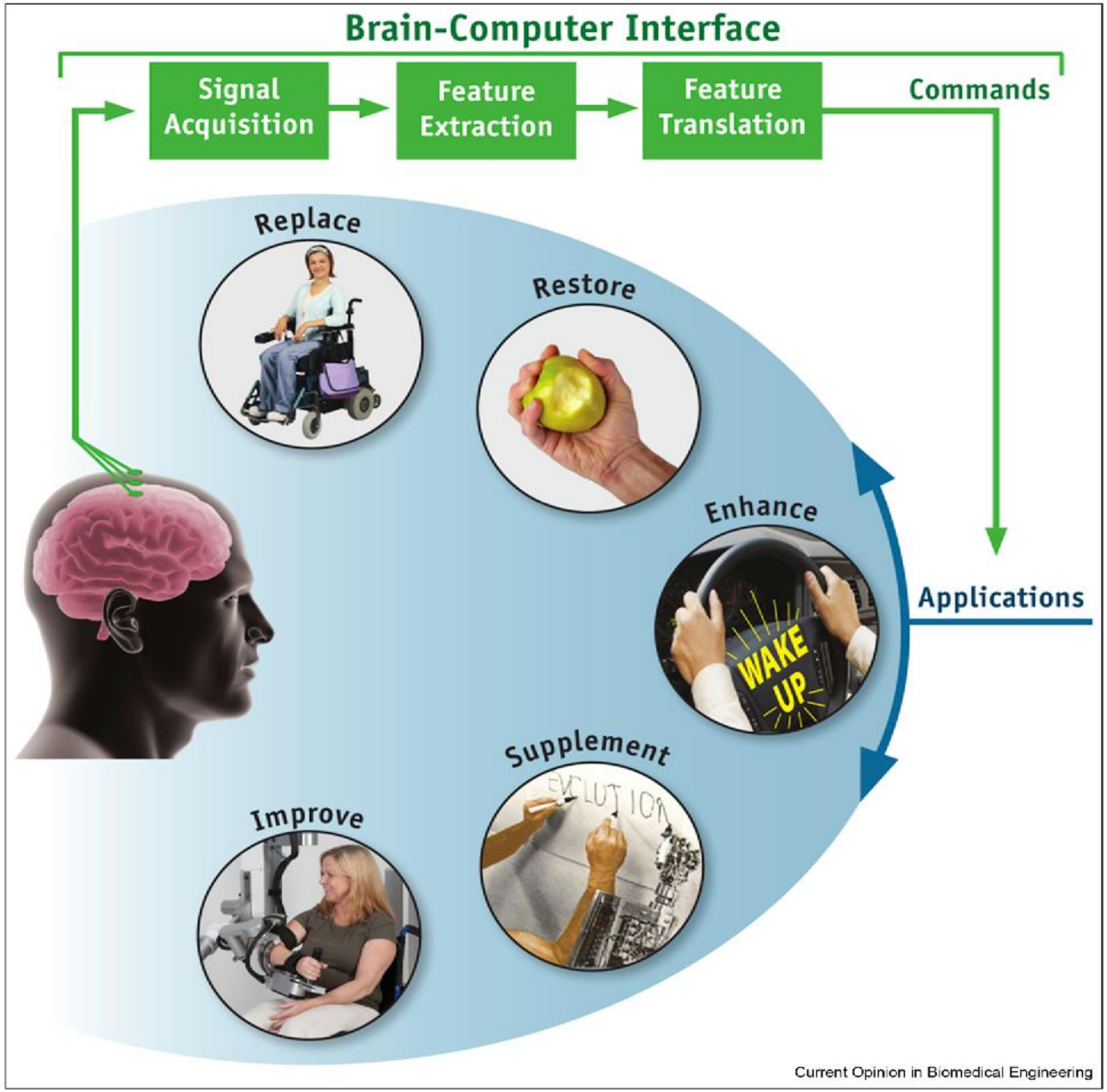
It is a system that allow communication between the brain and various machines.

They work in 3 main steps:

1) Collecting brain signals

2) Interpreting them

3) Outputting commands to a connected machine, according to the brain signal received.


Brain-Computer Interface
Signal Acquisition
Feature Extraction
Feature Translation
Commands
Replace
Restore
Enhance
WAKE UP
Applications
Supplement
Improve
Current Opinion in Biomedical Engineering

Let me think

Brain-computer interface components

Signal acquisition

The action potentials of neurons are recorded. Non-invasive recording techniques include electroencephalograms and near-infrared spectroscopy; invasive techniques typically use implanted electrodes

Decoding

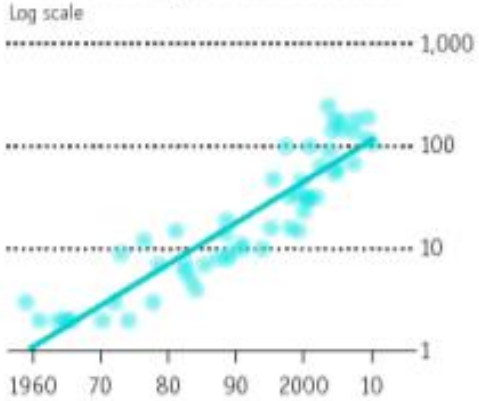
Brain signals are processed, usually with machine-learning techniques. Pattern recognition leads to the generation of a control signal

Application

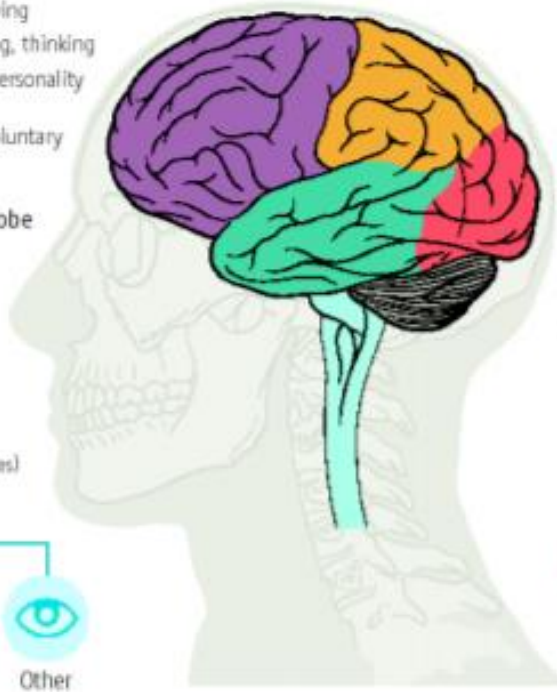
The control signal causes a change to an external device. Brain-computer interfaces can also be used to stimulate the brain

Cursors · Wheelchairs · Spellers · Robotic arms · Other

Simultaneously recorded neurons



Functional areas of the brain



Frontal lobe
- Movement
- Problem-solving
- Concentrating, thinking
- Behaviour, personality and mood
- Control of voluntary muscles

Temporal lobe
- Hearing
- Language
- Memory
- Smell
- High-level visual processing (faces & scenes)

Parietal lobe
- Sensations
- Language
- Perception
- Body awareness
- Attention

Occipital lobe
- Vision
- Perception
- Dreams

Cerebellum
- Posture
- Balance
- Co-ordination of movement
- Fear and pleasure

Brain stem
- Consciousness
- Breathing
- Heart rate

Sources: *Nature Neuroscience*; Patrick Lynch; *The Economist*

A RACE TO THE FRONTIER

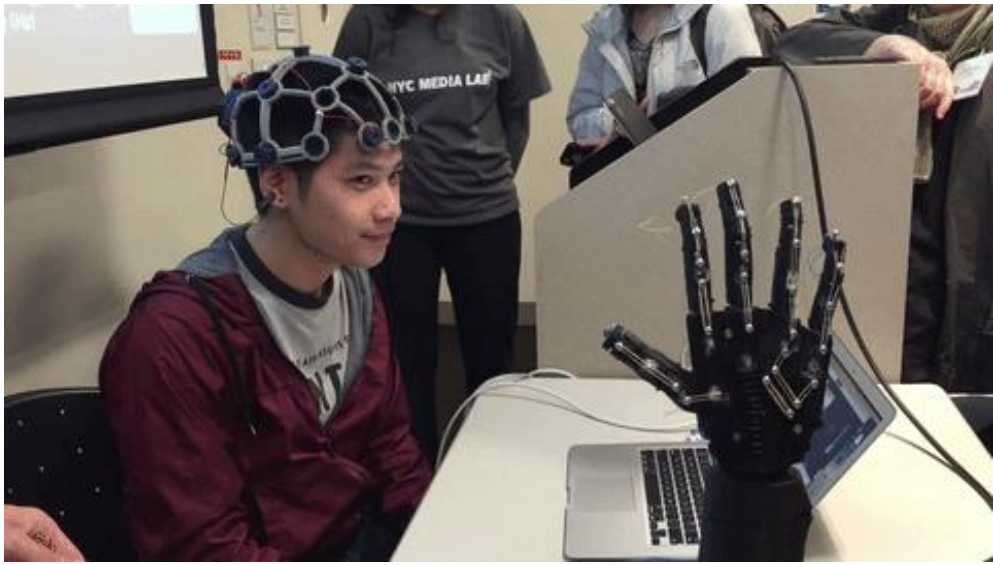
This is a list of the 29 different neurotech companies that are currently doing research in this area.

Note that some are looking at Brain-Computer Interfaces and others are focusing on other subjects.

Company	Founded	Funding	Application
Aleva Neuro	2008	$57M	**Neurostimulation**
Altoida	2016	Unknown	Alzheimer's Diagnosis
Biodirection	2010	$11.6M	Brain Injury Monitor
BrainCheck	2015	$4.49M	Brain Health App
BrainCo	2015	$5.9M	Attention Spans
BrainRobotics	2015	Unknown	Neuro-prosthesis
BrainSpec	2015	$100k	Virtual Biopsies
Cereve	2008	$38M	Sleep Disorders
ElectroCore	2005	$88M	**Neuromodulation**
Galvani Bioelectronics	2016	Unknown	Electroceuticals
InteraXon (Muse)	2007	$17.2M	Meditation
Kernel	2016	$100M	**BCI (Data Storage)**
MindMaze	2012	$108.5M	Rehabilitation
Mindstrong Health	2014	$14M	Digital Phenotyping
ModiusHealth	2014	$1.2M	Lose Weight
Neurable	2015	$2M	Brain Input Devices
Neuralink	2016	$27M	**BCI (Dust)**
NeuroLutions	2007	$1.25M	Neuro-prosthesis
Neuronetics	2003	$176.3M	**Neuromodulation**
NeuroPace	1997	$67M	Seizures
NeuroQore	2011	Unknown	**Neuromodulation**
Neuros Medical	2008	$38.8M	Pain Management
Paradromics	2015	$20.5M	BCI (Data Storage)
RightEye, LLC	2012	$10.4M	Concussion Test
Rhythm	2014	$22M	Sleep Disorders
Sense Diagnostics	2014	$1.3M	Brain Injury Monitor
Setpoint Medical	2006	$116M	Electroceuticals
SPR Therapeutics	2010	$44M	Pain Management
Synchron, Inc.	2016	$10M	BCI (Stents)

BCI CAN BE APPLIED TO A VARIETY OF TASKS:

- Neurofeedback
- Restoring motor function to paralyzed patients
- Allowing communication with locked-in patients
- Improving sensory processing

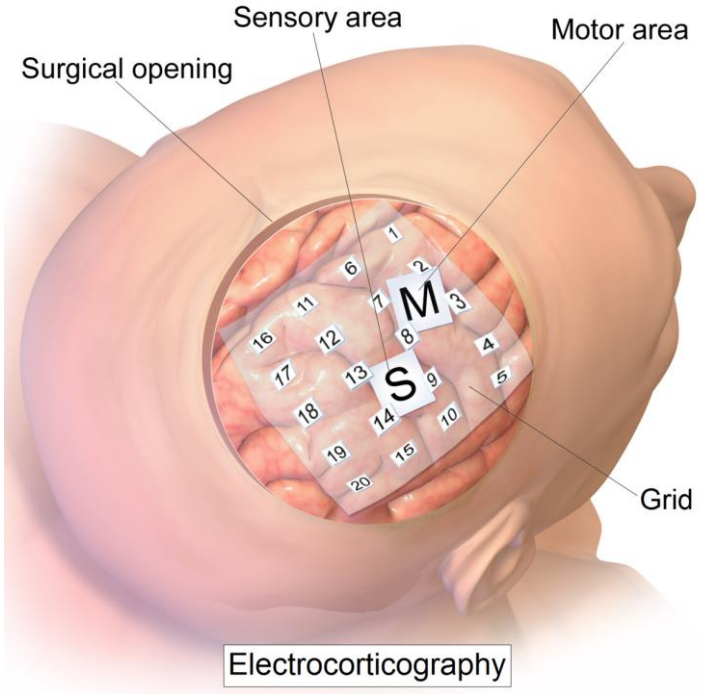


WHAT ARE THE 3 TYPES OF BCI'S ?

- Non-Invasive
- Semi-invasive
- Invasive

NON-INVASIVE

The sensors are placed on the scalp to measure the electrical potentials produced by the brain (EEG) or the magnetic field (MEG).



SEMI-INVASIVE

The electrodes are placed on the exposed surface of the brain - electrocorticography. (ECoG).

It is called semi-invasive but it still requires a craniotomy to implant the electrodes. For this reason it is used only when surgery is necessary for medical reasons (epilepsy for example).

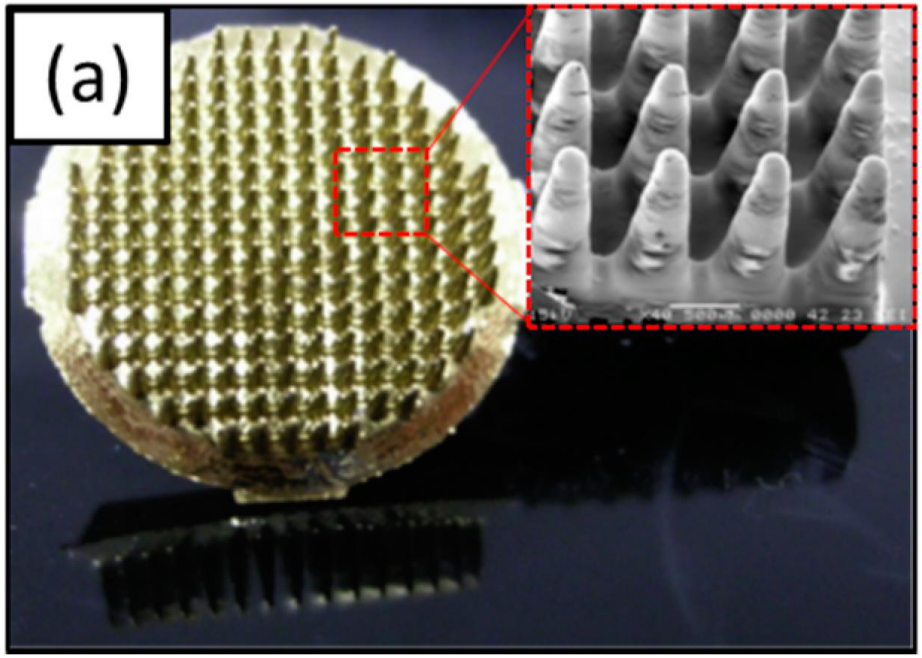
INVASIVE

They are implanted directly into the brain during neurosurgery.

The micro-electrodes are placed directly into the cortex, measuring the activity of one or more neurons.

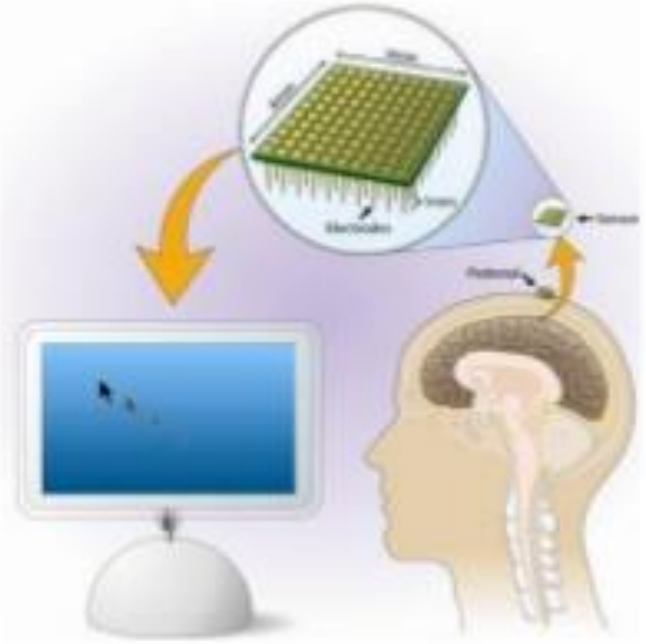
The Neuralink device connects to the brain with very small wires.

NEURALINK



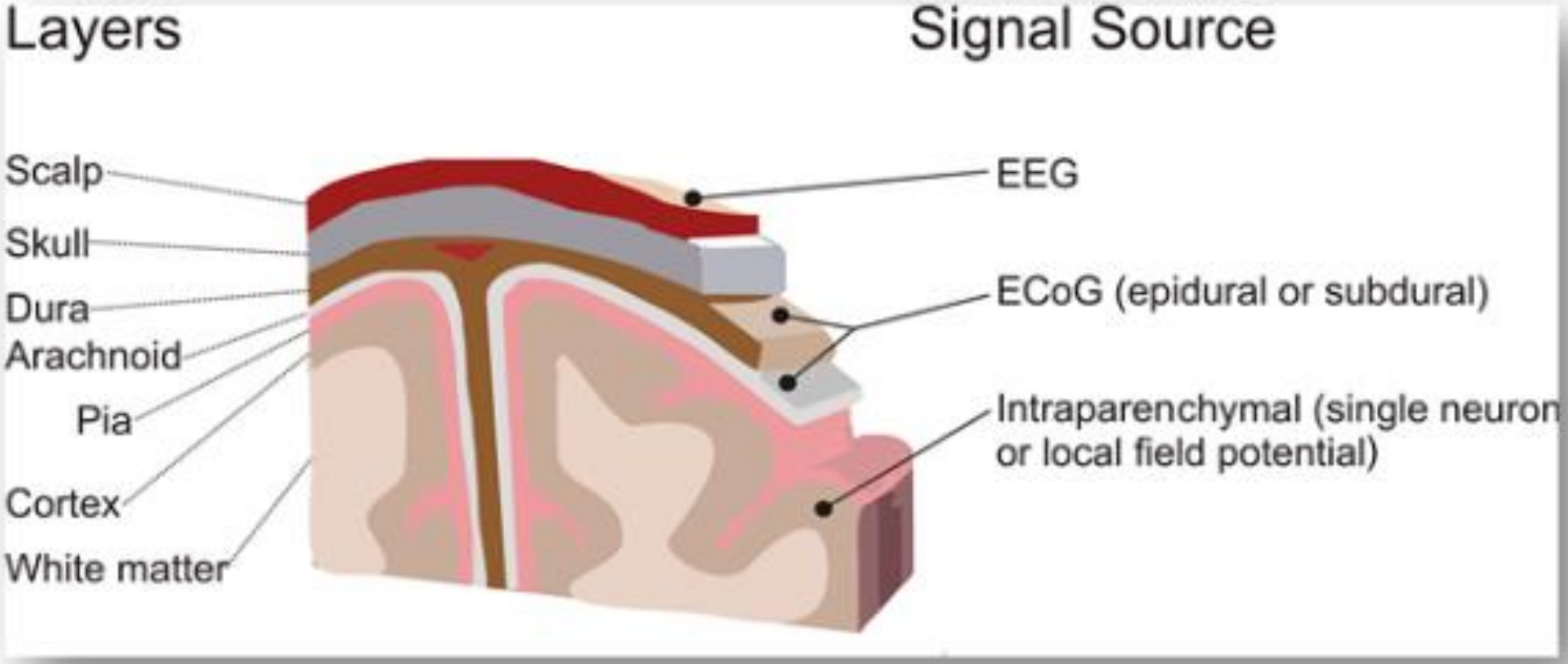
Invasive BCIs

- Invasive BCIs are implanted directly into the grey matter of the brain by neurosurgery.
- As they rest in the grey matter, invasive devices produce the highest quality signals of BCI devices.
- But are prone to scar tissue build-up, causing the signal to become weaker or even lost as the body reacts to a foreign object in the brain.



BrainGate Neural Interface System

THE IMAGE SHOWS THE DIFFERENT LAYERS OF THE BRAIN AND WHERE THE SIGNAL IS TAKEN FROM.

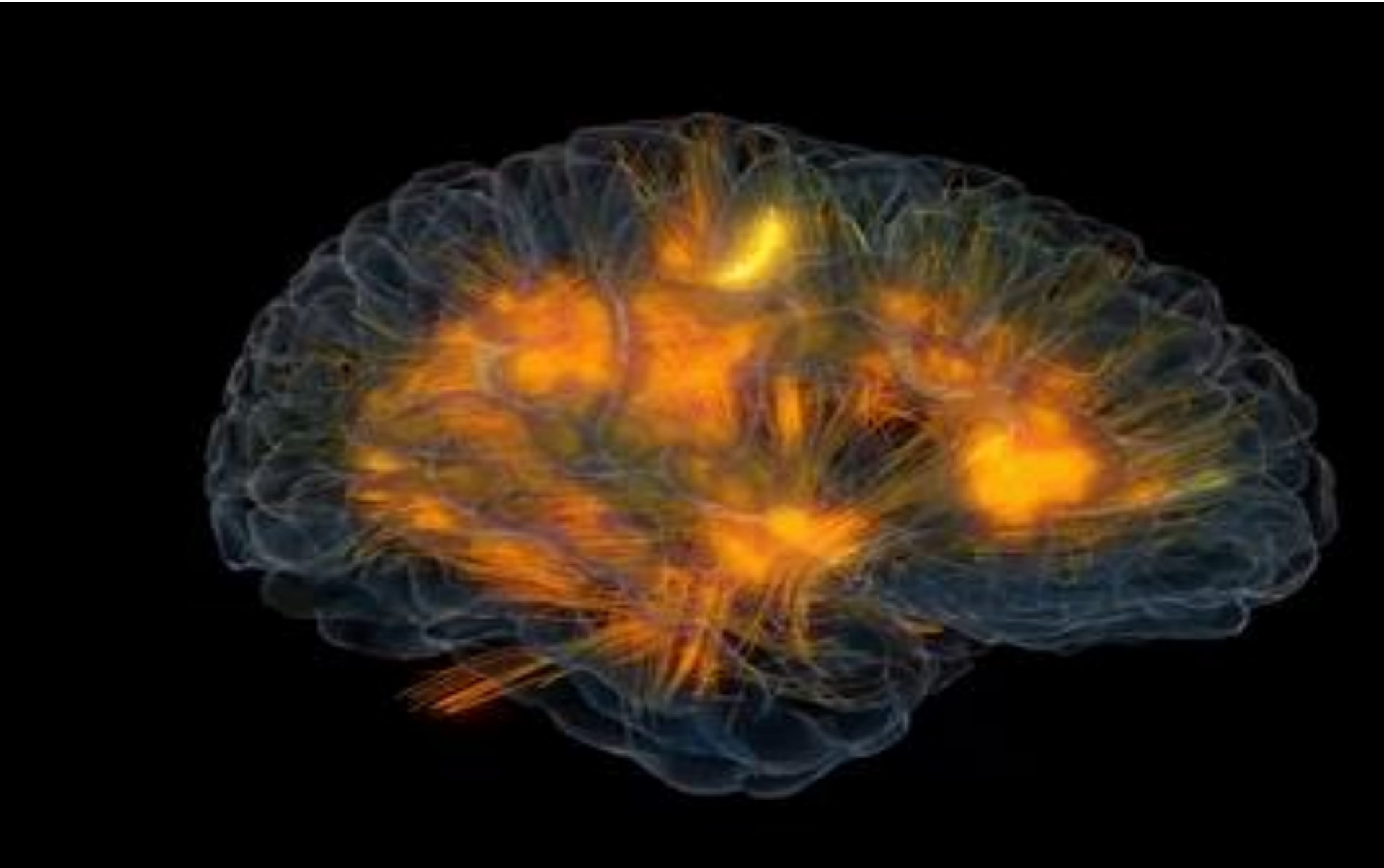


Non-invasive: the EEG signal is taken placing electrodes on the scalp, so on the most external part.

Semi-invasive: the electro-corticography (ECoG) signal is taken from electrodes placed in the dura or in the arachnoid.

Invasive: the Intra-parenchymal signal is taken directly implanting electrodes in the cortex.

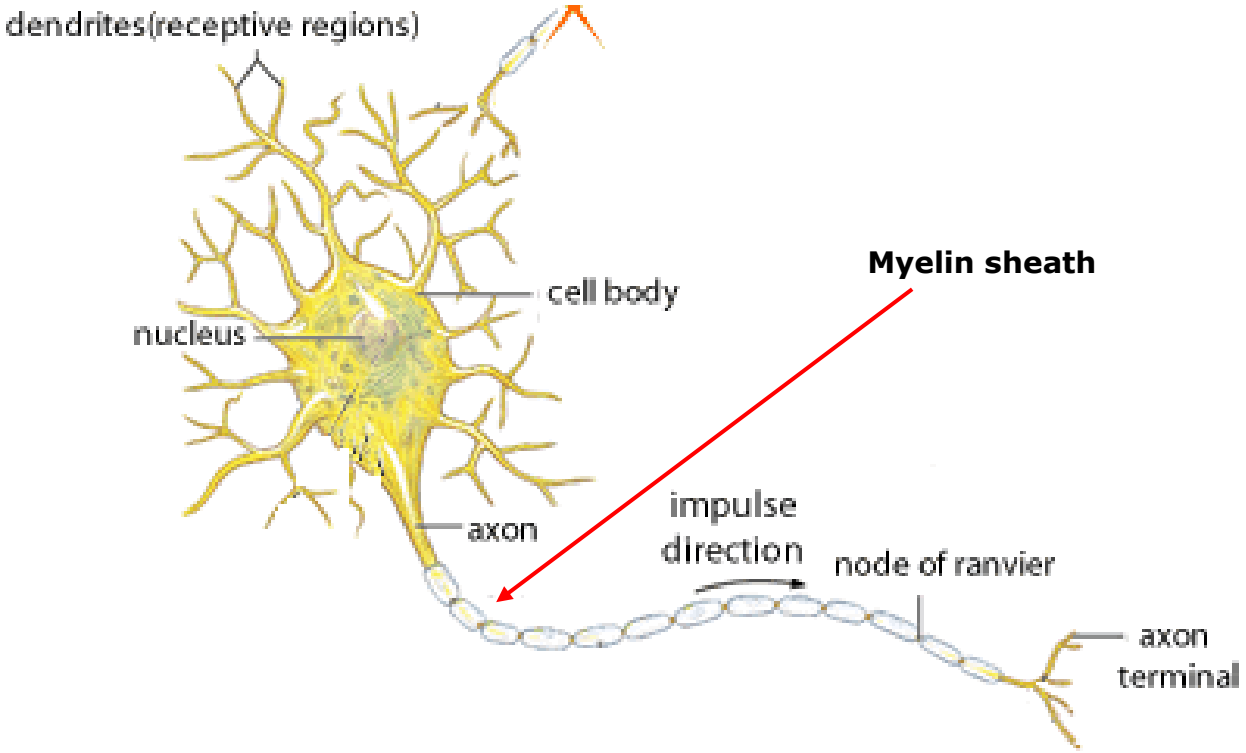
AN INTRODUCTION TO NEURONS, THE BRAIN, AND BRAIN WAVES



WHAT IS A NEURON ? - Neurons (also called nerve cells) are the fundamental units of the brain and nervous system.

They are the cells responsible for receiving sensory input from the external world, for sending motor commands to our muscles so we can move, and for transforming and relaying the electrical signals at every step in between.

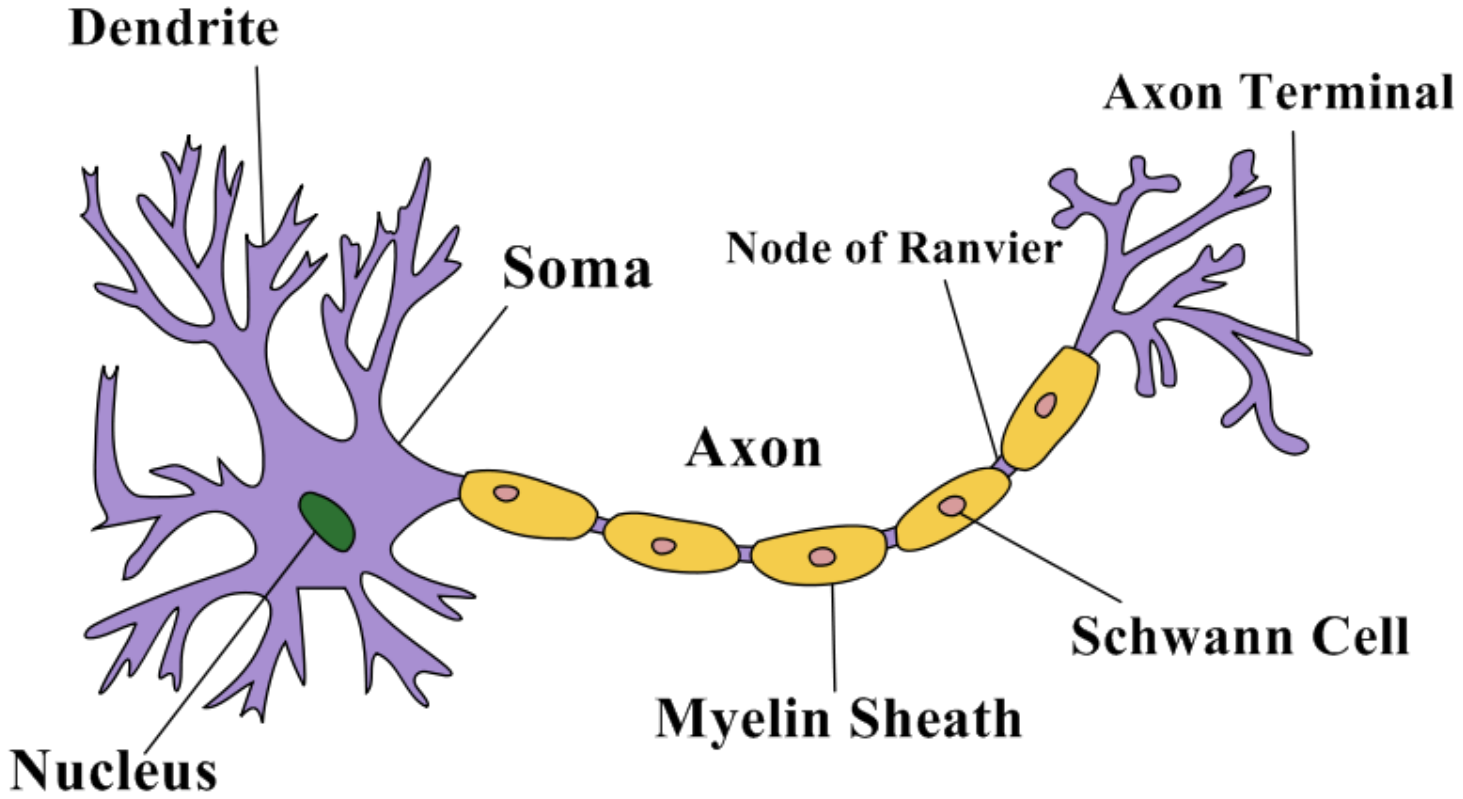
Using electrical and chemical signals, they help coordinate all of the necessary functions of life.



Neurons are one of the most fascinating types of cell in the human body.

They are essential for every action that our body and brain carry out. It is the complexity of neuronal networks that gives us our personalities and our consciousness.

They are responsible for the most basic of actions, and the most intricate -from automatic reflex actions to deep thoughts about the universe - neurons cover it all.



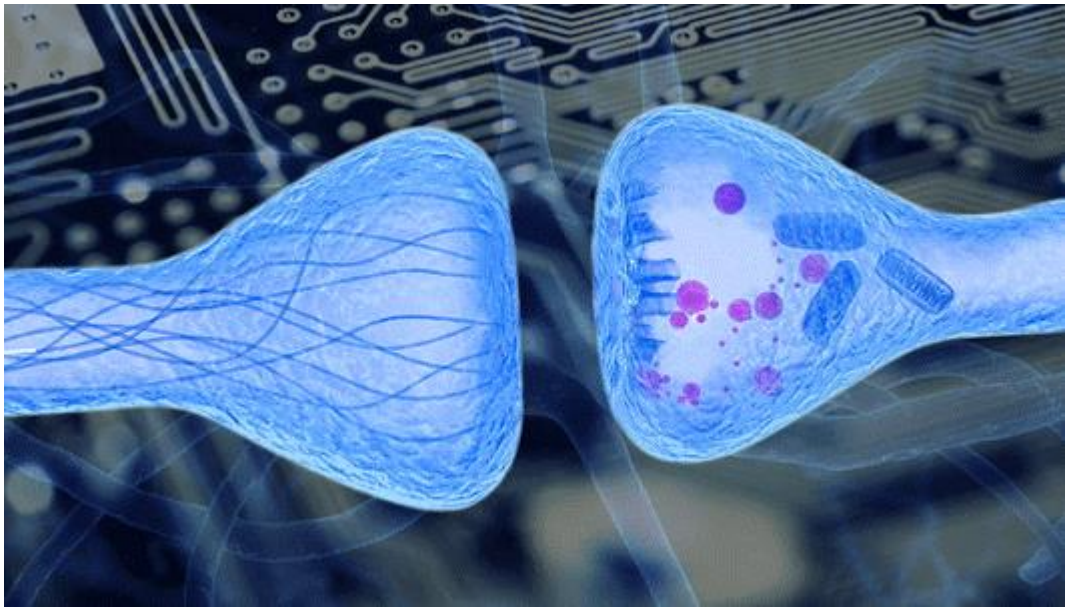
Our roughly **100 billion neurons** in the adult brain, interact closely with other cell types, broadly classified as glia and there may be more of these, than neurons !!

To reach this huge target, the brain in a developing fetus must create around 250,000 neurons per minute !!

This can also happen in adults, to repair a damaged brain area that happened from a stroke or other problem.

- Each of the 100 billion neurons are connected to at least 10,000 other neurons – giving well over **500 trillion connections in the brain.**

- **Amazingly, where each cell connects with the other one, <u>NONE</u> of these cells touch each other because the electrical and chemical signals cross between the ends of the cells, called Synapses !!**



INTERESTING FACTS:

- **The brain's memory storage capacity is about 2.5 petabytes (or 2.5 million gigabytes).**

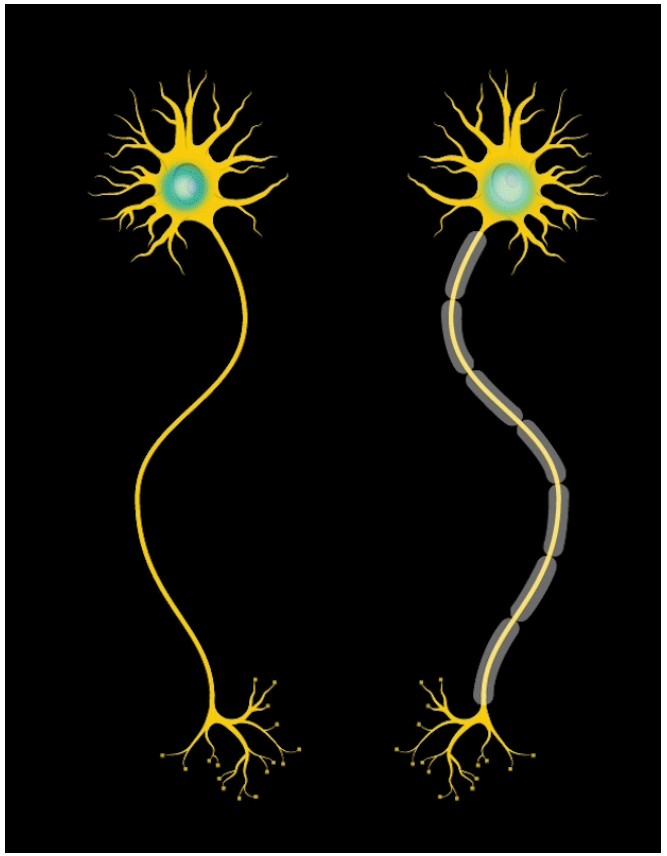
  For comparison, if your brain worked like a digital video recorder (DVR) in a television, **2.5 petabytes would be enough to hold three million hours of TV shows.**

  You would have to leave the TV running continuously for more than 300 years to use up all that storage.

- **Signals of neurons from the spinal cord to the muscles range from 156-270 miles per hour.**

- **Signals carried by nerve fibers of the pain receptors, travel at slower speeds ranging from 1.1 to 4.4 miles per hour.**

- Every second, hundreds of billions of electrical impulses called **action potentials** are transmitted in your body.



The Neuron on the right has short fatty sections of Myelin that insulates it.

The electric signal jumps between the sections of Myelin, which lets it move faster than the cell on the left, which doesn't have the insulating Myelin on it.

Multiple Sclerosis is a disease caused by the slow removal of Myelin on our nerves, which causes them to short-circuit.

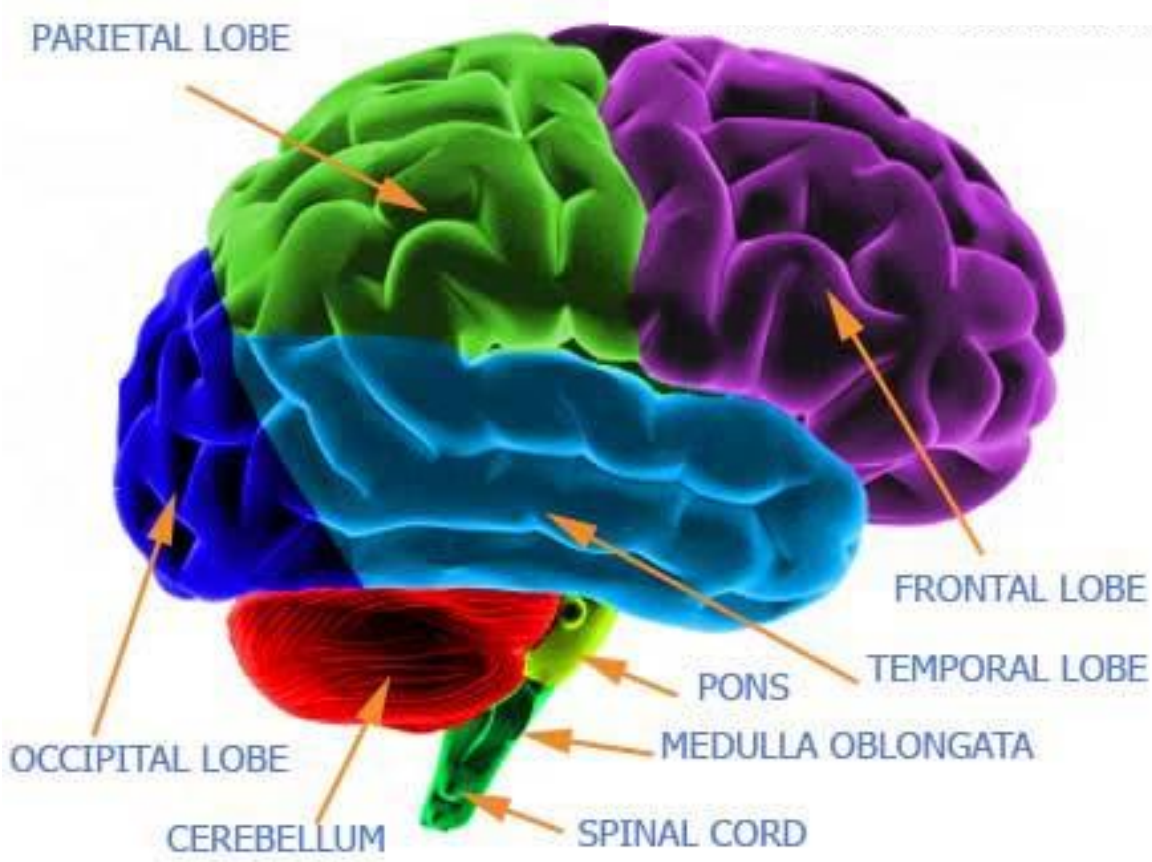
- The purpose of the axon is to transmit an electro-chemical signal to other neurons, sometimes over a considerable distance.

- **Neurons in the brain are very short**

- **Neurons from the spinal cord to your toes, can be as long as 3 feet!**

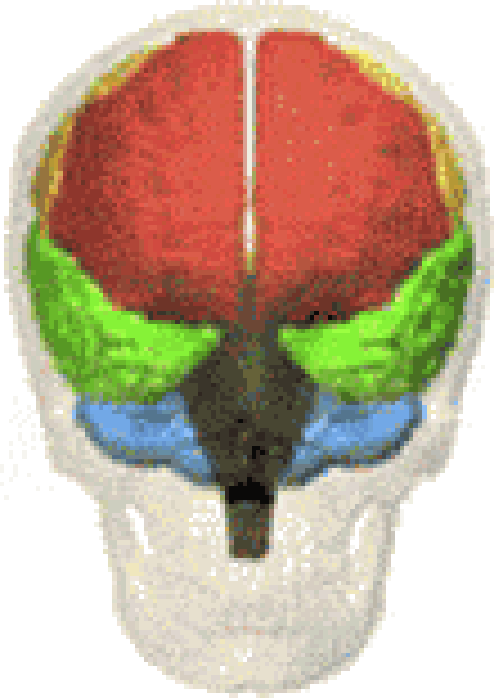
THE BRAIN

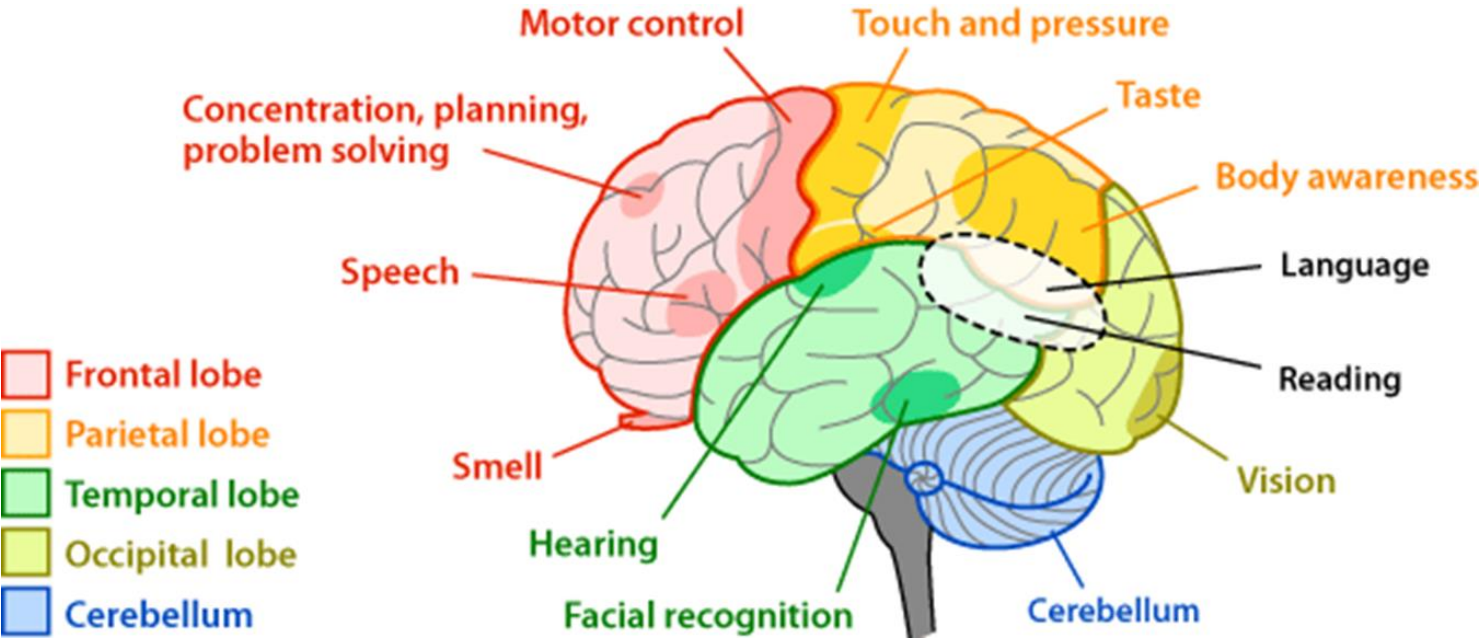
At the root of all the things we can do and think is the 3-pound generator we all carry in our head.



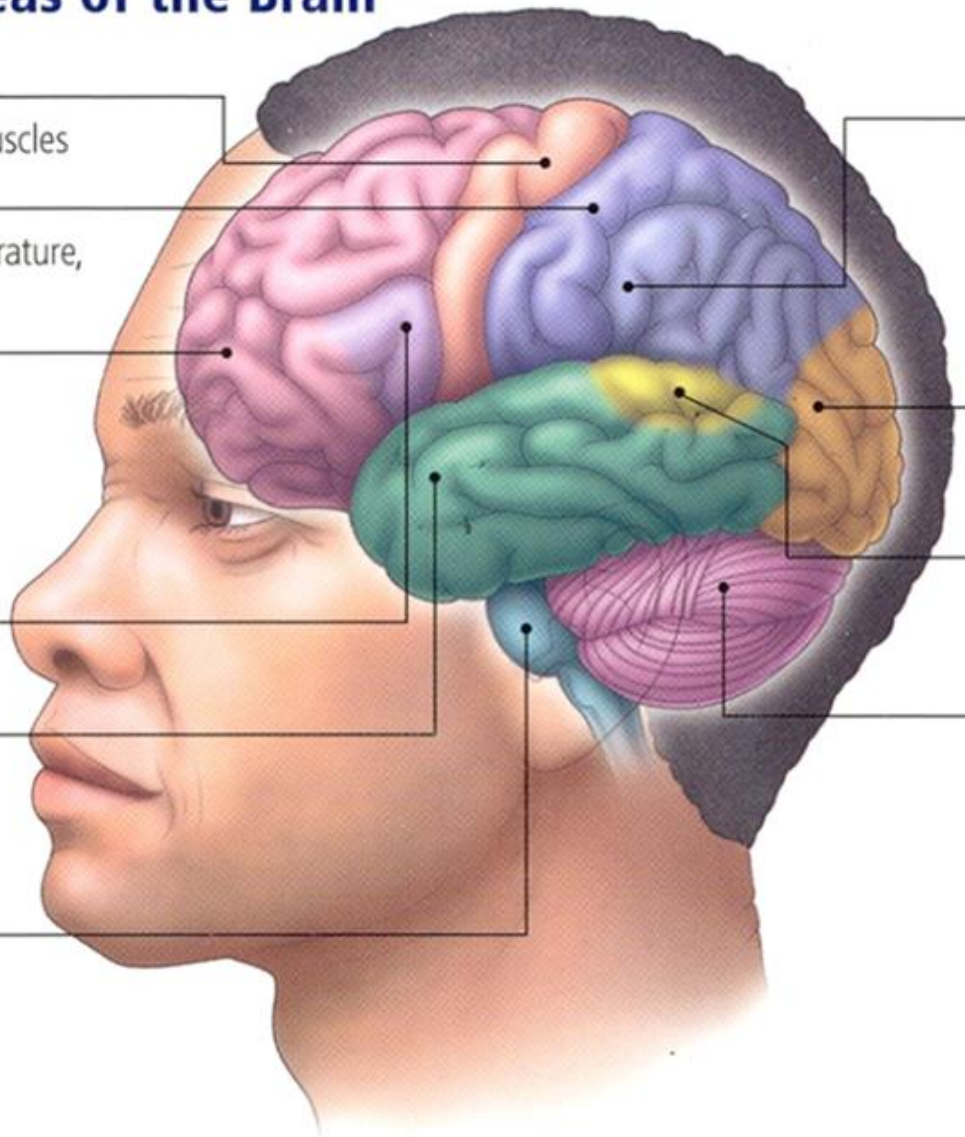
It produces electricity at the microvolt (millionth of a volt) level. But the signals are strong enough to move robots, wheelchairs and prosthetic limbs -- with the help of an external processor that amplifies the electric signals.

THE BRAIN IS DIVIDED INTO 4 LOBES AND THE CEREBELLUM WHICH IS LOCATED AT THE BOTTOM, BACK AREA





Functional Areas of the Brain[1]



Motor Area
- control of voluntary muscles

Sensory Area
- skin sensations (temperature, pressure, pain)

Frontal Lobe
- movement
- problem solving
- concentrating, thinking
- behaviour, personality, mood

Broca's Area
- speech control

Temporal Lobe
- hearing
- language
- memory

Brain Stem
- consciousness
- breathing
- heart rate

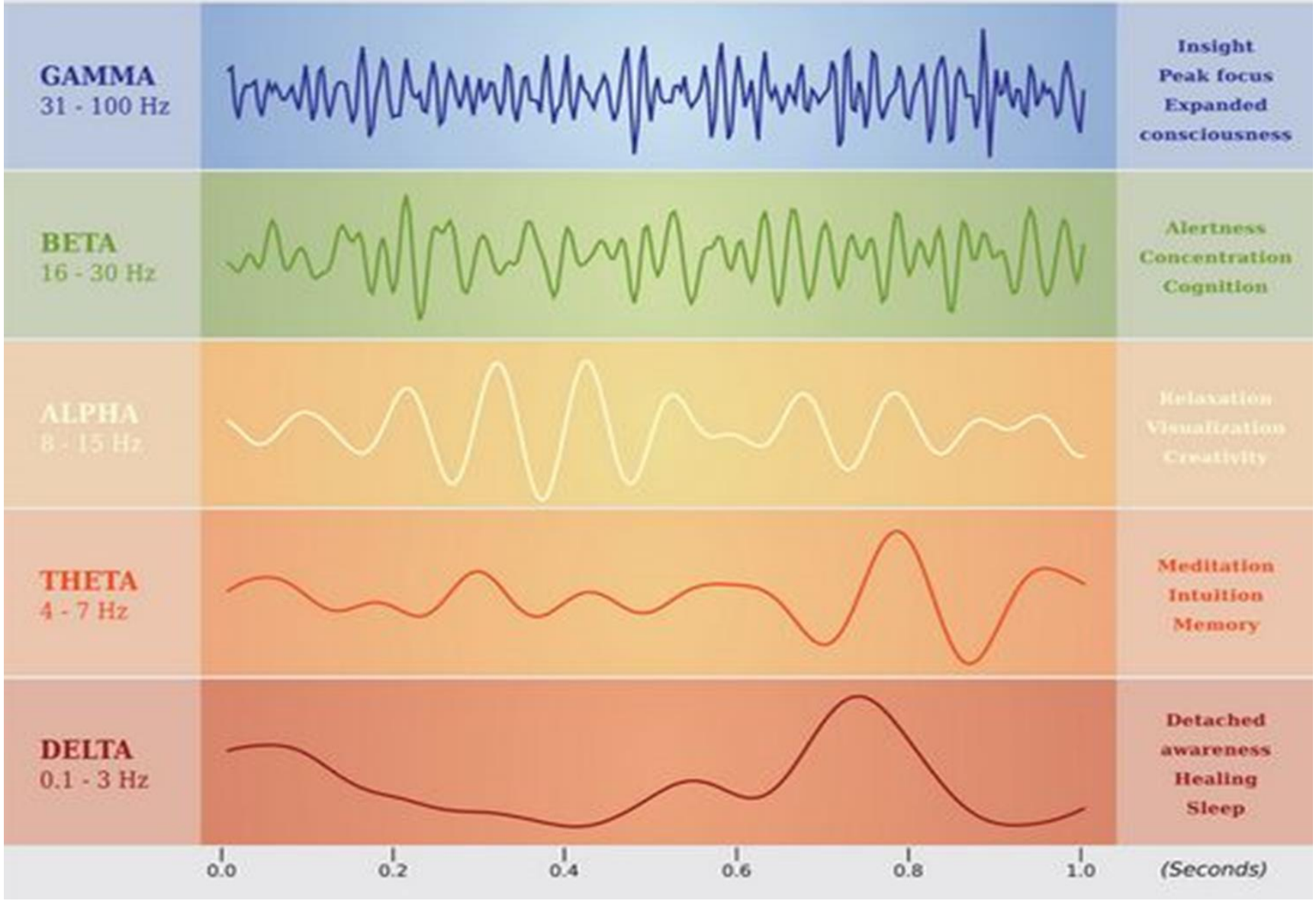
Parietal Lobe
- sensations
- language
- perception
- body awareness
- attention

Occipital Lobe
- vision
- perception

Wernicke's Area
- language comprehension

Cerebellum
- posture
- balance
- coordination of movement

HUMAN BRAIN WAVES



It is a handy analogy to think of brainwaves as musical notes –

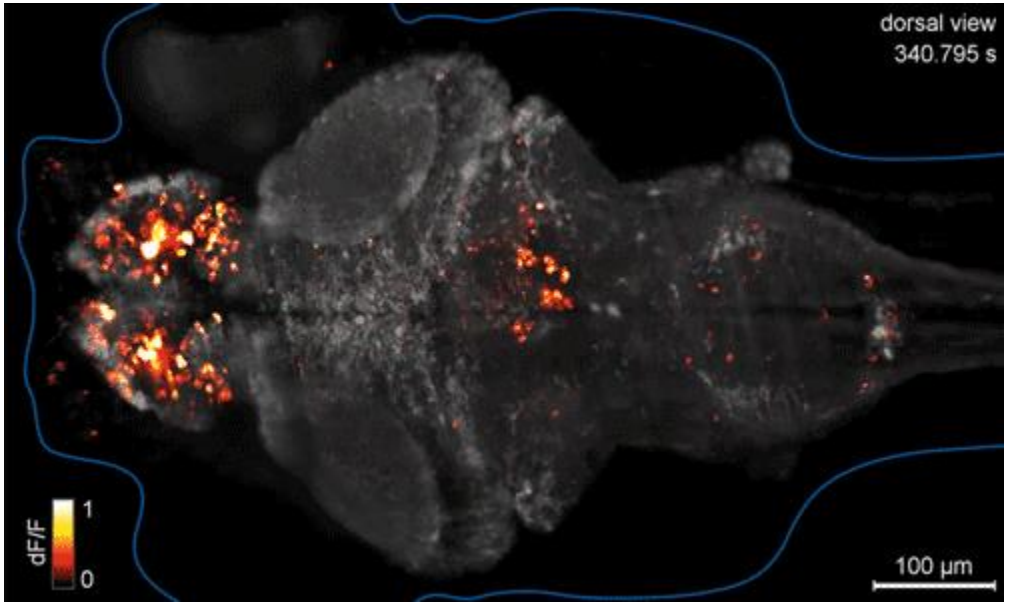
The low frequency waves are like a deeply penetrating drum beat

The higher frequency brainwaves are more like a subtle high pitched flute.

Our brainwaves change according to what we're doing and feeling. When slower brainwaves are dominant we can feel tired, slow, sluggish, or dreamy. The higher frequencies are dominant when we feel wired, or hyper-alert.

80,000 NEURONS FIRING IN THE BRAIN OF A BABY ZEBRA FISH AS IT RESPONDS TO WHAT IT SEES.

(the whole horizontal length shown is .04 inch – 4 hundredths of an inch)



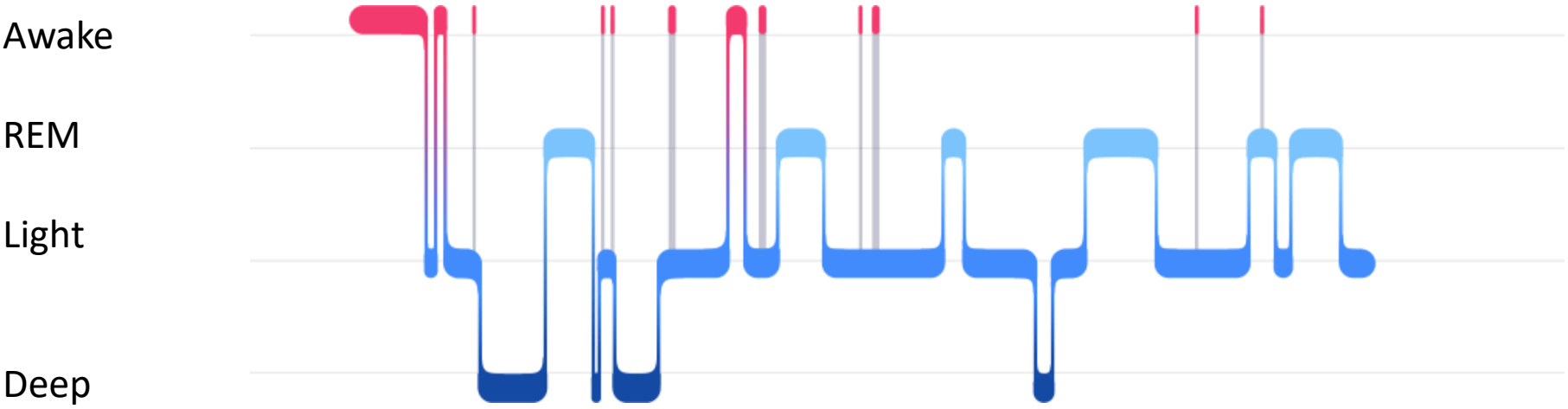
Brainwave speed is measured in Hertz (cycles per second) and they are divided into bands of slow, moderate, and fast waves and in order, they are 1) Delta, 2) Theta, 3) Alpha, 4) Beta, and 5) Gamma, as shown on the next set of slides.

THE FITBIT TRACKER AND HOW IT MEASURES OUR STAGES OF SLEEP

Each night, the body cycles through different sleep stages: light sleep, deep sleep and REM (Rapid Eye Movement).

Using the power of PurePulse® heart rate and sensitive motion detectors, **Fitbit** trackers can measure your time spent in each sleep stage, as well as your time awake.

This makes it easy for you to understand your sleep quality and learn whether you spent enough time in each sleep stage.



Awake - Being awake for brief periods—between 10-30 times—is a normal part of sleep.

Light Sleep - Light sleep usually makes up half your night and is good for memory and learning.

Deep Sleep - Deep sleep is important for the immune system and for physical recovery from workouts.

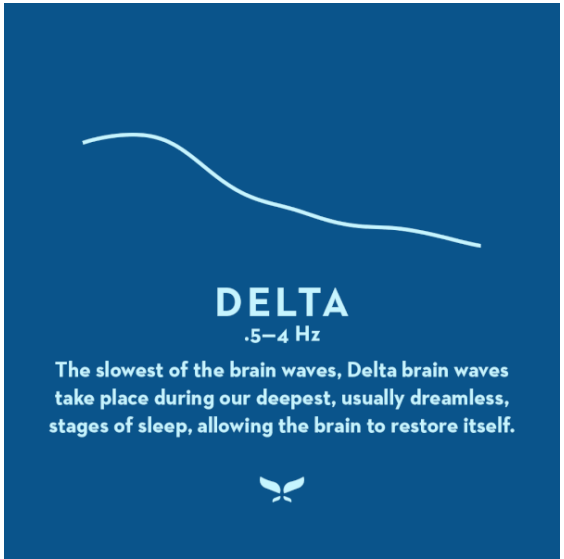
REM –Rapid Eye Movement
REM typically occurs when you're coming out of deep sleep and helps with mental restoration.

DELTA - 0.1 TO 4 HERTZ (Hz) (CYCLES PER SECOND) - The lowest frequencies are delta. These are less than 4 Hertz and occur in deep sleep and in some abnormal processes.

It is the dominant rhythm in infants up to one year of age and it is present in stages 3 and 4 of our sleep. It tends to be the highest in amplitude and the slowest waves.

We access information in our unconscious mind through Delta. Peak performers decrease Delta waves when high focus and peak performance are required.

Another way to look at Delta is to imagine you are driving in a car and you shift into 1st gear….you're not going to get anywhere very fast. So Delta would represent 1st gear.



THETA 4-7 HERTZ (Hz) (CYCLES PER SECOND) - It is seen in connection with creativity, intuition, daydreaming, and fantasizing and represents thoughts about memories, emotions, and sensations.

They are strong during internal focus, meditation, prayer, and spiritual awareness. It reflects the state between wakefulness and sleep and relates to the subconscious mind.

They are abnormal in awake adults but is perfectly normal in children up to 13 years old. It is also normal during sleep of everyone.

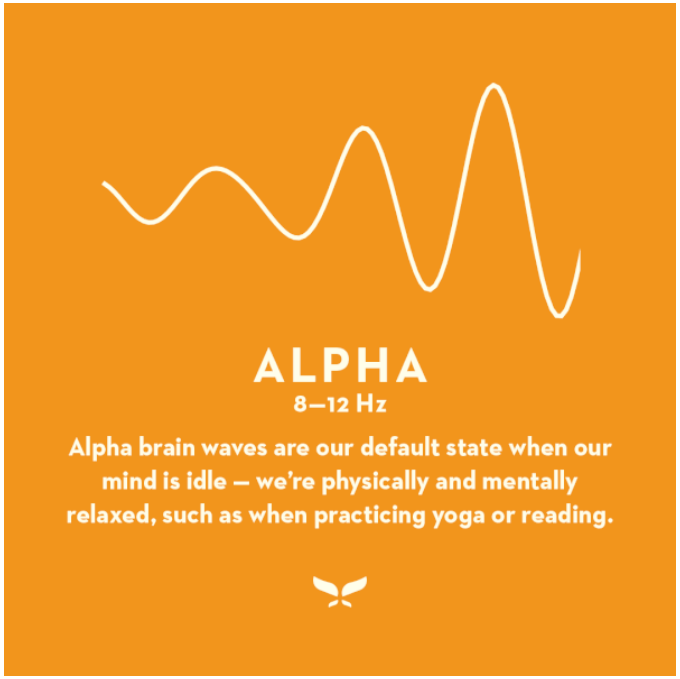
Back to our car example, Theta would be considered 2nd gear. Not as slow as 1st gear (Delta) but still not very fast.

ALPHA WAVES - THE ALPHA FREQUENCY BAND IS GENERALLY IN THE RANGE OF 7 – 12 Hertz (Hz) (CYCLES PER SECOND).

Alpha waves are opposite related to cortical (the brain cortex – see picture below) activation and increased activity in the left prefrontal cortex is associated with good motivation.

Alpha oscillations have been shown to play a key role in inhibition of non-essential processing, which in turn helps task performance.

Furthermore, alpha waves are closely linked with perceptual awareness and attention control.



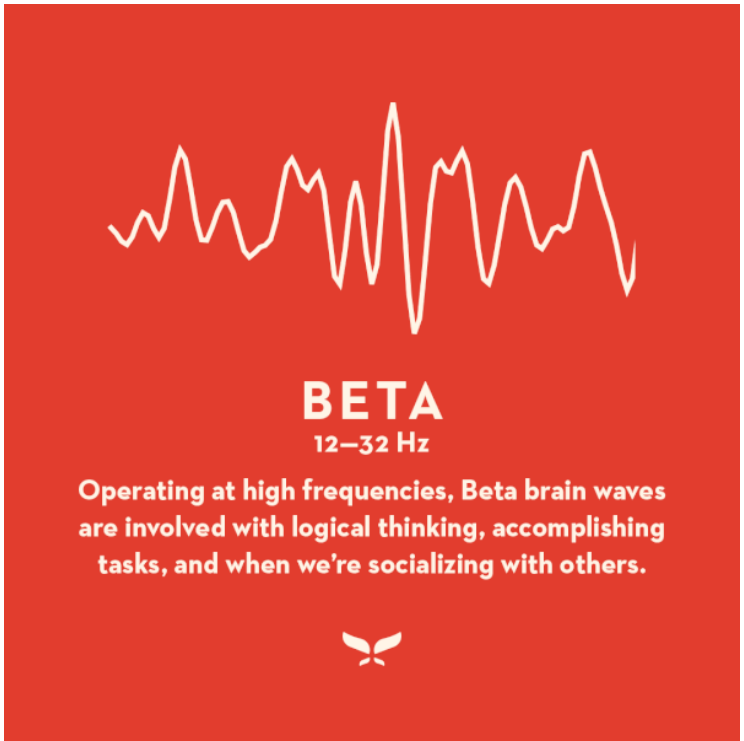
BETA (12 to 30 Hz)

Beta activity is 'fast' activity.

It is generally regarded as a normal rhythm and is the dominant rhythm in those who are alert, anxious, listening, thinking or who have their eyes open.

Beta would represent overdrive or hyperdrive in our car scenario.

The beta band has a relatively large range, and has been divided into low, mid-range, and high.

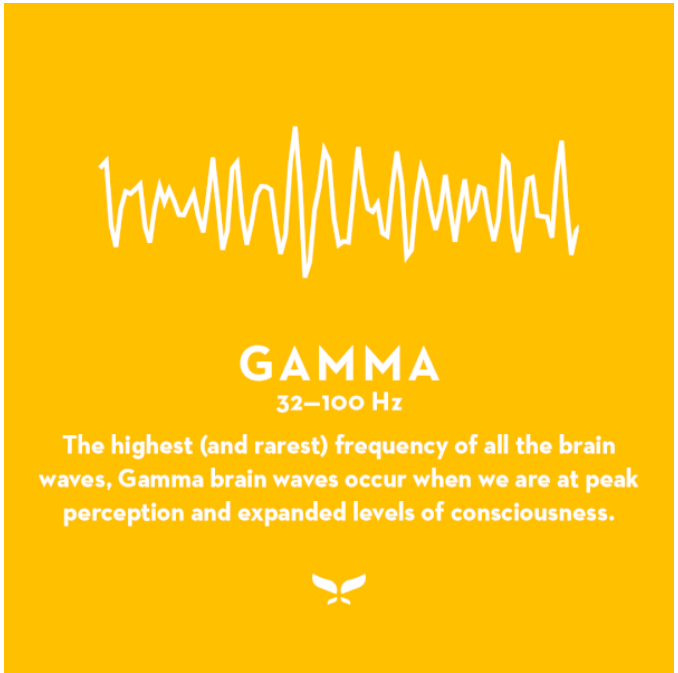


GAMMA WAVES (30 TO 50 Hertz) (cycles per second) - Gamma brainwaves are the fastest of brain waves and relate to simultaneous processing of information from different brain areas

They pass information rapidly and quietly. The most subtle of the brainwave frequencies, the mind has to be quiet to access gamma.

Gamma was dismissed as 'spare brain noise' until researchers discovered it was highly active when in states of universal love, altruism, and the 'higher virtues'.

It is speculated that gamma rhythms modulate perception and consciousness, and that a greater presence of gamma relates to expanded consciousness.



NON-INVASIVE DEVICES AND APPLICATIONS

The field of the Brain-Computer Interface (BCI) is a driving force for using electro-encephalography technology (EEG).

It records electrical activity from brain neurons, using a device on top of the head with electrodes which measure Beta, Delta, Alpha, and Theta brain waves.

Neurologists can identify patterns in a patient's brain wave activity, allowing them to spot abnormalities that could give rise to seizures or other neurological disorders.

Persons can also use them to operate toys and other devices.

TYPES OF HEADSETS ON THE MARKET AND WHAT THEY CAN DO FOR US

Wearable EEG devices: (a) Emotiv, (b) NeuroSky, (c) Zeo, (d) StarLab, (e) EmSense, (f) nia Game Controller, (g) Mindo 4 with dry foam electrodes, and (h) Mindo 16 with dry spring-loaded probe sensors.

NeuroSky's MindWave (also in XWave headsets)

- EEG with 1 dry electrode
- Measures "attention," "meditation" and eye-blinks
- Bluetooth communication
- SDK for iOS, Android, PC & Mac
- $129.99 to $79.95 retail neurosky.com
- Hacking:
  - http://makezine.com/2011/05/10/behind-the-brain-blinker/
  - http://hackaday.com/2012/12/20/modifying-an-eeg-headset-for-lucid-dreaming/

EMOTIVE EPOC (14 SENSORS)

EPOC +

INSIGHT (7 SENSORS)

FLEX (32 SENSORS)

In 2009, Emotiv Systems released a headset called the EPOC that allows the user to play video games with only their brainwaves.

The device can read 4 mental states, 13 conscious states, facial expressions, and head movements.

The Emotive EPOC system is a wireless neuro-headset.

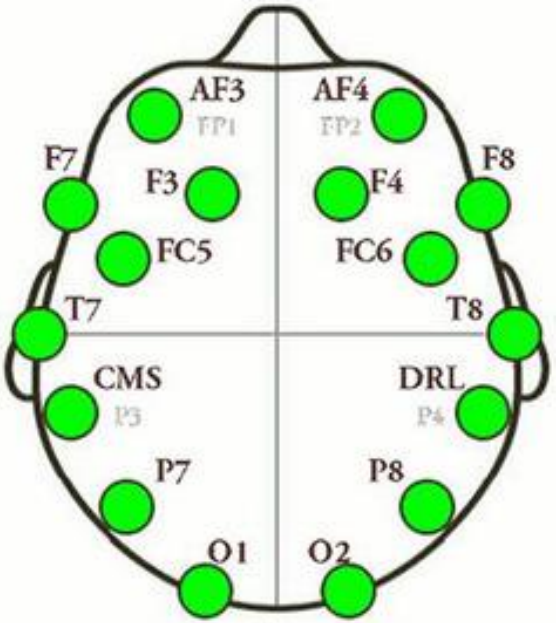
It uses a set of sensors to tune into electric signals produced by the brain to detect player's thoughts, feelings and expressions and connects wirelessly to most PCs.

EMOTIV EPOC+ HEADSET - (see Figure 1a) was originally marketed for video games where players control various aspects within the game environment.

Over the years, its use has increased within new research areas due to its low price and portability.

The Emotiv EPOC+ headset has 14 sensors and 2 references (see Figure 1b). The sampling frequency for each of the channels is 128 Hz and the battery life is approximately 12 hours with regular use. It also has a gyroscope built in to measure head rotation and is wireless, using Bluetooth technology.

(a)



(b)

Emotiv Insight

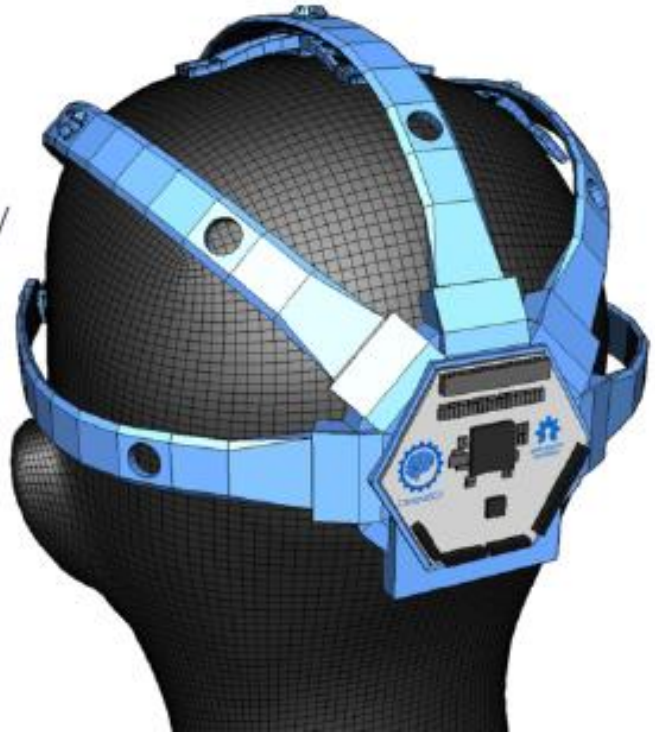
- Expected 2015
- Starting at $299
- 5+2 dry sensors
- Bluetooth 4.0 LE (Smart)
- Battery Life: 4+ hours
- SDK: Android, iOS, Mac, Linux and Windows Platforms

InteraXon's Muse

- 7 dry EEG sensors via Bluetooth
- Focuses on "brain fitness"
- 4 hour battery
- Basic Mac & Windows SDK now, full SDK coming soon (incl. iOS & Android)
- Works with Windows, OS X, iOS, Android, etc.
- $299 available now
- choosemuse.com

OpenBCI

- Open source hardware & software
- Bluetooth, Arduino, EEG
- 8 wet Electrodes per board (can daisy chain boards)
- Full open EEG & BCI platform
- $449 - $799 (now shipping)
- www.openbci.com
- No iOS or Android *yet*



THE MILTON FORCE TRAINER HEADSET

https://www.youtube.com/watch?v=C7bu26pp2Zs 2.5 minutes

For very detailed EEG measurements, a cap with a lot of electrode sensors is used.

The arrangement of the electrodes is called the 10–20 system, which is shown on the next slide.

For the **10-20 system**, the electrodes are labeled by their location on the different brain lobes, under the scalp:

F for frontal

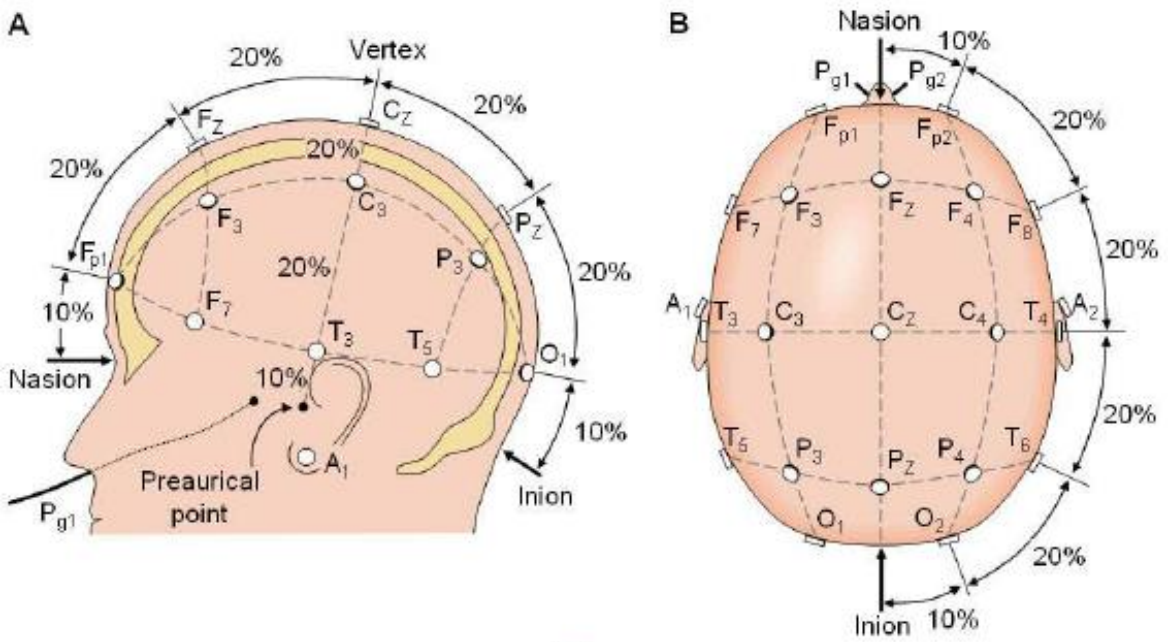
C for central

T for temporal

P for parietal

O for occipital

and numbered so that the Z (for zero) electrodes run down the center, odd electrodes are on the left hemisphere, and even electrodes are on the right.



Noninvasive techniques use electrodes placed on the scalp to measure electrical activity.

MYSTERIES OF THE BRAIN-COMPUTER INTERFACE
https://www.youtube.com/watch?v=p1XQ4uxqxZI 5 minutes

APPLICATIONS FOR NEURAL HEADSETS

1. Moving Things With the Mind

The EEG headset has helped paralyzed patients control an electric wheelchair and make music with a computer, using only the power of their minds.

The hope is that it's going to be more of a equalizing force, so that whether you are able-bodied or not you're still going to be able to communicate and interact with your world in a meaningful way.

BRAIN-CONTROLLED WHEELCHAIR

2) Diwakar Vaish, an inventor of a brain-controlled wheelchair, that uses a brain–computer interface:

An electroencephalogram (EEG) measuring device worn on the user's forehead detects neural impulses that reach the scalp.

This lets the micro-controller on board to detect the user's thought process, interpret it, and control the wheelchair's movement.

3) QAOBO CHILDREN'S EDUCATIONAL TOYS BRAINWAVE MIND CONTROL SPIDER INTELLIGENT MACHINE

Make the robot spider move with your brain !!

$90.00 on Amazon

BRAINWAVE CONTROLLED DRONE

The Emotive Epoc EEG device was used to read the raw EEG data.

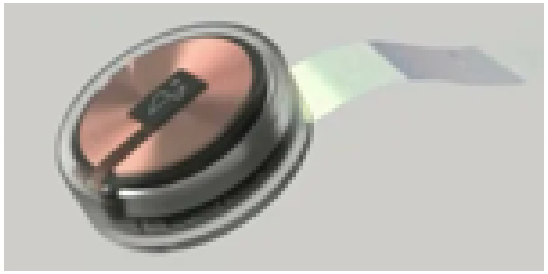
You need to pay attention to one of the blinking led with a specific frequency and this system can detect in your visual cortex which one you looked.

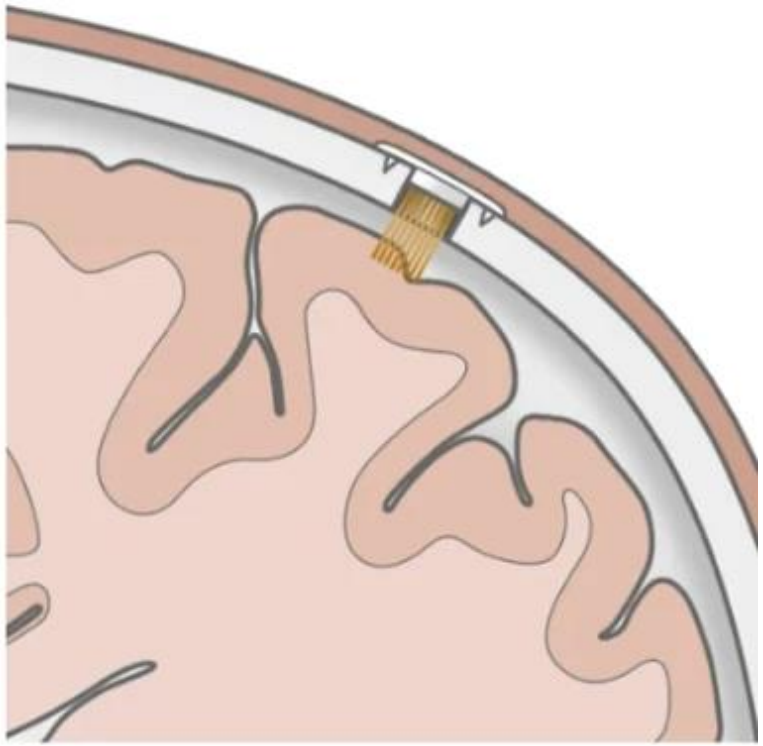
This system can be used by completely paralyzed people to help achieve improvement in quality of their life.

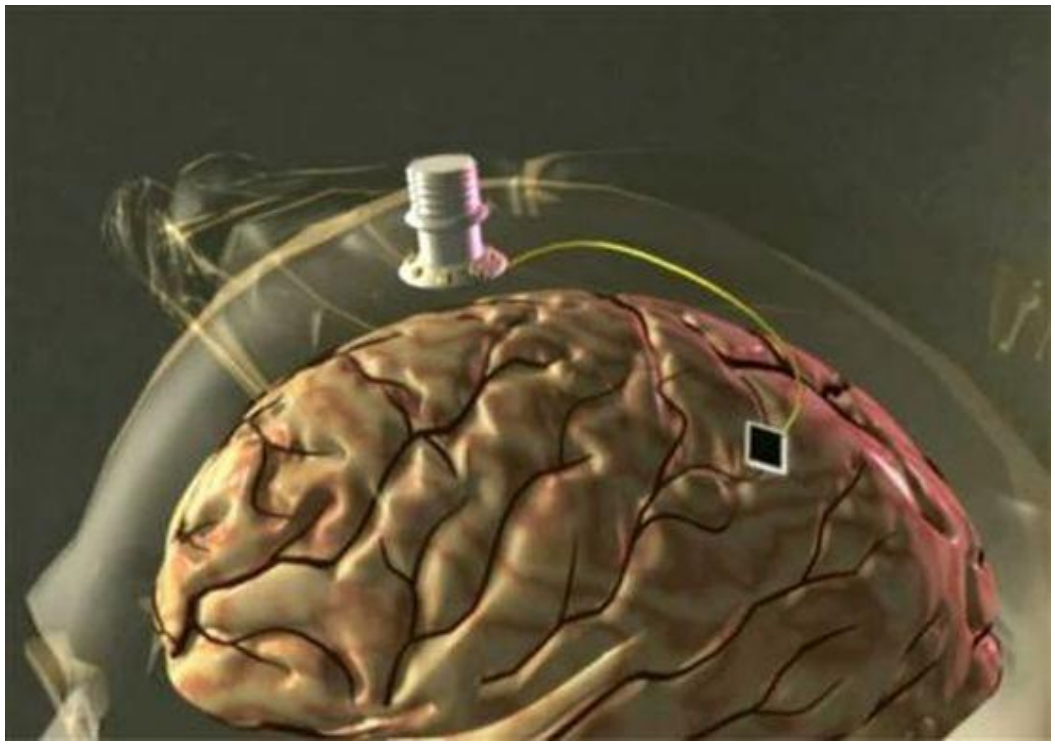
https://www.youtube.com/watch?v=MZ7fAJguac0

INVASIVE BRAIN-COMPUTER INTERFACES

NEURALINK





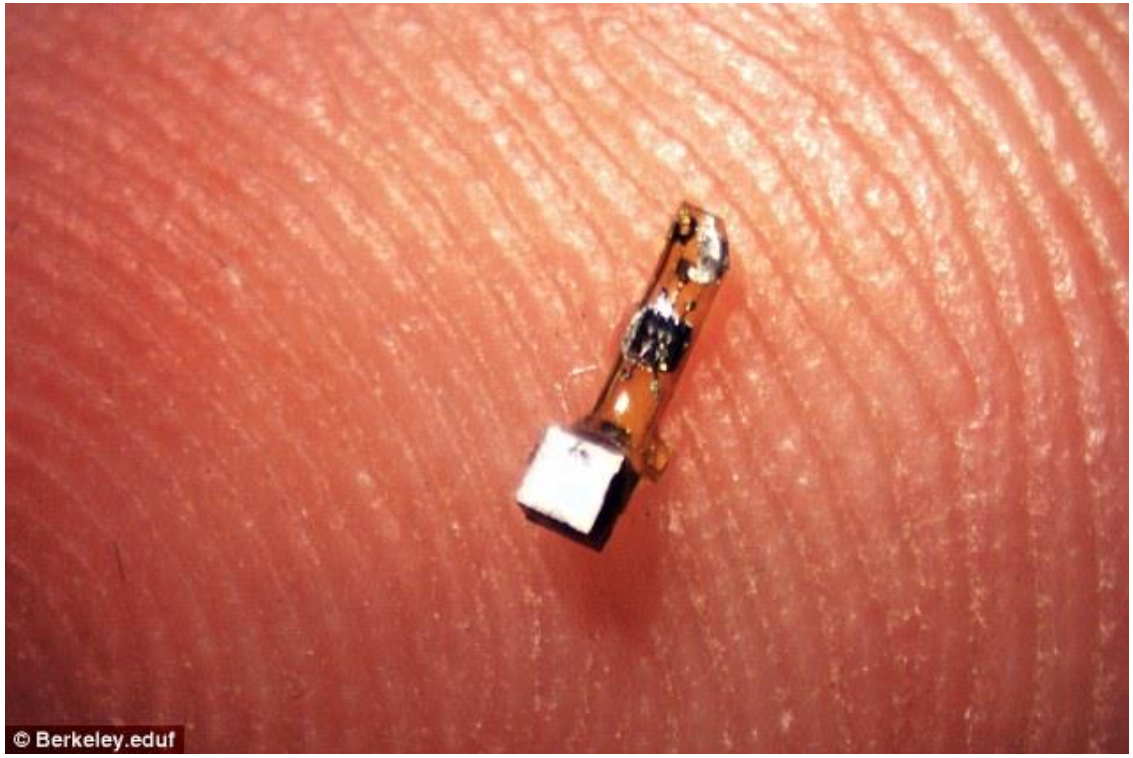


https://www.youtube.com/watch?v=A4BR4Iqfy7w 2.3 minutes

Scientists have created a very small 'neural dust' electrical circuit that can be implanted into the body.

It can be placed in the brain, or monitor internal nerves, muscles or organs in real time.

The so-called neural dust, which the team implanted in the muscles and peripheral nerves of rats, is unique in that ultrasound is used both to power and read out the measurements.



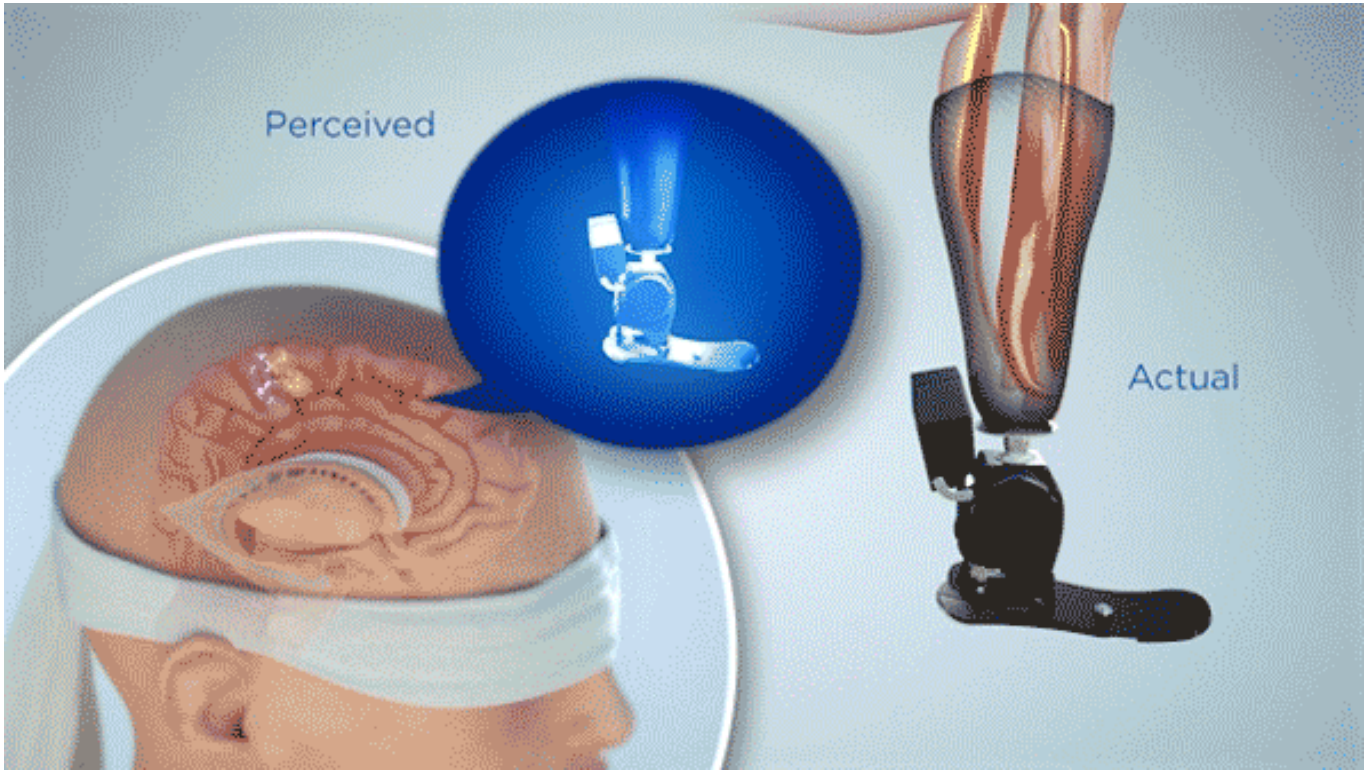
https://www.youtube.com/watch?v=oO0zy30n_jQ 1.8 minutes

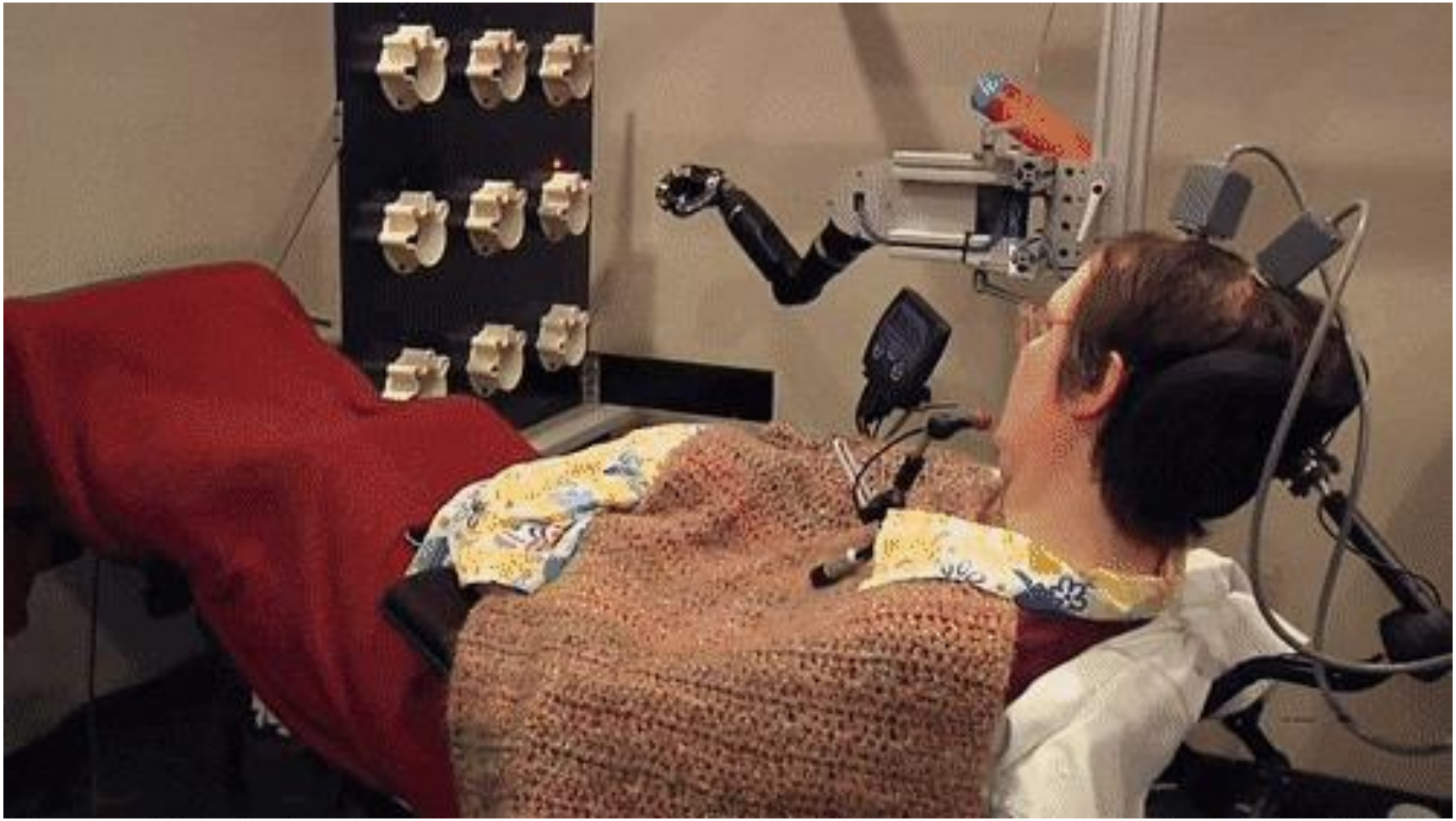
FIRST PROSTHETIC TO REALLY LET THE USER FEEL IT'S PRESENCE

A new neural interface for a patient's leg that can both send and receive signals from the brain.

The new neural interface has allowed the patient to sense his prosthetic much like a native leg instead of relying on another method of stimulation, such as vibration.

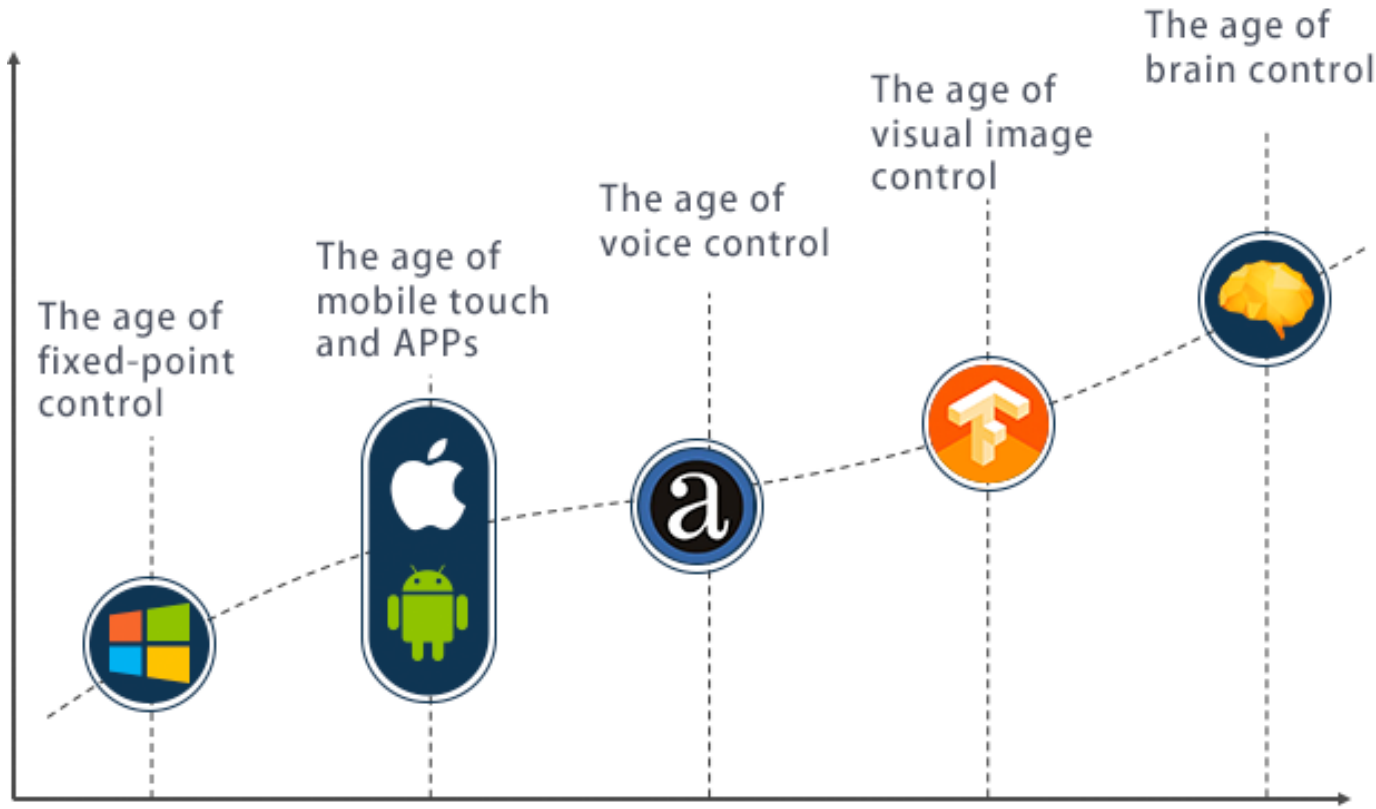
The patient is able to know the prosthetic's joint position, speed of movement, and even torque applied to the foot.





https://www.youtube.com/watch?v=3zjKUgrUIwg 2.5 minutes

HISTORY AND FUTURE ISSUES ABOUT THE BRAIN-COMPUTER INTERFACE

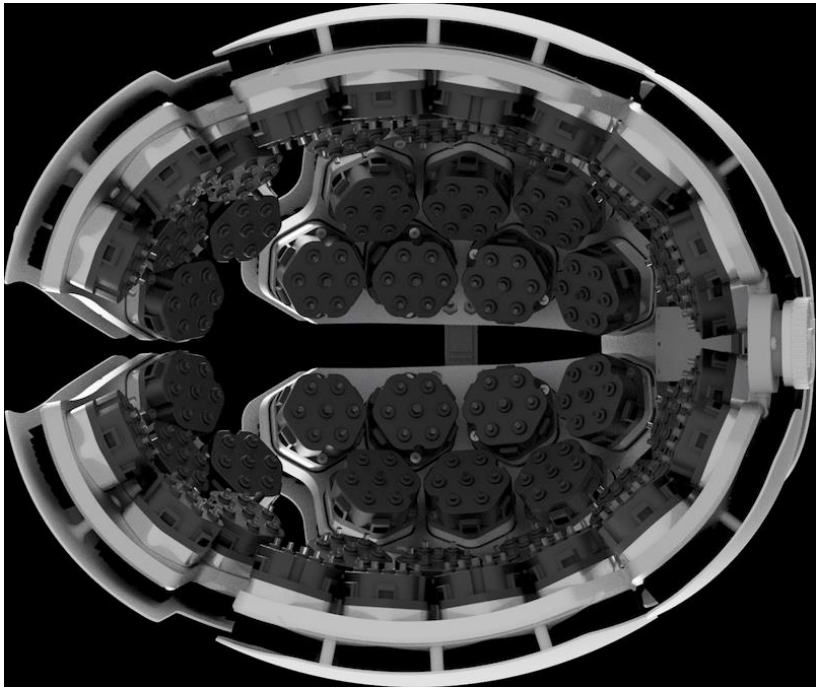


1. KERNEL - It is an early-stage brain-machine interface company.

It originally intended to build memory prostheses which would allow for the external storage anc subsequent upload of human memories into the hippocampus.

The company is now working on a way to measure and stimulate the electrical impulses of many neurons at once.

The technology will be used clinically for diseases such as depression or Alzheimer's.



2. DREEM

It was founded in France and is now based in San Francisco and is a neurotechnology startup that has developed a sleep-monitoring, head-mounted wearable.

The device uses EEG electrodes to monitor and analyze brain activity during the course of sleep.

It then uses “bone conduction technology” to modulate brain activity by emitting subtle sounds at precise moments that the company claims enhances the overall quality of deep sleep.

3. THYNC

It has developed a small, wearable “pod” that attaches to the back of the neck and uses neurostimulation to combat stress and promote better sleep.

Their lead product, the Thync Relax Pro, uses low levels of electrical stimulation to activate nerve pathways in the head and neck.

According to the company, these pathways communicate with areas of the brain to help control stress levels and sleep quality.

4. HALO NEUROSCIENCE

It is based in San Francisco, has developed a brain-stimulating device called the Halo Sport.

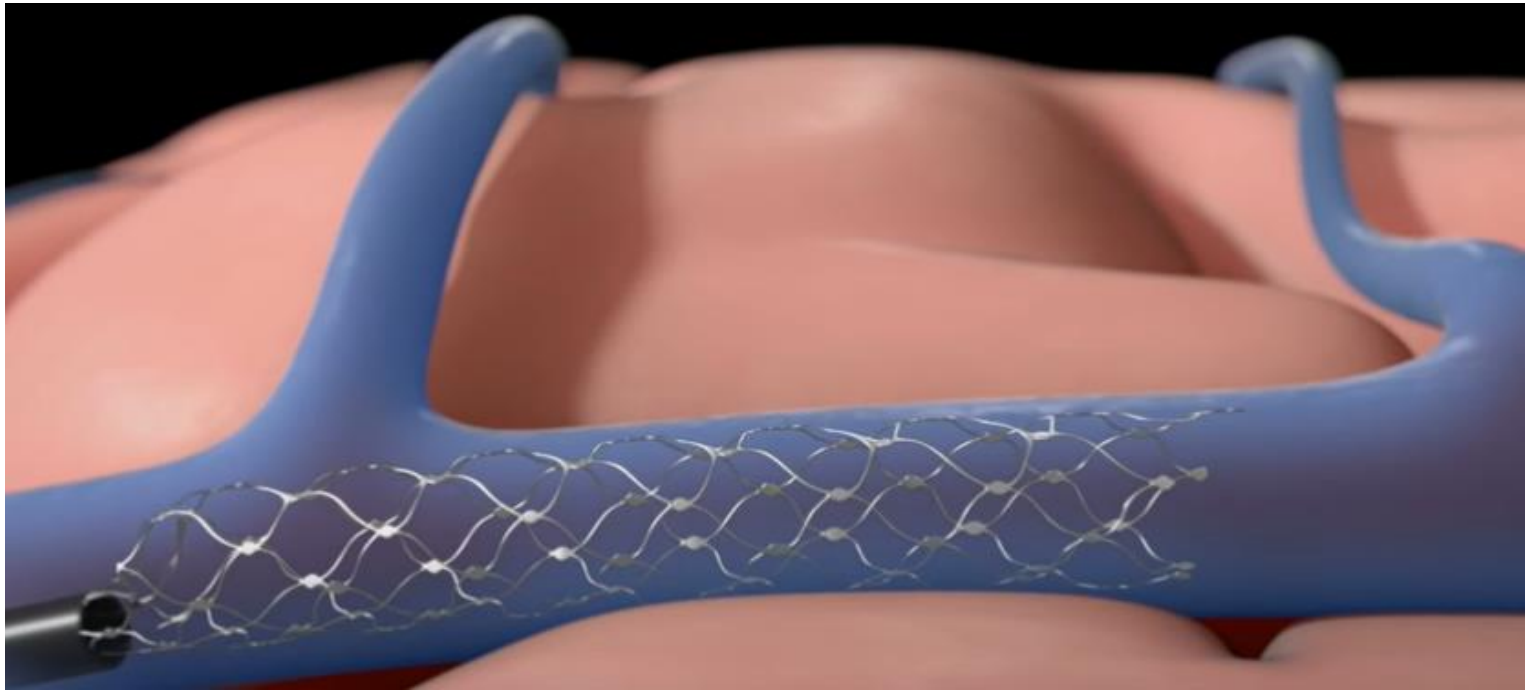
The device sends weak electrical pulses into the user's brain with the intent of enhancing the efficiency of physical training.

The product is based on the concept of neuropriming, i.e. using electrical stimulation to increase plasticity in the brain prior to an activity.

5. SYNCHRON

It is developing an implantable device, called the Stentrode, that aims to provide a safe way for paralyzed patients to achieve direct brain control of mobility-assistive devices.

The system involves a small and flexible device that can pass through cerebral blood vessels, allowing it to implant in the brain and interpret electrical data emitted by neurons to enable patient-directed brain control.



6. BRAINCO

BrainCo, a product of the Harvard Innovation Lab, specializes in brain-machine interface wearables.

The company's main product line is the Focus series, which offers wearable headbands for education, fitness, and mind-controlled games.

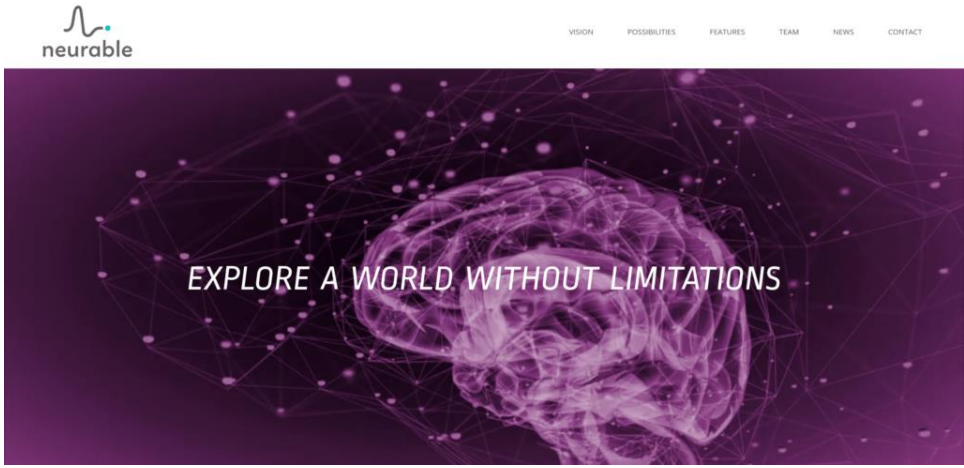
BrainCo has also expanded into prosthetics, working under the name BrainRobotics.

The company is developing a robotic prosthetic hand which can be controlled by the user's mind.

7. NEURABLE

Neurable is developing brain-computer interfaces that allow people to control software and devices using only their brain activity, using machine learning methods

Their current headset uses six dry electrodes and takes two minutes to calibrate, a notable improvement on its previous design which relied upon 32 wet electrodes to monitor brain activity and a calibration process of 30 minutes.



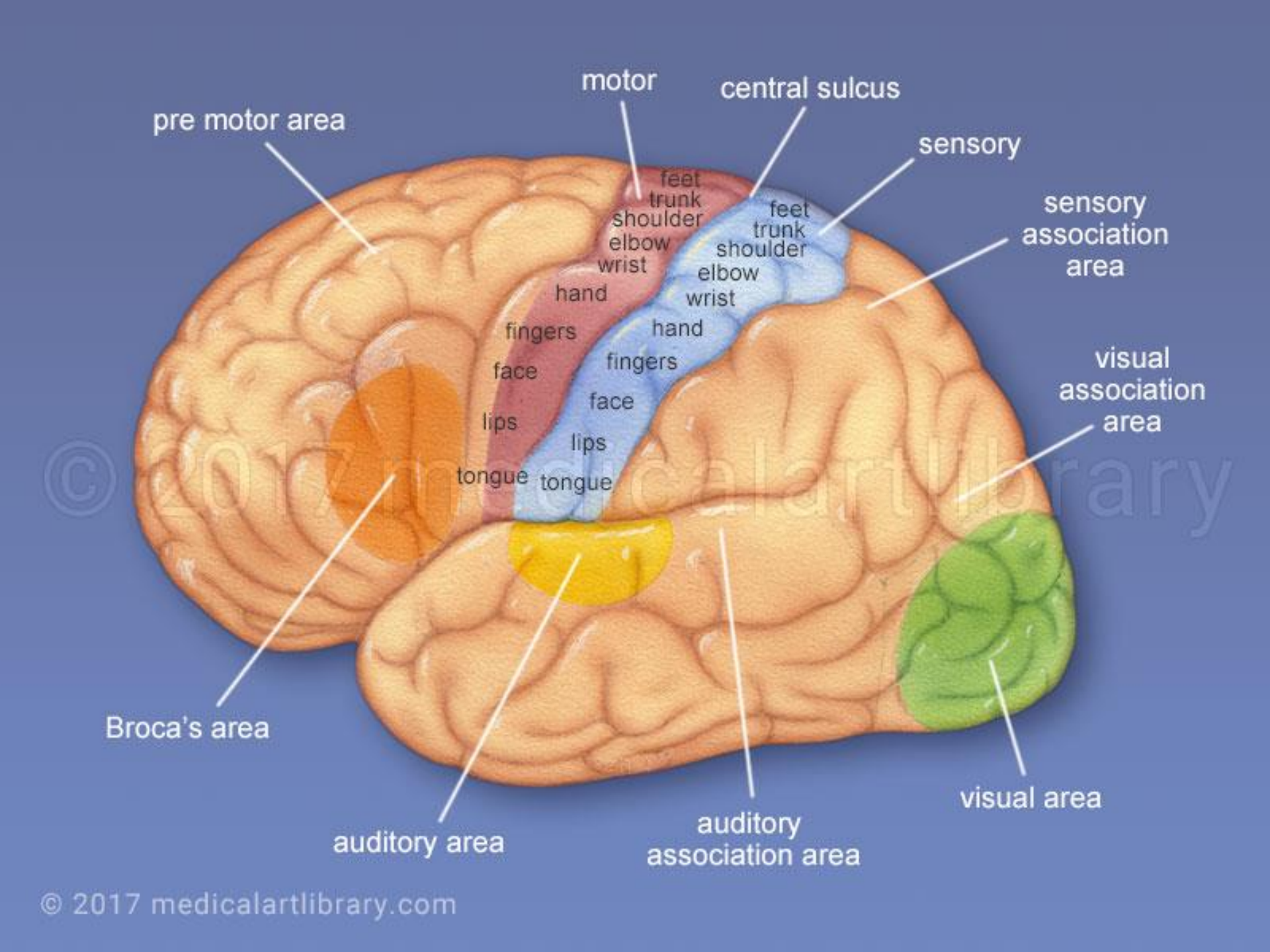
NEURALINK

8. Neuralink

Elon Musk started a new company to build brain implants to directly link human minds to computers.

Their goal is to make AI an extension of the human brain, essentially creating a symbiotic human-Artificial Intelligence (AI) relationship.

https://www.youtube.com/watch?v=E0ZJh8wfGVs
4.2 minutes


motor
central sulcus
pre motor area
sensory
feet
trunk
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elbow
wrist
hand
fingers
face
lips
tongue
sensory association area
visual association area
Broca's area
auditory area
auditory association area
visual area
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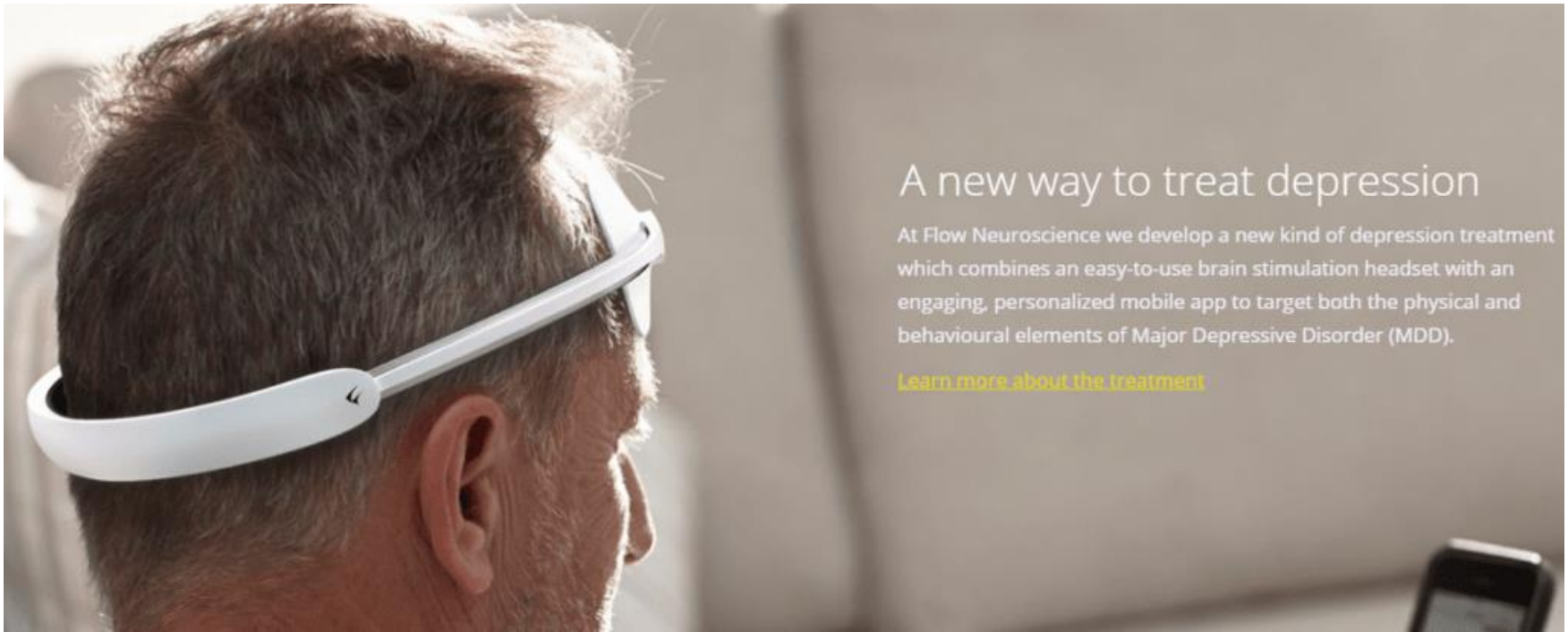
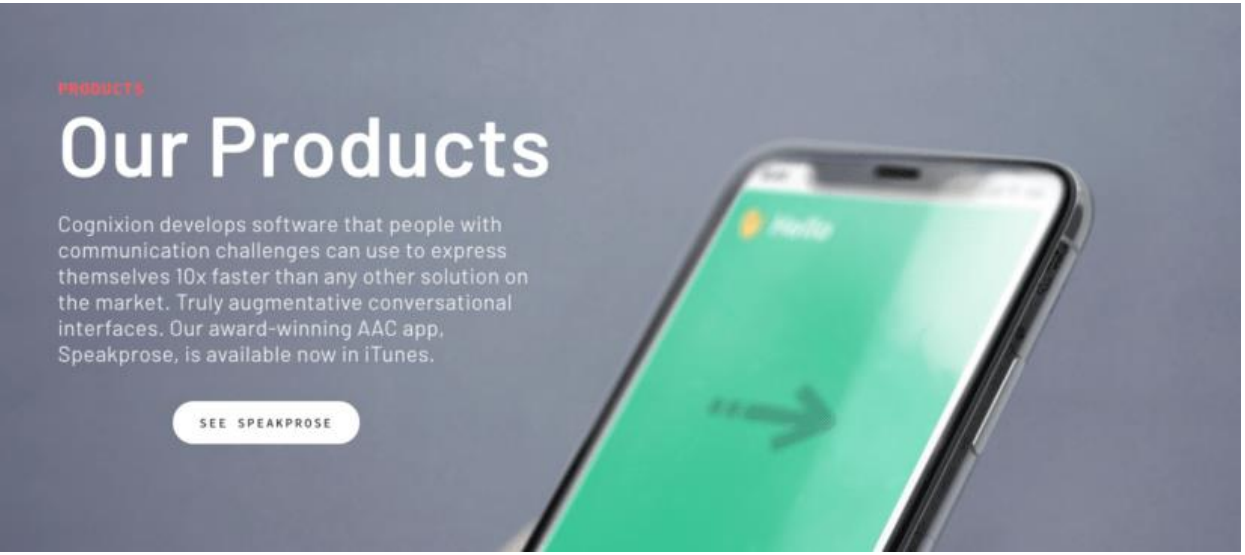
9. Flow Neuroscience

They use brain stimulation to treat depression.

They developed a headset that **delivers transcranial direct current stimulation (tDCS)** to the forehead which they say, reverses neural activity imbalances in the frontal lobe observed in people with depression.

The device pairs with a smartphone app that guides the user through a 6-week wellness program.





10. Cognixion

Founded in 2014, they aim to develop products that facilitate communication for people with speech pathologies, and other communication difficulties, through artificial intelligence and augmented reality.

The company's first software product, an app called Speakprose, is currently available for iOS devices.

They are also working on several other technologies, including brain control interfaces.

11. Bitbrain Technologies

They are doing research and development of several brain sensor technologies including:

- EEG devices
- Vehicle neuro-configurators
- Artificial Intelligence (AI)-driven neuro-marketing, which aims to provide insights into the subconscious motivations of consumers.

12. Paradromics

They develop neuro-prostheses designed to help patients with disabilities, such as blindness, better navigate and interact with the world around them.

Since being founded in 2015, the company has received institutional support from the U.S. Department of Defense.

13. MELTIN MMI

The Japanese technology company intends to blur the line between humans and machines.

The company develops cybernetic augmentation technologies, including a “cyborg” hand called MELTANT-α.

This cybernetic device is operated by a handheld control module, mimicking a range of tactile motions and adjusting the strength of its grip.

14. Neuros Medical

They are a biomodulation company based in Ohio with a primary focus on pain relief.

Its Electrical Nerve Block technology aims to help patients suffering from chronic pain manage their symptoms more effectively.

The technology works by interfering with high-frequency electrical signals transmitted by the brain to the nervous system.

15. NextMind

The French neurotech startup develops brain-machine interface technology.

The company has built a small, head mounted sensor that is intended to allow users to send commands to external peripherals with their thoughts.

NextMind is initially targeting the consumer gaming market with its device.

16. Emotiv

They develop both hardware and software products.

Emotiv’s range of EEG technologies are designed to help physicians in complex tasks, such as building 3D visualizations of the human brain for diagnostic purposes.

The company also makes a headset targeted towards the consumer market, which can detect six cognitive states, including stress and relaxation, for wellness tracking.

17. Q30 Innovations

Q30 Innovations, based in Connecticut, is developing technology which claims to reduce traumatic brain injury.

Targeting athletes and military personnel, the company's main product is the Q-Collar, a wearable device designed to cushion the brain by increasing blood flow.

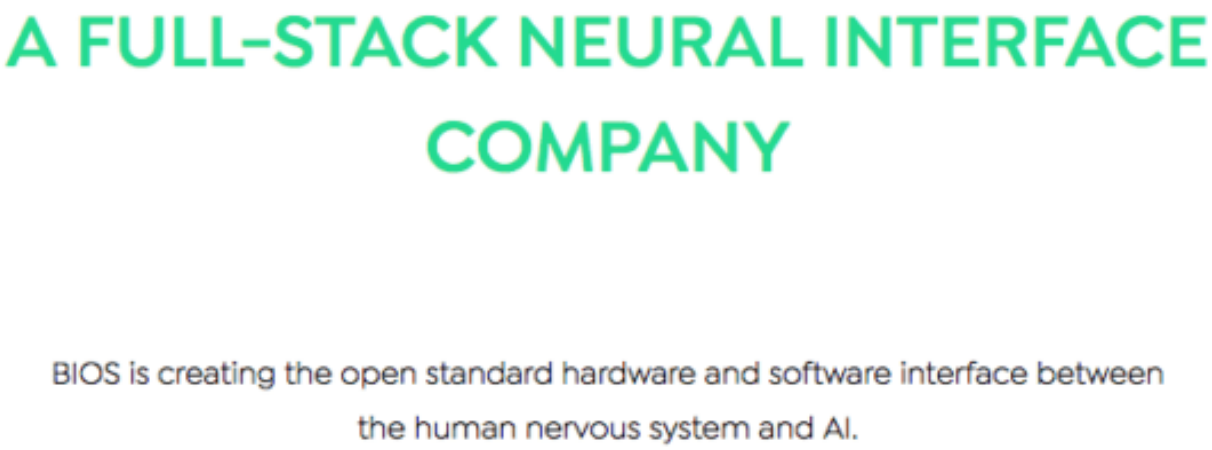
The product was approved for sale in Canada in 2017.

18. BIOS

They are a neural interface company based in Cambridge, UK.

The company is building what it describes as a “USB connector for the body,” more generally known as a prosthetic interface device.

This device is intended to allow amputees to control prostheses with brain signals.



19. NeuroScouting

They are a sports technology company.

The company's stated approach is to use artificial intelligence to analyze an athlete's performance and try to predict their potential.

They are also developing medical technologies, targeting conditions such as ADHD and traumatic brain injury.

20. NeuroPace

They are orking to develop medical technologies to help reduce epileptic seizures, a condition which affects 1.2% of the US population, according to the CDC.

The company's main product is the RNS System, an electrostimulation device that is surgically implanted by a neurosurgeon into a patient's brain.

The company claims to have reduced the incidence of epileptic seizures by 90% in roughly 1/3 of clinical trial participants.


THE END

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