QUICK START GUIDE FOR THE BCIA NEUROFEEDBACK DIDACTIC WORKSHOP

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What is neurofeedback?

Biofeedback Certification International Alliance (2016) definition of neurofeedback

Neurofeedback is employed to modify the electrical activity of the CNS, including EEG, event- related potentials, slow cortical potentials and other electrical activity either of subcortical or cortical origin. Neurofeedback is a specialized application of biofeedback of brainwave data in an operant conditioning paradigm. The method is used to treat clinical conditions as well as to enhance performance.

2

What is neurofeedback?

International Society for Neurofeedback and Research (2010) definition of neurofeedback

Like other forms of biofeedback, NFT uses monitoring devices to provide moment-to-moment information to an individual on the state of their physiological functioning. The characteristic that distinguishes NFT from other biofeedback is a focus on the central nervous system and the brain. Neurofeedback training (NFT) has its foundations in basic and applied neuroscience as well as data-based clinical practice. It takes into account behavioral, cognitive, and subjective aspects as well as brain activity.

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What is neurofeedback?

NFT is preceded by an objective assessment of brain activity and psychological status. During training, sensors are placed on the scalp and then connected to sensitive electronics and computer software that detect, amplify, and record specific brain activity. Resulting information is fed back to the trainee virtually instantaneously with the conceptual understanding that changes in the feedback signal indicate whether or not the trainee's brain activity is within the designated range. Based on this feedback, various principles of learning and practitioner guidance, changes in brain patterns occur and are associated with positive changes in physical, emotional, and cognitive states. Often the trainee is not consciously aware of the mechanisms by which such changes are accomplished although people routinely acquire a 'felt sense' of these positive changes and often are able to access these states outside the feedback session.

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What is neurofeedback?

NFT does not involve either surgery or medication and is neither painful nor embarrassing. When provided by a licensed professional with appropriate training, generally trainees do not experience negative side-effects. Typically trainees find NFT to be an interesting experience. Neurofeedback operates at a brain functional level and transcends the need to classify using existing diagnostic categories. It modulates the brain activity at the level of the neuronal dynamics of excitation and inhibition which underlie the characteristic effects that are reported.

Research demonstrates that neurofeedback is an effective intervention for ADHD and Epilepsy. Ongoing research is investigating the effectiveness of neurofeedback for other disorders such as Autism, headaches, insomnia, anxiety, substance abuse, TBI and other pain disorders, and is promising.

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What is neurofeedback?

Being a self-regulation method, NFT differs from other accepted research-consistent neuro-modulatory approaches such as audio-visual entrainment (AVE) and repetitive transcranial magnetic stimulation (rTMS) that provoke an automatic brain response by presenting a specific signal. Nor is NFT based on deliberate changes in breathing patterns such as respiratory sinus arrhythmia (RSA) that can result in changes in brain waves. At a neuronal level, NFT teaches the brain to modulate excitatory and inhibitory patterns of specific neuronal assemblies and pathways based upon the details of the sensor placement and the feedback algorithms used, thereby increasing flexibility and self-regulation of relaxation and activation patterns.

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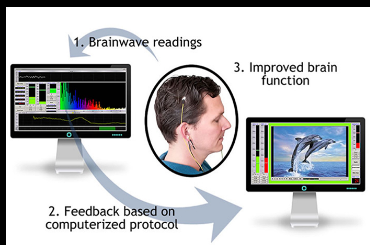
What is neurofeedback?



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Why do neurofeedback?

The brain is intimately responsible for how a person thinks, feels, experiences their body, and behaves. It functions using electrochemical activity. The electrical activity of the brain is seen in EEG activity. Patterns of activity within EEG bands and communication between brain regions are associated with diverse thinking and feeling states. Because neurofeedback changes EEG frequencies and nervous system communication, it can enhance attention, cognition, emotion, and performance.

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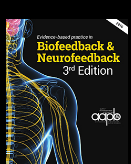
Why do neurofeedback?

Evidence-Based Practice in Biofeedback and Neurofeedback provides a scientific review of neurofeedback's efficacy in treating diagnosed disorders (e.g., ADHD and depression) and enhancing performance. Its findings show that neurofeedback achieves equal or greater efficacy than many accepted medical treatments.



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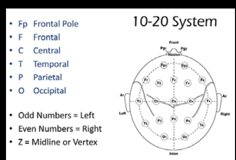
Where do the electrodes go and how do you find those places?

- The International 10-20 system is a standardized procedure for electrode placement on 19 scalp and reference and ground sites. Electrodes measure electrical activity from a surrounding area the size of a quarter. The site recorded may be distant from the EEG generator due to neural pathways.



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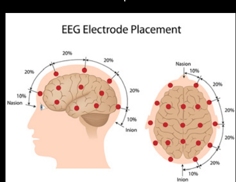
Where do the electrodes go and how do you find those places?

- The International 10-20 system calculates the distance from the nasion to the inion and from the left preauricular notch to the right preauricular notch. The 19 active electrode positions are found taking either 10% or 20% of these distances. Four essential landmarks are the nasion, inion, preauricular points, and vertex. Graphic © Alila Medical Media/Shutterstock.com.



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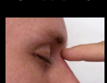
Where do the electrodes go and how do you find those places?

- The nasion is the depression at the bridge of the nose.



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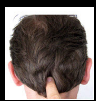
Where do the electrodes go and how do you find those places?

- The inion is the bony prominence on the back of the skull in the middle of the inion ridge.



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Where do the electrodes go and how do you find those places?

- The left and right preauricular points are slight depressions located in front of the ears and above the earlobe. The flap at the opening of the ear is called the tragus.

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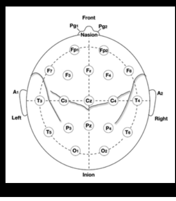
Where do the electrodes go and how do you find those places?

- The vertex (Cz) is the intersection of imaginary lines drawn from the nasion to inion and between the two preauricular points. Cz is 50% of the total distance between the nasion and inion and 50% of the total distance between the two preauricular points. John Balven adapted the diagram below from Fisch (1999).



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How do you apply electrodes to record the EEG?

- Once a site is identified and marked, site preparation and sensor placement when using individual sensors follow these steps:
  - Instruct clients to wash their hair and not use any conditioner or hair-styling products. A recent haircut is helpful (particularly for children), and hair must be brushed or combed.
  - Prepare the scalp by cleaning with alcohol. Let the alcohol dry before applying the electrodes.

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How do you apply electrodes to record the EEG?

- The following is a typical recommendation when using older amplifiers. Modern amplifiers with high input impedance do not require this step. Additionally, the following step is controversial because the old standard of achieving skin-electrode impedance below 5 Kohms has been challenged as unnecessary and risking the transmission of infection (Ferree et al., 2001; Kappenman & Luck, 2010).
- Slightly abrade the skin with a blunted needle that you must discard after use to remove dead skin, dirt, and oil that can weaken the EEG signal.
- Ask your client to remove jewelry. If your client has pierced ears, do not place the electrode over the hole.

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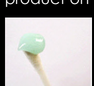
How do you apply electrodes to record the EEG?

- Scoop up a small quantity of NuPrep™ skin preparation gel or a similar product on a cotton swab or tissue.



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How do you apply electrodes to record the EEG?

- With the thumb and index finger of one hand, separate the hair around the electrode site that was previously found and marked. Graphic courtesy of Thought Technology Ltd.

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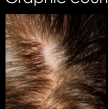
How do you apply electrodes to record the EEG?

- Wipe away the excess prepping gel with a dry, lint-free cloth. Take care to keep the hair parted and to keep track of the site after wiping clean. Graphic courtesy of Thought Technology Ltd.



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How do you apply electrodes to record the EEG?

- Use a popsicle or craft stick to cover the electrode with a 1/4-inch layer of Ten20™ conductive paste. Gently press the electrode onto the skin surface until the paste flattens out under the electrode.

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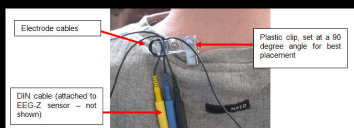
How do you apply electrodes to record the EEG?

- Start by securing the electrode cables to the patient and ensure strain relief. Graphic courtesy of Thought Technology Ltd.



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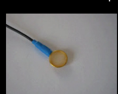
How do you apply electrodes to record the EEG?

- Fill the electrode cup with Ten20™ conductive paste so that no air bubbles exist in the cup. Graphic courtesy of Thought Technology Ltd.



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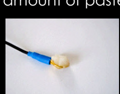
How do you apply electrodes to record the EEG?

- Add more Ten20™ conductive paste onto the cup electrode, just enough to form a ball on the cup, not so much that it spills over the edge. The ideal amount of paste is shown. Graphic courtesy of Thought Technology Ltd.



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How do you apply electrodes to record the EEG?

- Place the cup face down on the landing pad previously prepared. Gently push the electrode down to fix it to the scalp. A little bit of paste should run out along the edge of the cup to form a thin ring around it. Place the electrode so that the direction of the cable does not place undue stress on the cup (so that it gets pulled, lifted, or twisted off). The cable should hang naturally and towards the plastic clip (as shown). Leave enough slack in the cable to allow for comfortable head movement as well. Graphic courtesy of Thought Technology Ltd.

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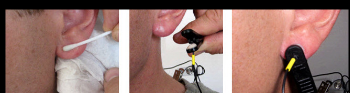
How do you apply electrodes to record the EEG?

- Repeat the above preparation and placement steps on the earlobes. Do not put too much paste on the ear clip electrode but ensure that the gold disc is completely covered. Graphic courtesy of Thought Technology Ltd.



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What instrumentation is needed to detect EEG?

In this section, we will discuss:

- Channels
- Frequency
- Amplitude
- Magnitude
- Montages
- Filters
- Artifacts

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What are channels?

- A channel is an EEG amplifier output that is the result of scalp electrical activity from three electrode/sensor connections to the scalp. These sensors are commonly known as active, reference, and ground electrodes, though they are more appropriately called positive +, negative - and reference. They are placed on the head in the following manner: An active or positive electrode is placed over a known EEG generator location like Cz. A reference or negative electrode may be located on the scalp, earlobe, or mastoid. A ground/reference electrode may also be placed on an earlobe or mastoid (adapted from Thompson & Thompson, 2016).

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What are channels?

- Active and reference sensors are identical balanced inputs and interchangeable. However, some neurofeedback data acquisition systems require the designation of a specific sensor as a "reference," as in a linked-ears reference.

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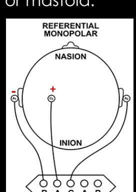
What is a referential montage?

- A referential (monopolar) montage places one active electrode (A) on the scalp and a "neutral" reference (R) and ground (G) on the ear or mastoid.



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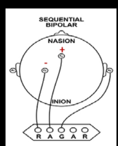
What is a sequential montage?

- A sequential (bipolar) montage presents a sequence of comparisons of positive (+) and negative (-) electrodes (often called 'active' and 'reference') that are attached to sites on the scalp and therefore considers the reference electrode to be a second active electrode. The ground (G) electrode is attached to the scalp, to an earlobe, or over the mastoid process.



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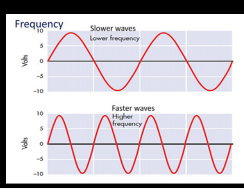
What is frequency?

- Frequency measures the speed and represents the number of cycles completed each second. The higher the frequency (f), the shorter the wavelength (λ). To measure frequency in the raw waveform, count the number of peaks above the zero line or the number of zero crossings divided by 2.



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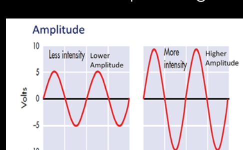
What is amplitude?

- Amplitude measures size, which is the "amount" of energy within an EEG frequency band. The amplitude and morphology of any EEG frequency band reflect the number of neurons discharging at the same time in that frequency. High amplitude means that many neurons are depolarizing and hyperpolarizing at the same time.



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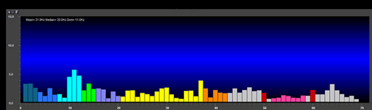
What is magnitude?

- Magnitude represents the average amplitude over a unit of time using quantification methods like peak-to-peak (P-P), and root mean square (RMS). The peak-to-peak method measures waveform "height" from peak to trough. In contrast, the root mean square method calculates the area under the EEG waveform and is analogous to the weight of an object (Collura, 2014). The graphic below that illustrates EEG spectrum magnitude © John S. Anderson.



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Which filters are used to select EEG frequencies?

- A low-frequency filter (high-pass filter) filters out low-frequency activity and passes only the frequencies above a set value (e.g., 1.6 Hz).
- A high-frequency filter (low-pass filter) filters out high-frequency activity and passes only the frequencies lower than the set value (e.g.,15 Hz). This filter can help reduce the distortion that EMG artifact causes to the raw EEG waveform (Thompson & Thompson, 2016).
- A bandpass filter passes the frequencies between the set values, which constitute the "band" of the filter.

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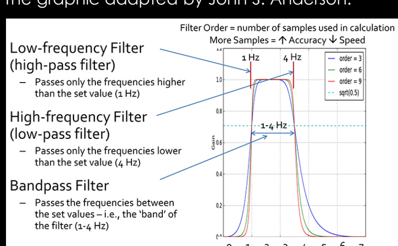
Which filters are used to select EEG frequencies?

- The graphic adapted by John S. Anderson.



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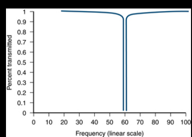
What is a notch filter?

- A notch filter excludes a narrow frequency band to control 50/60Hz artifact produced by line current (Libenson, 2010). A 60-Hz notch filter attenuates adjacent frequencies (e.g., 58 Hz and 61 Hz). The 60-Hz notch filter graphic is courtesy of Wikipedia.



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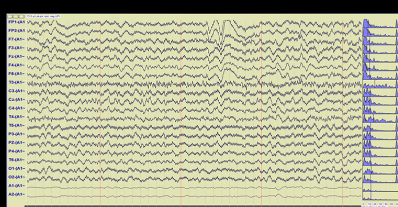
What are artifacts?

- Artifacts are false signals like 50/60Hz noise produced by line current. Graphic © John S. Anderson.



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Strategies to reduce artifact

- Demos (2019) recommends several precautions to reduce artifact in raw EEG recordings:
  - Demonstrate how to create artifacts for your clients using screen displays while they clench their teeth, move their eyes, blink, swallow, and fidget
  - Confirm the cap fits properly
  - Use reclining chairs with negligible neck cushioning that can force the head downward to minimize SEMG artifact
  - Limit eyelid movement with cotton balls gently touching the closed eyelids, secured by a loose sleep mask, flexible band, or tape in the eyes-closed recording. There should be no pressure against the eyes
  - Ensure that impedance values or DC offset values are appropriate for your amplifier (values under 5 Kohms are expected for publishable research, but values of less than 20 Kohms are acceptable for general clinical sessions and do not require excessive skin abrasion)
  - Only record qEEG data when the raw waveforms appear clean

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EEG frequency bands

- Most EEG power or signal energy falls within the 0-20 Hz frequency range. You may recall that hertz (Hz) is an abbreviation for cycles per second.

  The dominant frequency is the frequency with the greatest amplitude. It varies by age and condition e.g., eyes open or eyes closed, awake, drowsy or asleep. It is at least 13 Hz in awake adults in the eyes-open condition. EEG voltage or amplitude is measured in microvolts (µV) (millionths of a volt).

  Power is a term that generally means the amplitude squared ($\mu V^2/R$) and the results are in picowatts (pW) (trillionths of a watt).

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EEG frequency bands

- Higher frequencies reflect cognitive activity and active processing of sensory input. They involve relatively desynchronized activity like alert wakefulness and REM sleep. Lower frequencies reflect strongly synchronized activity like interactive neuronal communication, control of network activity, nondreaming sleep, and coma.
- The table on the next slide is adapted from Wilson et al. (2011) and based on Thompson and Thompson (2016). Different authors define frequency bandpasses differently. For example, delta 0.5-3 Hz or 1-4 Hz.

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EEG frequency bands

EEG Frequency Band Correlations at Cz and FCz	
1-3 Hz Delta	dominant in stage 3 sleep, and indicates brain damage and learning disabilities in waking EEG; eye blink, eye movement, and electrode movement artifacts fall within this band
4-5 Hz Low Theta	drowsiness and tuning out external stimuli
6-7 Hz High Theta	internal focus, crucial in memory retrieval; 7-10 Hz activity linked with visualization
8-10 Hz Low Alpha	internal focus, increased during specific forms of meditation
11-12 Hz High Alpha	highly alert, broadly focused awareness seen when elite athletes are "in the zone"
13-21 Beta	used to calculate theta/beta ratios in ADHD
12-15 SMR (C_3, Cz, C_4)	calm, alert, focused state characterized by inhibited motor activity and sensory intake; anxiety and impulsivity are decreased
12-16 Hz Beta	conscious problem-solving and cognitive or motor performance; more beta is observed during task acquisition than after mastery
19-22 Hz High Beta	emotional intensity, which may include anxiety, associated with excessive effort
23-36 Hz High Beta	highly active brain that is working on multiple problems or negatively ruminating; may represent an elite athlete's most important source of distraction ("busy brain")
40 Hz Gamma	attention and cognitive performance, hypothesized as a binding rhythm; bursts observed as athletes recover balance on a stabilimeter; up-training may aid learning disabilities
45-58 Hz EMG artifact	jaw, neck, and scalp EMG artifact; use 53-59 Hz EMG inhibit range in Asia, Australia, and Europe
50/60 Hz Electrical artifact	line current artifact (50 Hz in Asia, Australia, and Europe)

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What do normal EEG patterns look like?

- We need to know what normal looks like so that we can see abnormal deviations from normal.
- The healthy adult EEG is a cerebral symphony comprised of theta, alpha, sensorimotor rhythm, beta, and gamma activity. EEG rhythms correlate with patterns of behavior (level of attentiveness, sleeping, waking, seizures, and coma), occur in distinct frequency ranges, and are characterized by synchrony and desynchrony.

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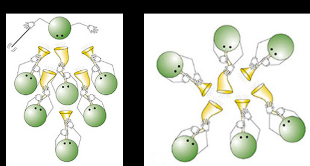
What do normal EEG patterns look like?

- Synchrony means that pools of neurons coordinate their firing due to pacemakers (left) and mutual coordination (right).



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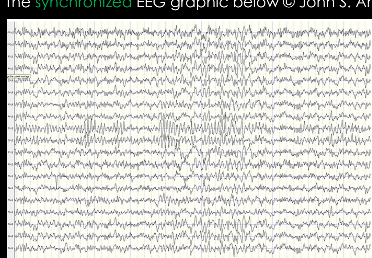
What do normal EEG patterns look like?

- The synchronized EEG graphic below © John S. Anderson.



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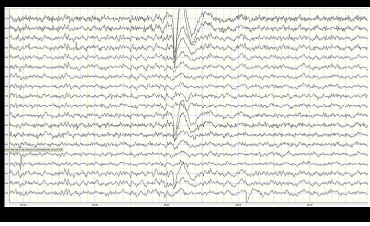
What do normal EEG patterns look like?

- Desynchrony means that pools of neurons firing independently due to stimulation of specific sensory pathways up to the midbrain and high-frequency stimulation of the reticular formation and nonspecific thalamic projection nuclei. Graphic © John S. Anderson.



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What do normal EEG patterns look like?

Gamma:	*20-60 Hz ("cognitive" frequency band)*	*Desynchronized*
Beta:	*14-20 Hz (activated cortex)*	
Alpha:	*8-13 Hz (quiet waking)*	*Synchronized*
Theta:	*4-7 Hz (sleep stages)*	
Delta:	*less than 4 Hz (sleep stages, especially "deep sleep")*	

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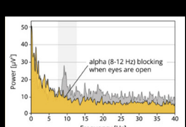
What do normal EEG patterns look like?

- The alpha rhythm is strongly modulated by visual input. Opening the eyes blocks or reduces the occipital alpha rhythm. Hans Berger (1929) originally described this phenomenon. In contrast, eyes-closed alpha is associated with alert wakefulness and reduced visual input (Thompson & Thompson, 2016). The graphic below illustrates alpha-blocking and is courtesy of iMotions.



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What do normal EEG patterns look like?

- The posterior dominant rhythm (PDR) is the highest-amplitude frequency detected at the posterior scalp when eyes are closed. A healthy adult PDR is 10 Hz. Values below 9 Hz and above 11 Hz are abnormal, may result from psychoactive drugs, and may be associated with clinical symptoms like anxiety (Demos, 2019). Graphic © eegatlas-online.com.

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