What Is A ‘Traumatic’ Brain Injury?

DONALD STEIN, PhD.

Brain Repair, Fall, 2026

AWell-documented Case Of Penetrating TBI





Is TBI An Important Health Issue In The United States?

- Every 15 seconds in the USA someone suffers a TBI.
- TBI causes more deaths in men under 35 than all other diseases combined.
- TBI can lead to long-term deficits in cognitive, memory, sensory and motor functions.
- Costs for long term care estimated at $40-50 billion each year.

Head Injury In Daily Life:
A Close to Home Example

Each year there are approximately 1,000,000 cases of sports-related injuries in the United States

Some Statistics On TBI Incidence

- An estimated **2.8 million people** in the United States sustain a TBI annually (brainline.org)
- In 2025 CDC reports that up to 3.0% of Americans (approximately 9.7 million people) reported a TBI in the past year.
- Recent CDC data notes there were over 68,000 TBI-related deaths in 2023 and over 214,000 hospitalizations in 2020 .
- Because TBI data can be categorized differently—such as by fatalities, hospitalizations, or emergency room visits—these numbers should be viewed as estimates rather than precise counts.


© Splash News

Bicycling: Does Wearing A Helmet Make A Difference?

- An analysis in the *International Journal of Epidemiology* reviewed 40 separate studies and found helmet use significantly reduced the odds of head injury. They also found the odds of a fatal head injury to be lower when cyclists wore a helmet.

- The *New York Times* reported that cycling had the highest concussion rate among all sports, including American football.

- A report by the National Highway Traffic Safety Administration found that 70 percent of cyclist deaths occurred in urban areas. Only 3 percent of those fatalities took place in a bike lane.

- If you really want to make your road rides safer, joining your local advocacy group, or organizing one to push your city and state for better bike networks, is a great place to start. Simply donning a helmet is no substitute for safer streets.

Are "Mild" Repetitive Head Injuries Dangerous?

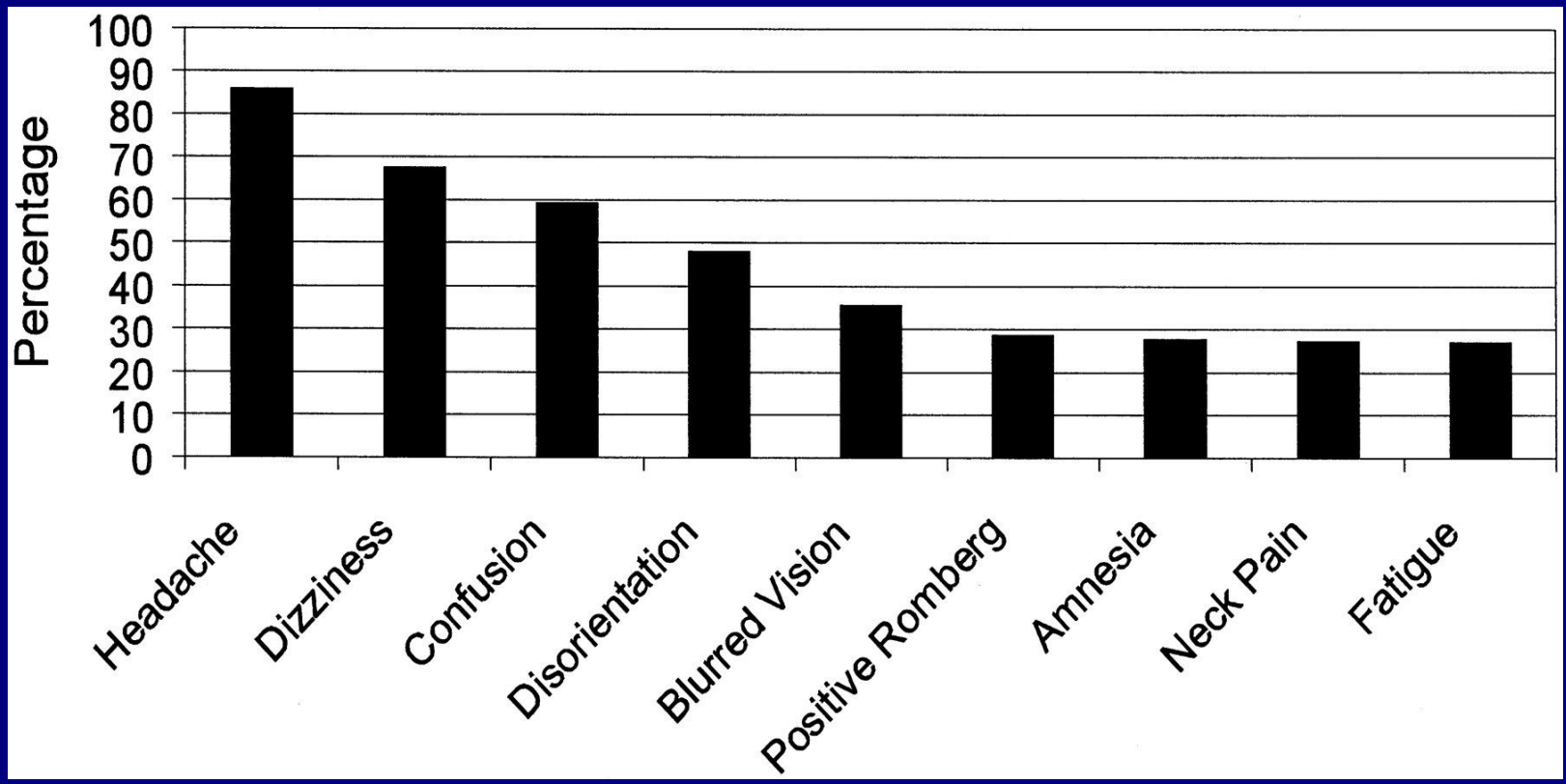
Much Is At Stake For School and Professional Sports

Competitive Sports and Head Injuries



These Are Not Just Games For Adults

% Injured Players With Symptoms Of Brain Injury



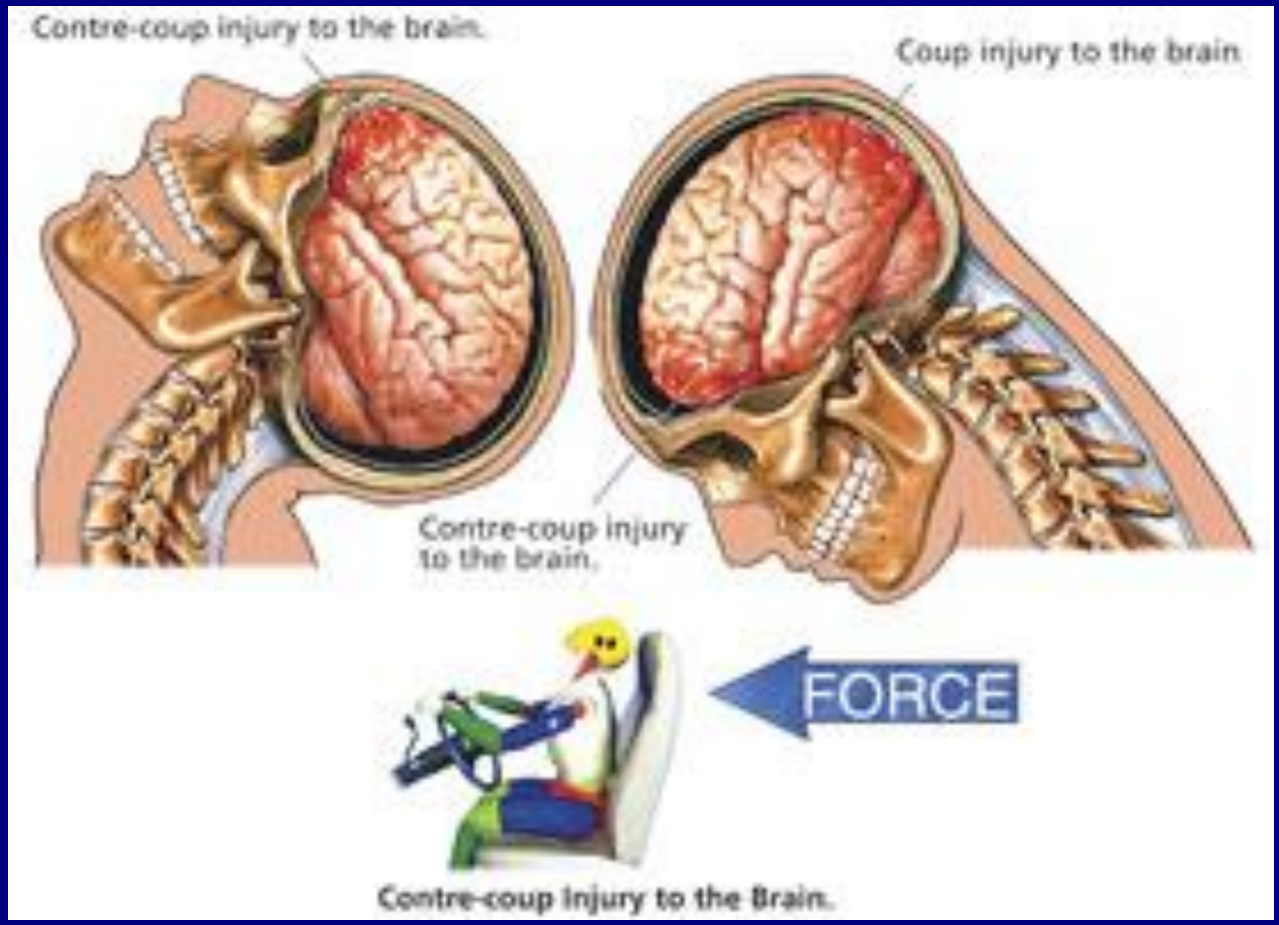
Brain Injury Is Pervasive in N.F.L

- A new study estimates that: three out of four former N.F.L. players who died between 2008 and 2023 had C.T.E. in their brains at death.
- By contrast, the same researchers studied brain banks that reflect the general population and estimate that only 0.6 percent of people have C.T.E.
- Across nearly 400 brains of former N.F.L. players that were donated and studied, the statistics look impossibly grim: More than 90 percent showed signs of C.T.E.
- Brains are usually donated because former players or their families saw symptoms that aligned with C.T.E., including headaches, memory loss and unrecognizable shifts in personality.
- *NYT Oct. 28, 2026*

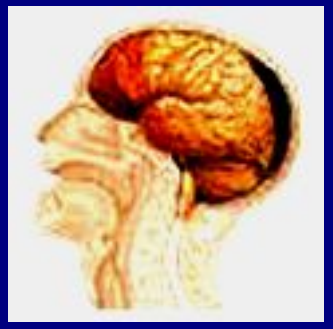
“A football player’s real issue isn’t simply with repetitive concussive trauma. It is, as the concussion specialist Robert Cantu argues, with repetitive *subconcussive trauma. It’s not just the handful of big hits that matter. It’s lots of little hits, too.”*


TITANS

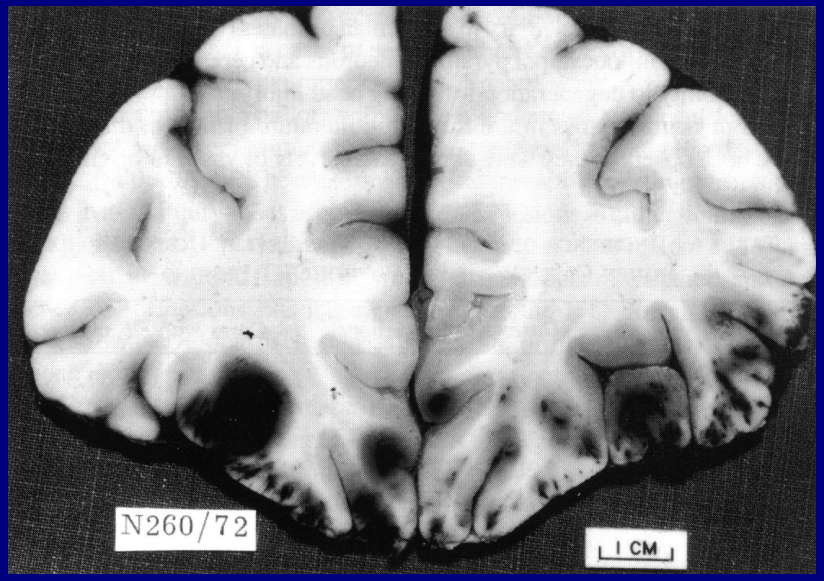
Common Contrecoup Injury

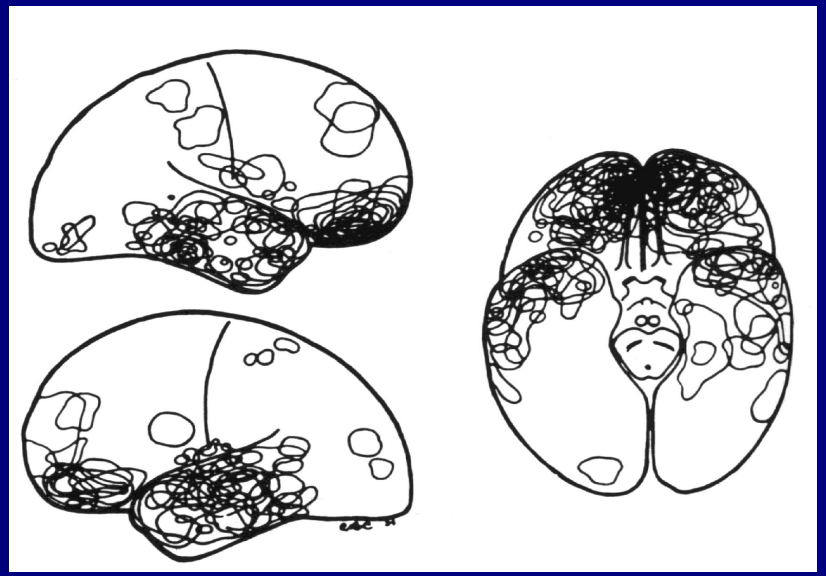


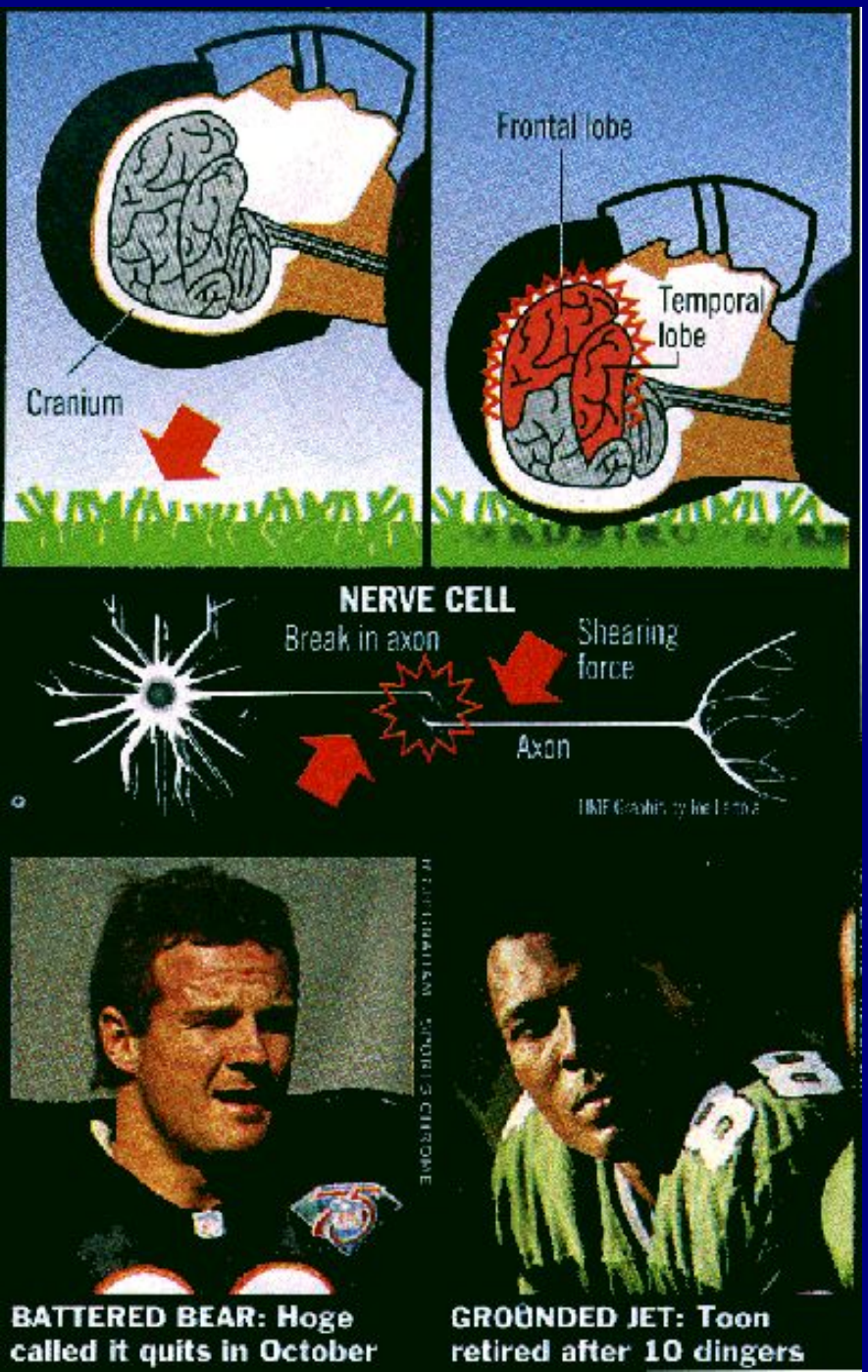
The Initial Injury









- A concussion is a temporary loss of consciousness caused by a blow to the head. The brain shifts violently, sometimes smashing into the skull. Many nerves cells may break, producing such symptoms as headaches, slurred speech and loss of balance or memory

  – *Time Magazine 12/12/94*

Football Concussions Are Still A Problem

- According to the most recent official data, the NFL reported 182 concussions during the 2024 season (covering both preseason and regular season games and practices: espn.com . guardiansports.com)

- Regarding an "average" season, reports have cited a five-year average (excluding the 2020 season due to pandemic-related anomalies) of 211 concussions/season.

- During the 2025 NFL season, players sustained 168 total concussions across all plays, including offensive, defensive, and special teams . (nytimes.com) This total represented a decrease compared to the previous season .

Symptoms of ‘Mild’ Concussion

- Persistent Headaches
- Loss of balance and slowed reflexes
- Depression
- Disrupted memory and attention
- Brain swelling and secondary neuronal loss
- Early onset dementia

“Heading In Soccer”



Can ‘Heading” Cause A Brain Injury?

- Repeated head-to-head contact can generate enough force to cause brain injury.

- “Recent research found that commercially available soft helmets fail to reduce head trauma to a safe level, *which implies* that these helmets have only a limited protective role in soccer.”

A Small Study Shows New Worries About Heading The Soccer Ball

- A brain-scan study of experienced, adult soccer players found changes in parts of the brain that *might be associated* with repeated slight impacts.

- "Recent research found that commercially available soft helmets fail to reduce head trauma to a safe level, *which implies* that these helmets have only a limited protective role in soccer.

- "Female soccer players are second only to football players in the number of concussions" that they develop each year. Girls are also more likely than boys to sustain injuries during soccer heading.

- The more years a girl had played, the slower *she tended to be* on cognitive tests. Similarly, the more hours per week a girl played, the worse she performed on these tests.

New Concussion Guidelines Stress Individual Treatment

- The American Academy of Neurology has revised its guidelines for handling concussions to emphasize treating athletes case by case rather than according to a predetermined scale (article appears in *Neurology*).

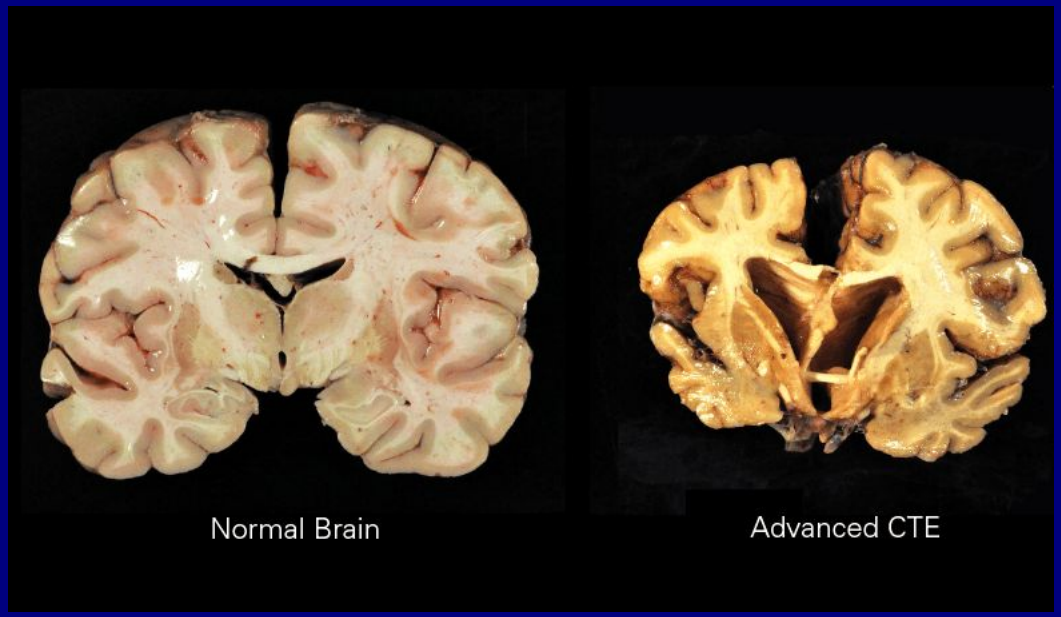
- Report essentially acknowledges that concussions are too idiosyncratic to be categorized neatly.

- Now recommending concussion and return to play be assessed in each athlete individually."

- More than a million American athletes experience concussions each year.

- Guidelines recommend that athletes suspected of having a concussion should be immediately removed from play.

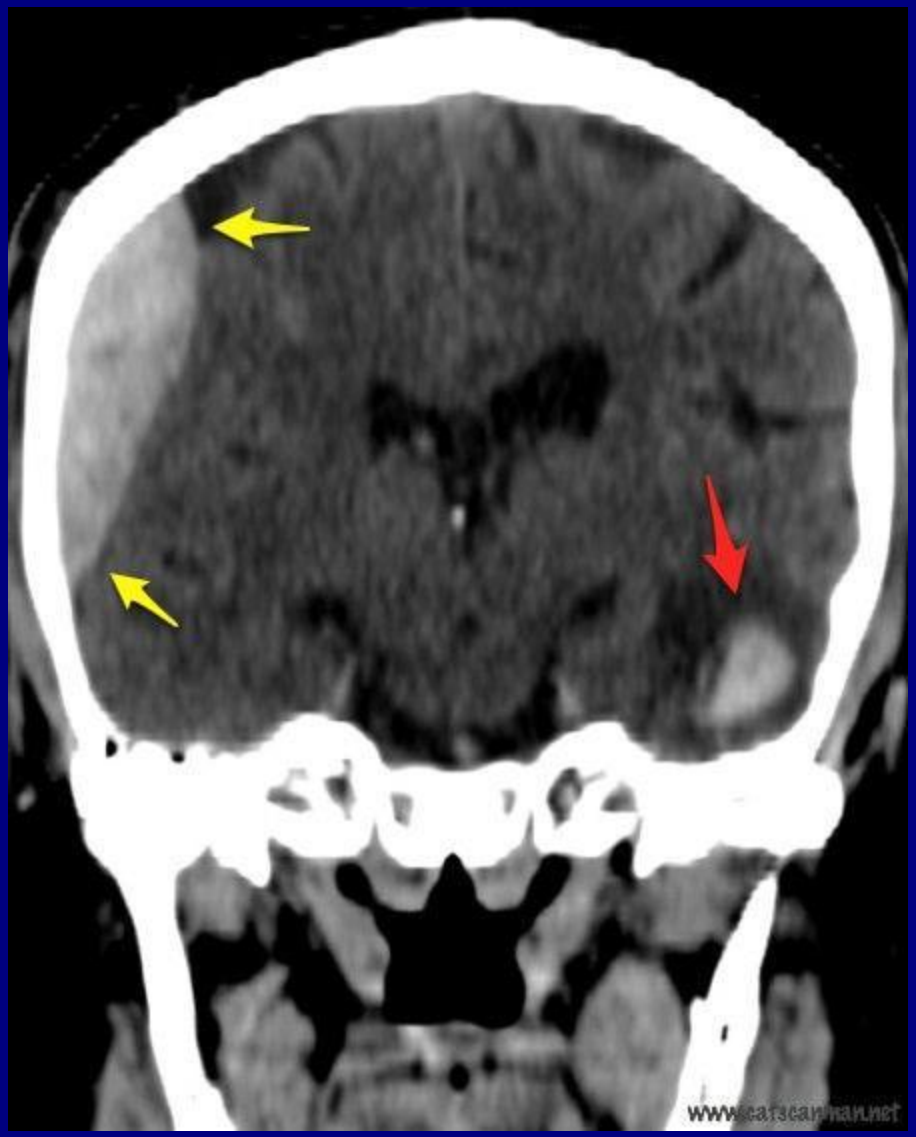
CTE: What Repeated Concussion Can Do To Your Brain



Contrecoup Injury On Purpose



Contrecoup Injury





Early Diagnosis of TBI In The Field and In The EM

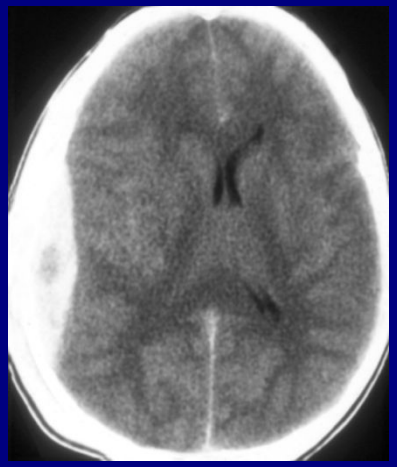
The Glasgow Coma Scale

Mild: 13-15
Moderate: 9-12
Severe: ≤8

EYES OPEN	
Never	1
To pain	2
To verbal stimuli	3
Spontaneously	4
BEST VERBAL RESPONSE	
No response	1
Incomprehensible sounds	2
Inappropriate words	3
Disoriented and converses	4
Oriented and converses	5
BEST MOTOR RESPONSE	
No response	1
Extension (decerebrate rigidity)	2
Flexion abnormal (decorticate rigidity)	3
Flexion withdrawal	4
Localizes pain	5
Obeys	6
Total	3–15

A Problem: TBI Is a Heterogenous Disease

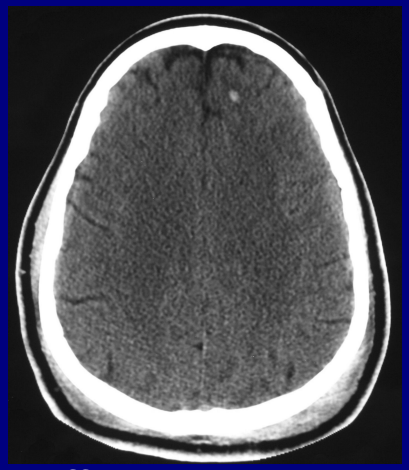
All These Patients Have The Same GCS Score



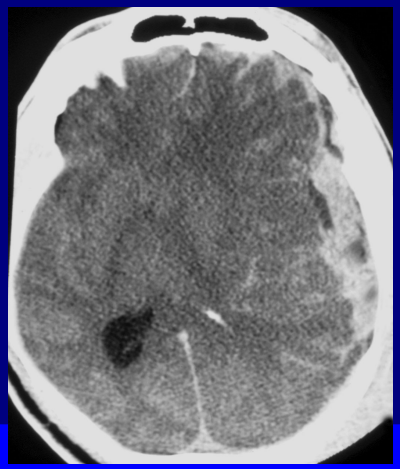
Epidural hematoma



Contusion/Hematoma



Diffuse axonal injury



Subdural hematoma



Subarachnoid hemorrhage



Diffuse swelling

Early Diagnosis Is Critical

- Many athletic organizations now recommend establishing a baseline picture of an athlete's brain function at the beginning of each season, ideally before any head injuries occur. Baseline testing should begin as soon as a child begins a competitive sport.

- *All* suspected TBIs require immediate assessment by a professional. Baseline screening tools for coaches and athletic trainers can help to identify the most concerning concussions for further medical evaluation.

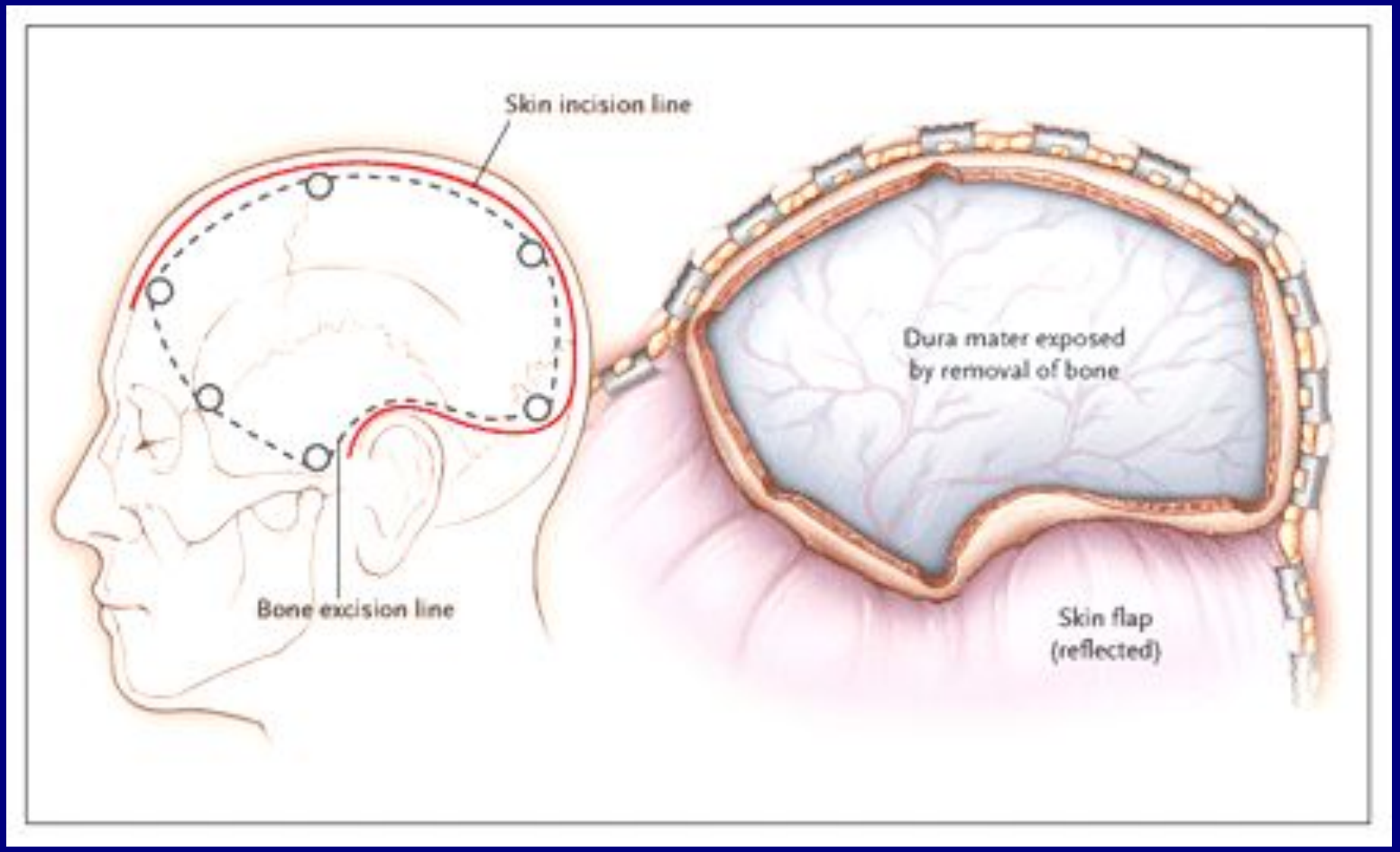
- Need to test motor and sensory skills and hearing and speech, coordination and balance, mental status, and changes in mood or behavior, among other abilities.

- Neuropsychological tests to gauge brain functioning should be used along with imaging in people who have suffered TBI.

- When necessary, medical providers will use brain scans to evaluate the extent of the primary brain injuries and determine if surgery will be needed to help repair any damage to the brain. The need for imaging is based on a physical examination by a doctor and a person's symptoms.
  - *Quotes are from the latest NINDS Health Information Guide on TBI*

Battlefield TBI

TBI: Was The Signature Injury Of The Iraq War

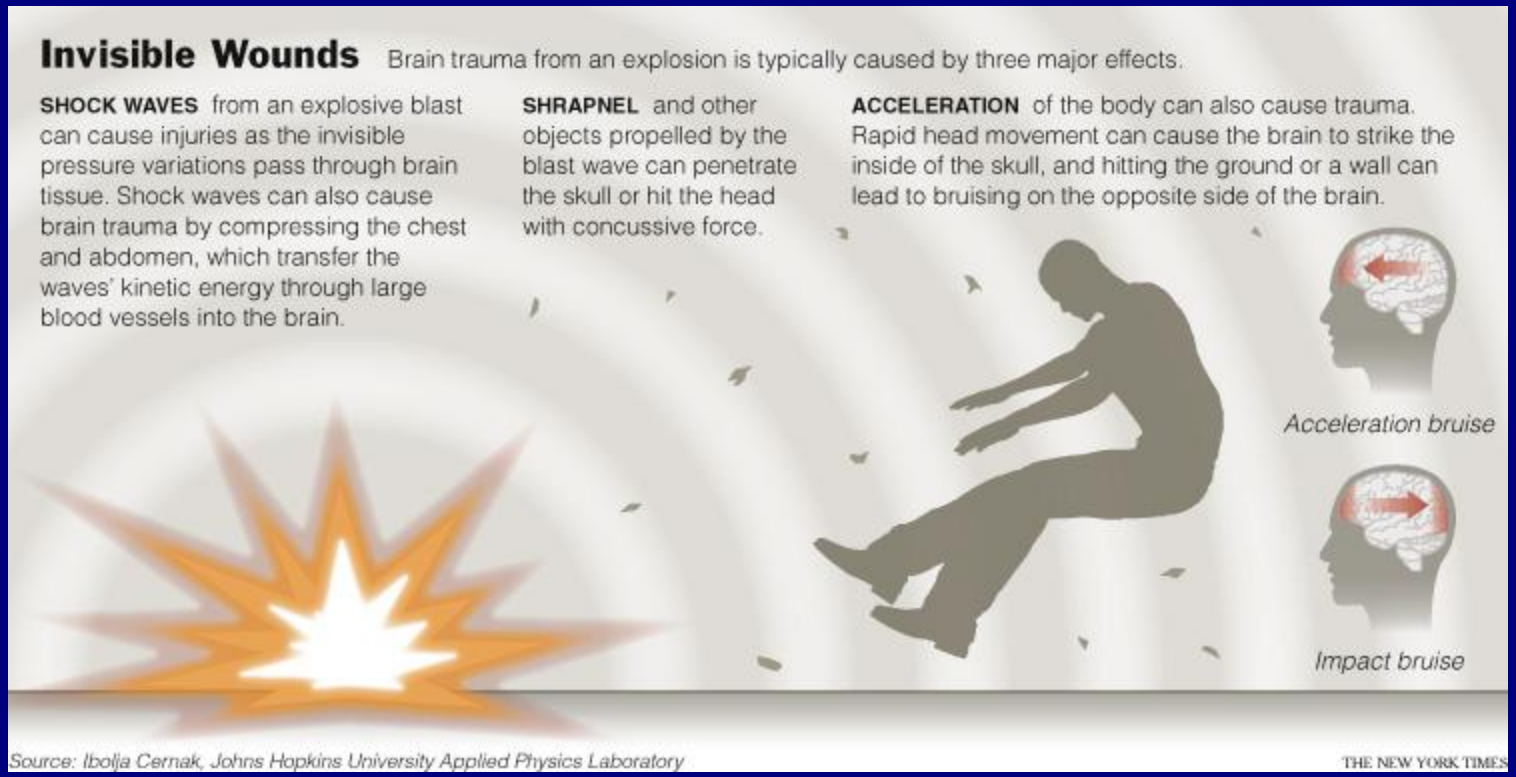




IEDs Caused 60% Of Casualties In Iraq



BLAST-RELATED TBI

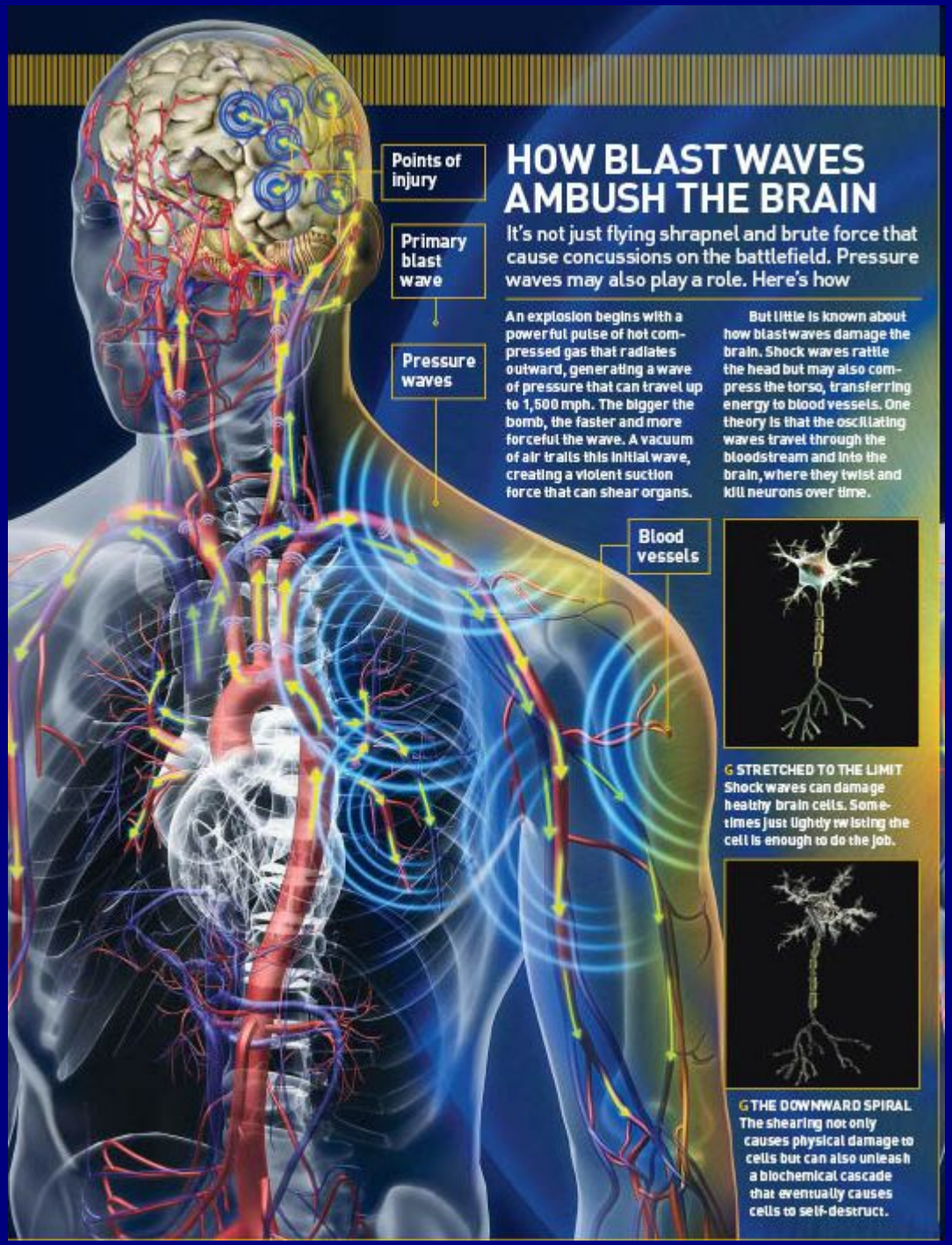


Repetitive Small Blast Waves



HOW BLAST WAVES AMBUSH THE BRAIN

It's not just flying shrapnel and brute force that cause concussions on the battlefield. Pressure waves may also play a role. Here's how



An explosion begins with a powerful pulse of hot compressed gas that radiates outward, generating a wave of pressure that can travel up to 1,500 mph. The bigger the bomb, the faster and more forceful the wave. A vacuum of air trails this initial wave, creating a violent suction force that can shear organs.

But little is known about how blast waves damage the brain. Shock waves rattle the head but may also compress the torso, transferring energy to blood vessels. One theory is that the oscillating waves travel through the bloodstream and into the brain, where they twist and kill neurons over time.

STRETCHED TO THE LIMIT Shock waves can damage healthy brain cells. Sometimes just lightly twisting the cell is enough to do the job.

THE DOWNWARD SPIRAL The shearing not only causes physical damage to cells but can also unleash a biochemical cascade that eventually causes cells to self-destruct.

Mild Traumatic Brain Injury in U.S. Soldiers Returning from Iraq

Charles W. Hoge, M.D., Dennis McGurk, Ph.D., Jeffrey L. Thomas, Ph.D., Anthony L. Cox, M.S.W., Charles C. Engel, M.D., M.P.H., and Carl A. Castro, Ph.D.

***NEJM* 358:453-463 2008 Number 5**

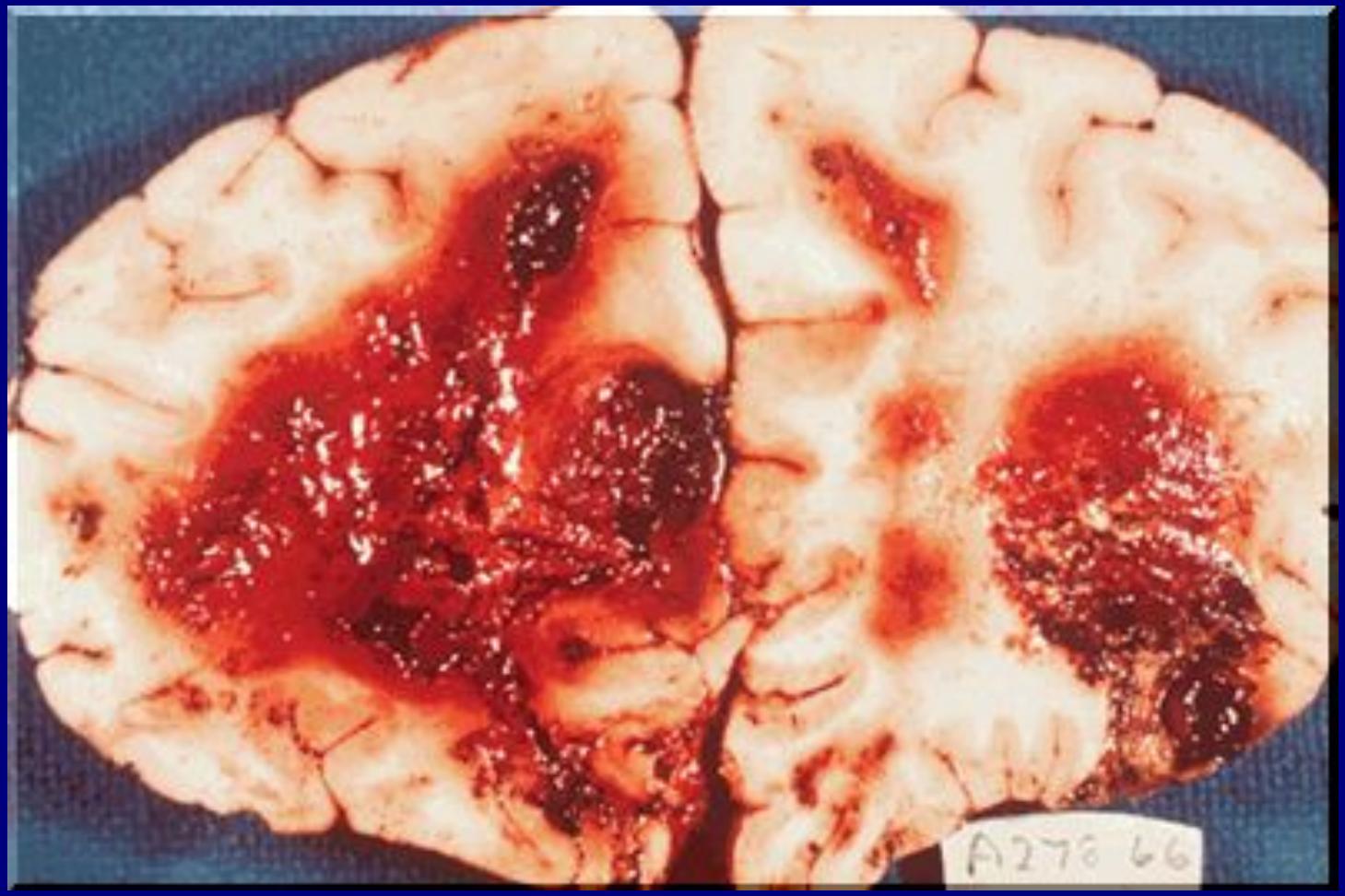
- Surveyed 2525 U.S. Army infantry soldiers 3 to 4 months after their return from a year-long deployment to Iraq.
- 43.9% met criteria for post-traumatic stress disorder (PTSD), compared with 16.2% with other injuries, and 9.1% with no injury.
- *Conclusions: Mild traumatic brain injury (i.e., concussion) occurring among soldiers deployed in Iraq is strongly associated with PTSD and physical health problems 3 to 4 months after the soldiers return home.*

Pentrating Injury



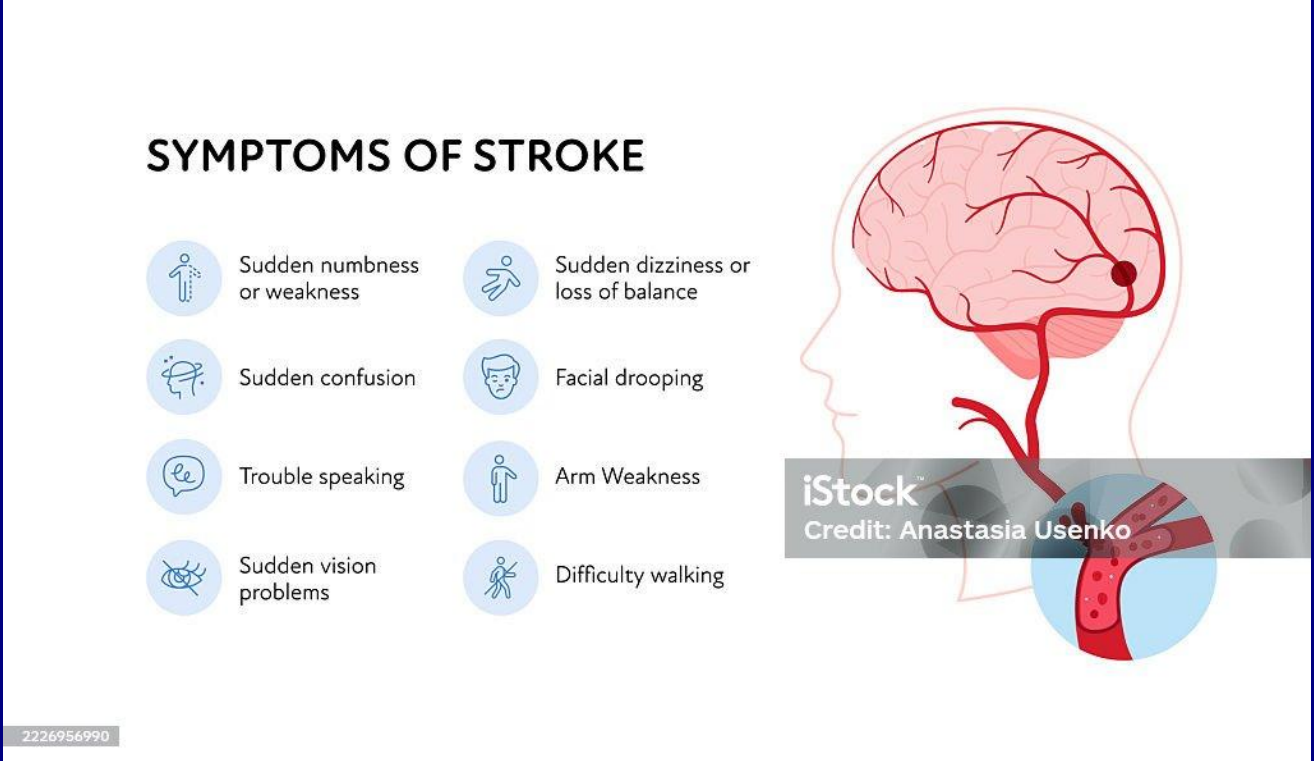


Penetrating Brain Injury

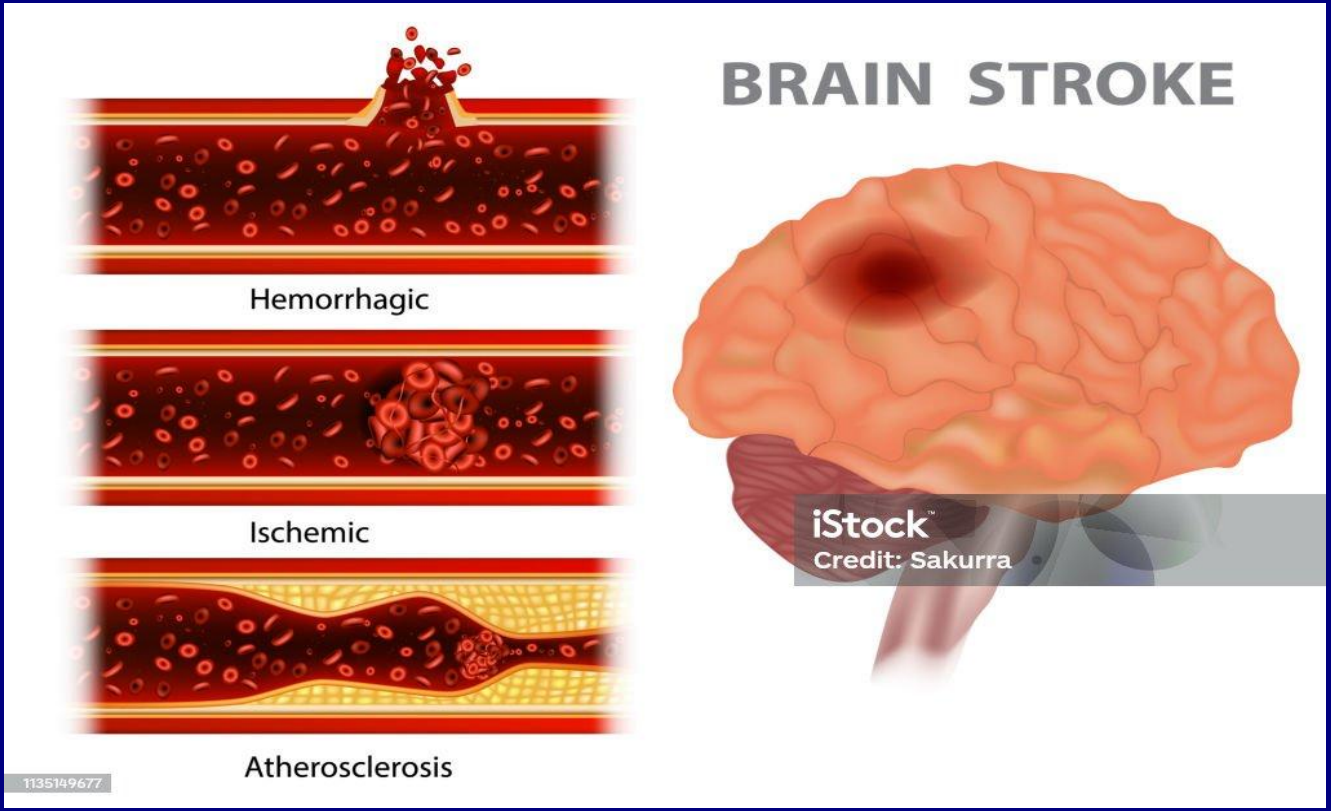


Then There Is Stroke: A Brief Overview

Stroke Symptoms



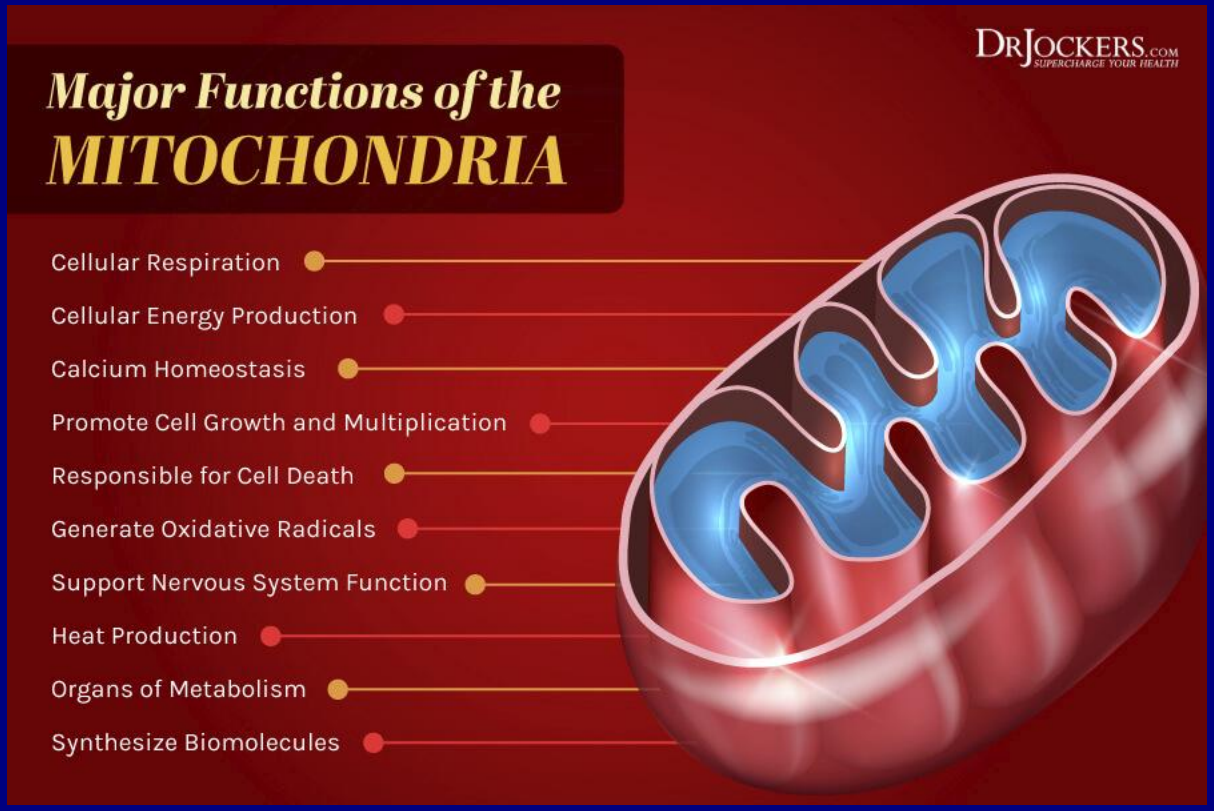
Types Of Stroke



Some Molecular Details On What Happens When A Brain Injury Occurs

Brain Injury Is A Complex & Systemic Cascade Of Events

The Molecular and Cellular Aspects of Traumatic Brain Injury

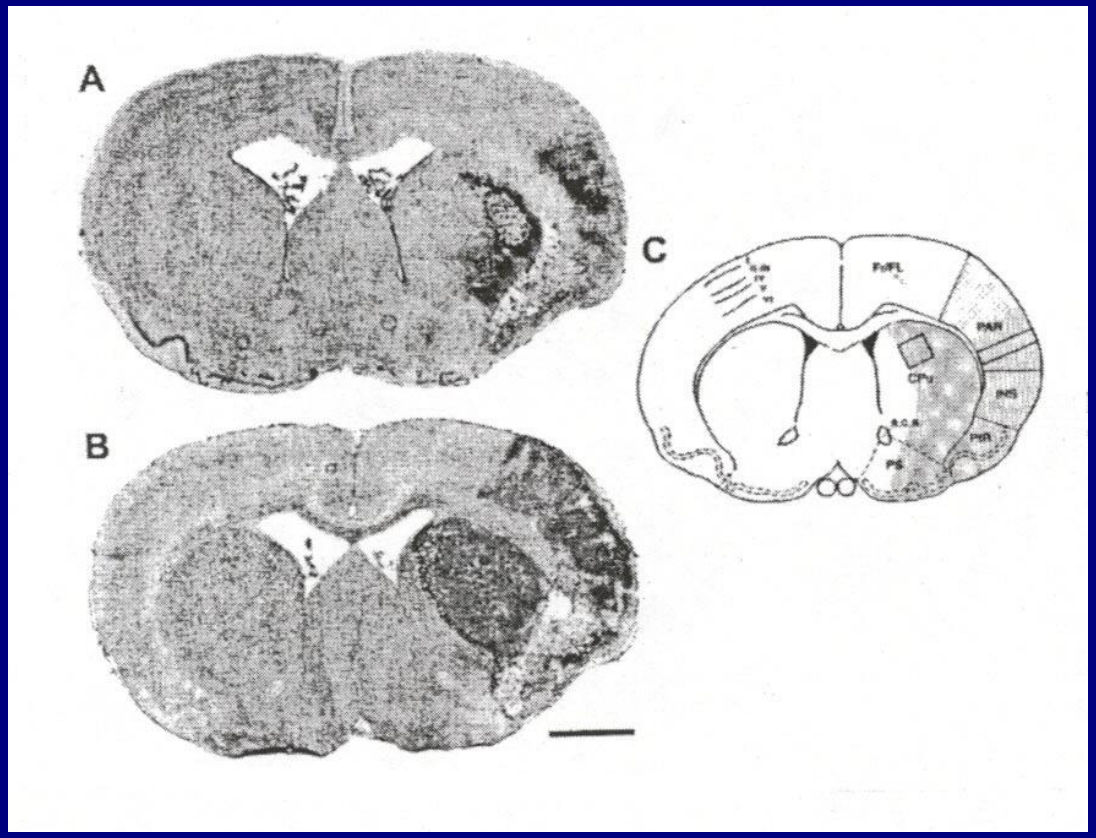

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Major Functions of the
MITOCHONDRIA
Cellular Respiration
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Calcium Homeostasis
Promote Cell Growth and Multiplication
Responsible for Cell Death
Generate Oxidative Radicals
Support Nervous System Function
Heat Production
Organs of Metabolism
Synthesize Biomolecules

Defining And Treating Traumatic Brain Injury Still Remains A Major Medical Challenge

- No clinical trials have identified specific treatments that make a dependable and measurable difference in people with TBI.

- A key challenge facing doctors and scientists is the fact that each person with a TBI has a unique set of circumstances based on many factors:
  - location and severity of the injury
  - the person's sex, age and overall heath
  - the time between the injury
  - initiation of treatment and differences in care available at different treatment centers.

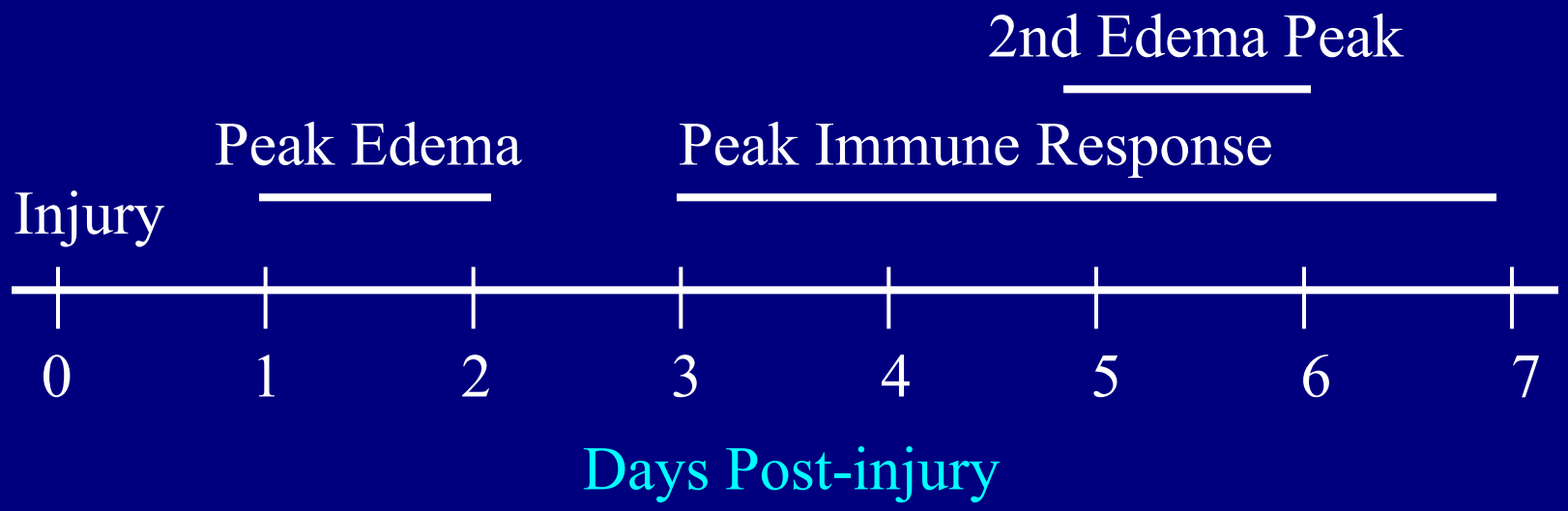
Trauma, Ischemia And Edema In Traumatic Brain Injury



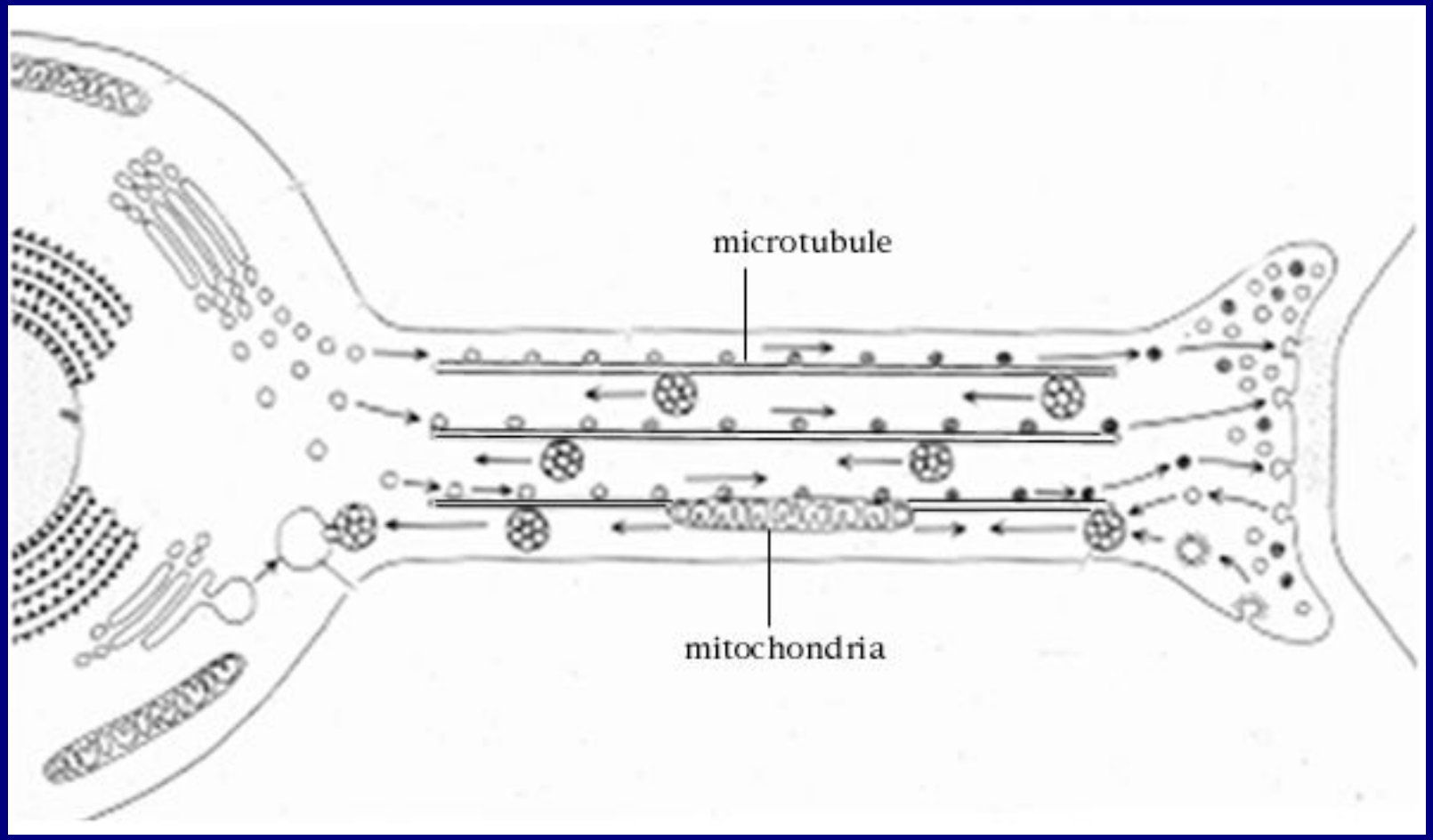
Cerebral Edema

- Increased water content of brain tissue.
- Increased intracranial pressure.
- Decreased blood flow.
- Death of nervous tissue.
- Pressure on critical brain areas, leading to dysfunction.

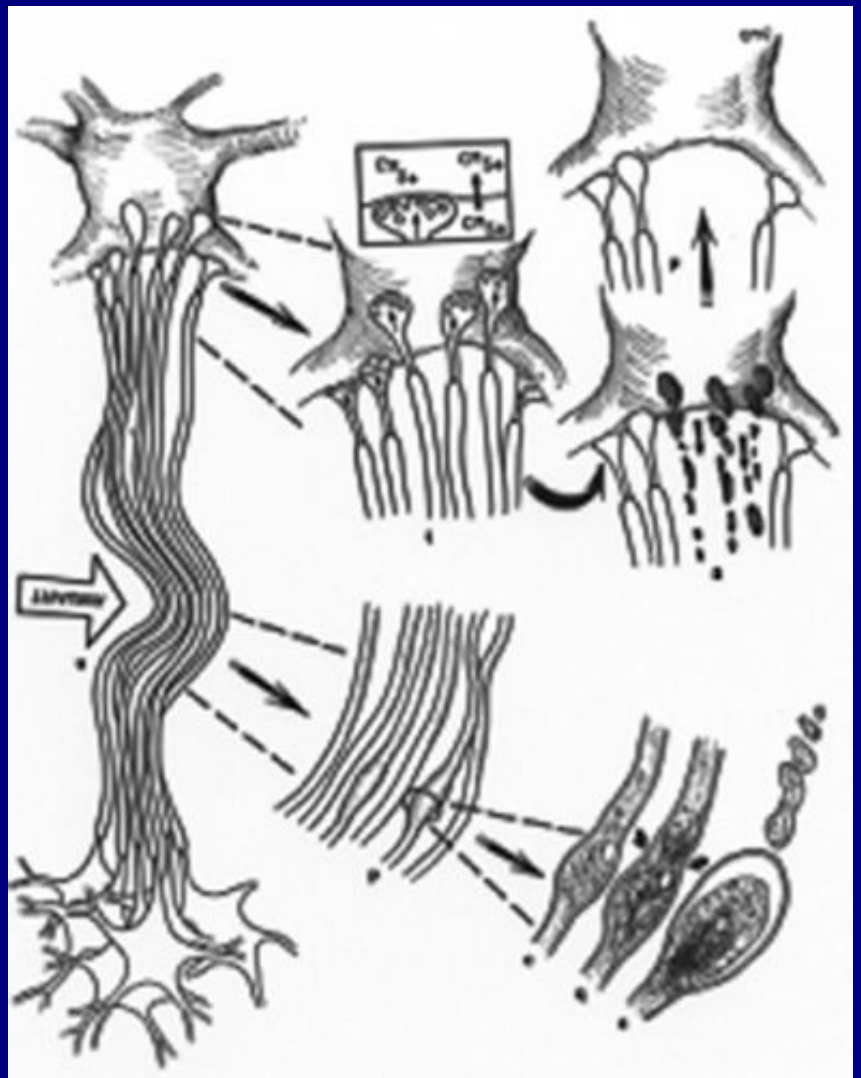
Time Course for Edema after TBI



Altered Molecular Mechanisms: Axonal Transport



Deafferentation



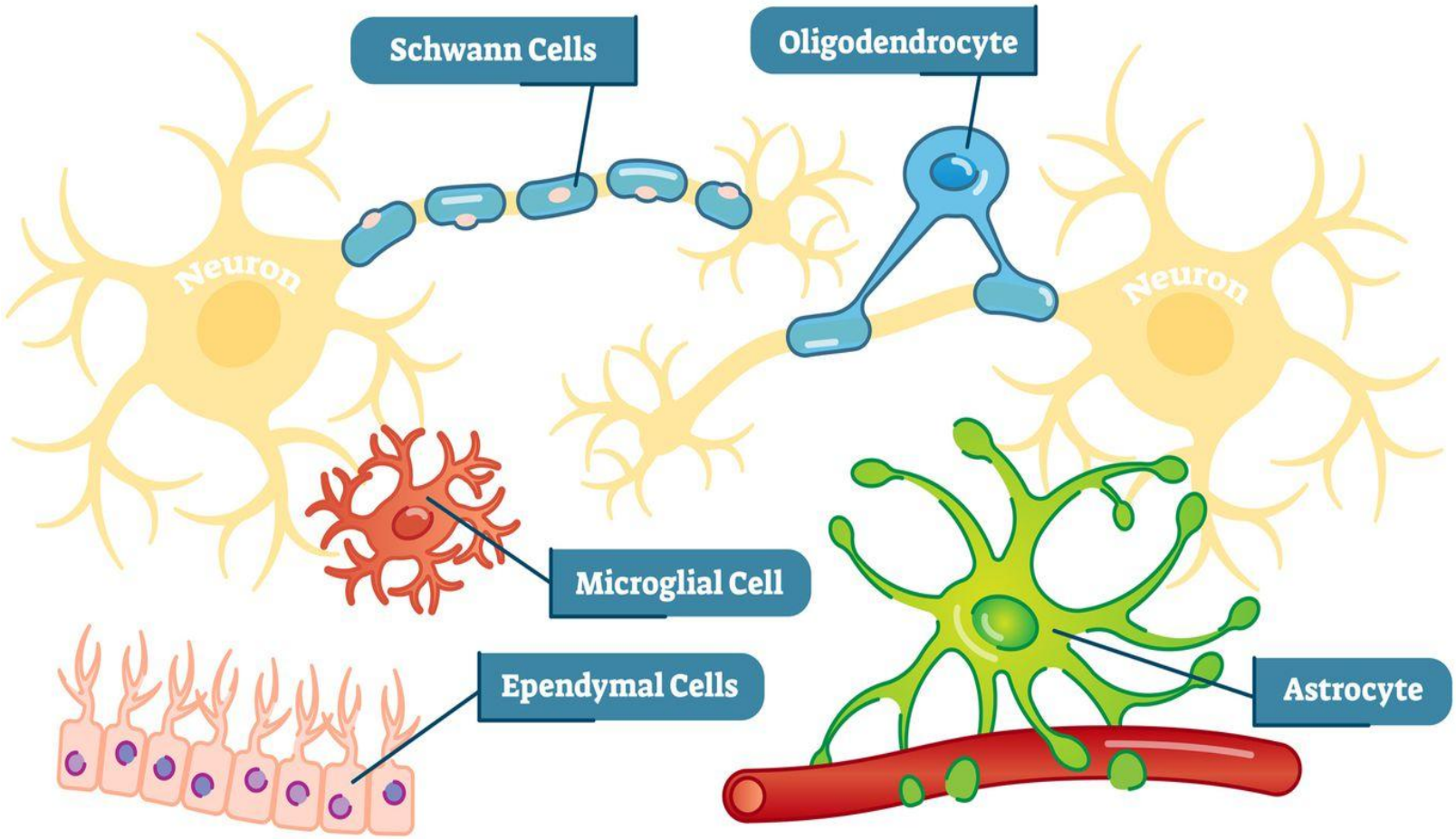
- *Stretch*
- *Disconnection*
- *Degeneration*
- *Deafferentation*
- *Loss of inter-neuronal communication*
- *Behavioral morbidity*

Systemic Inflammation & Brain Injury

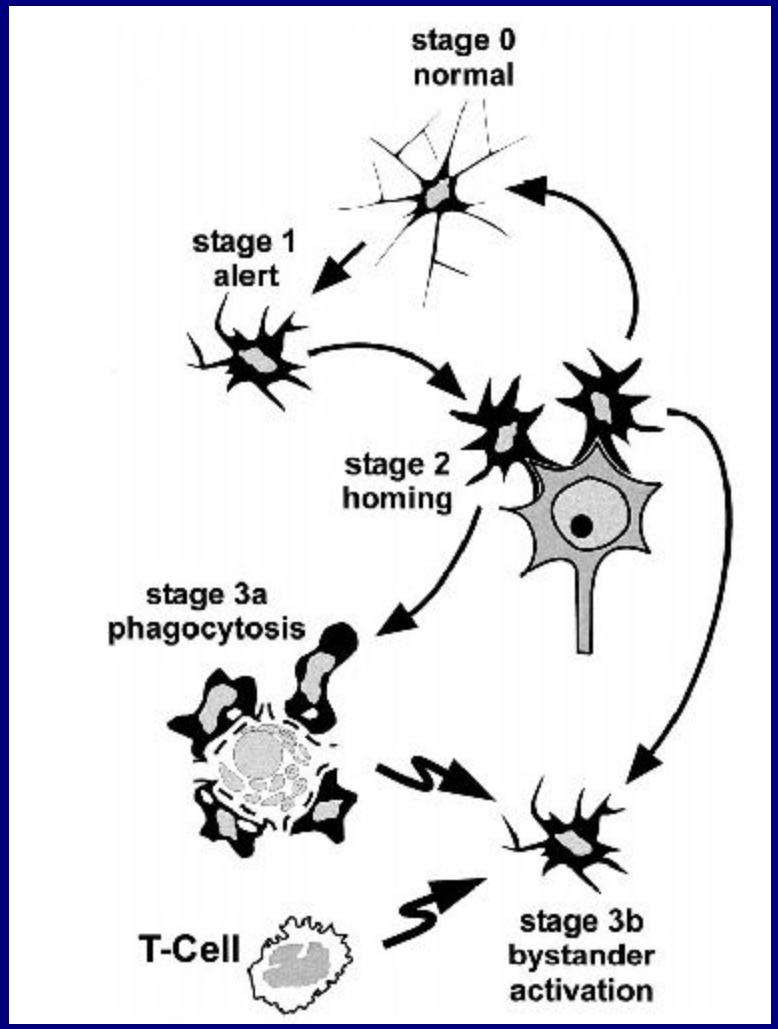
Not A Minor Issue

- Sepsis-Induced **Brain** Dysfunction: Pathogenesis, Diagnosis, and Treatment.
- **Brain**-gut axis dysfunction in the pathogenesis of traumatic **brain injury**.
- Microglia-Mediated Neuroinflammation: A Potential Target for the Treatment of Cardiovascular Diseases.
- Blood-based biomarkers of inflammation in mild traumatic **brain injury**.
- Dysregulated **brain**-gut axis in the setting of traumatic **brain injury**.

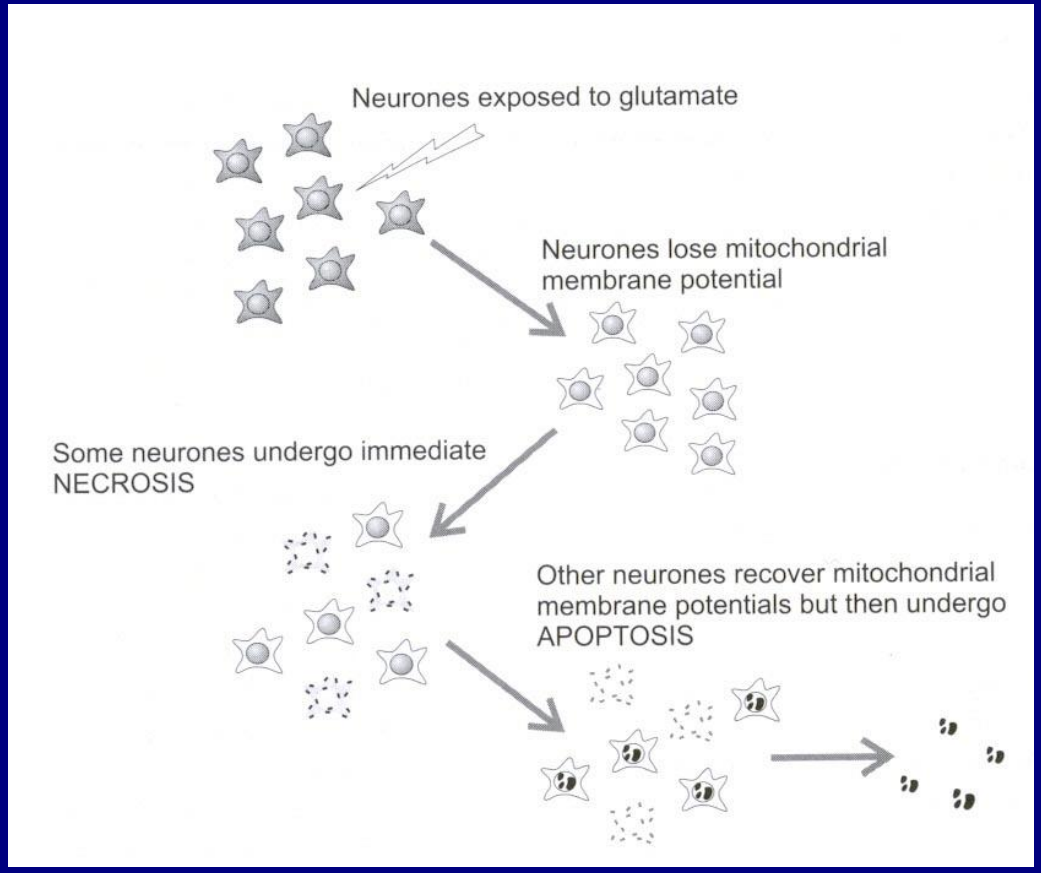
Glial Cells


Schwann Cells
Oligodendrocyte
Neuron
Neuron
Microglial Cell
Ependymal Cells
Astrocyte

Microglial Activation



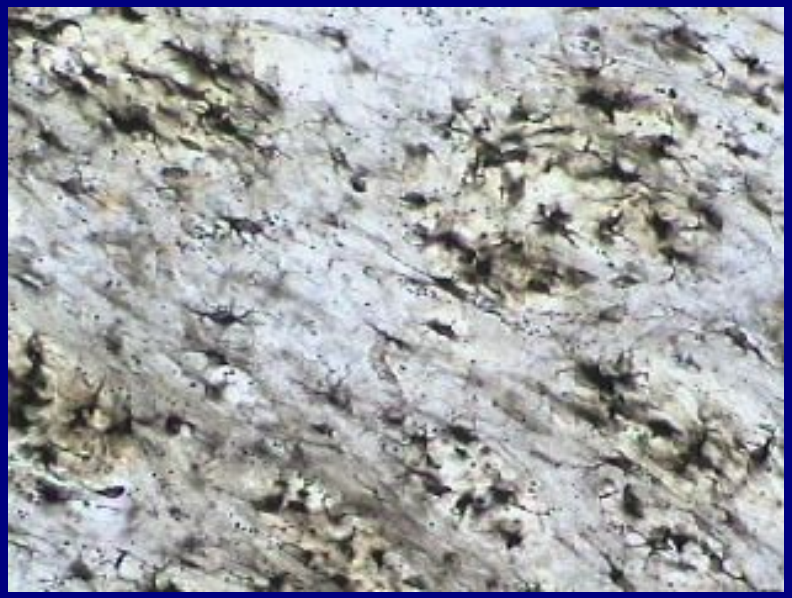
How Neurons Die



Microgliosis

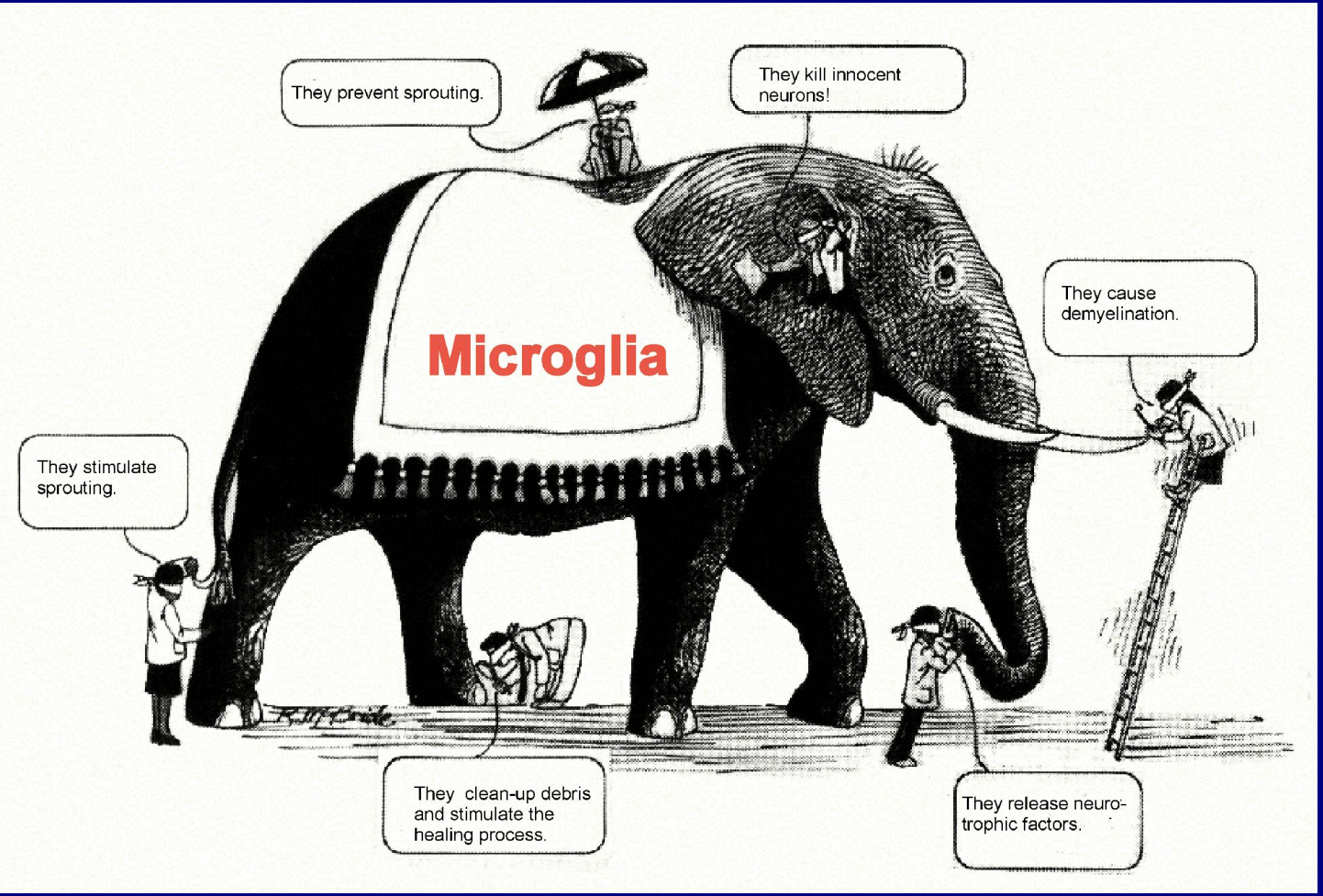


Normal



Injured

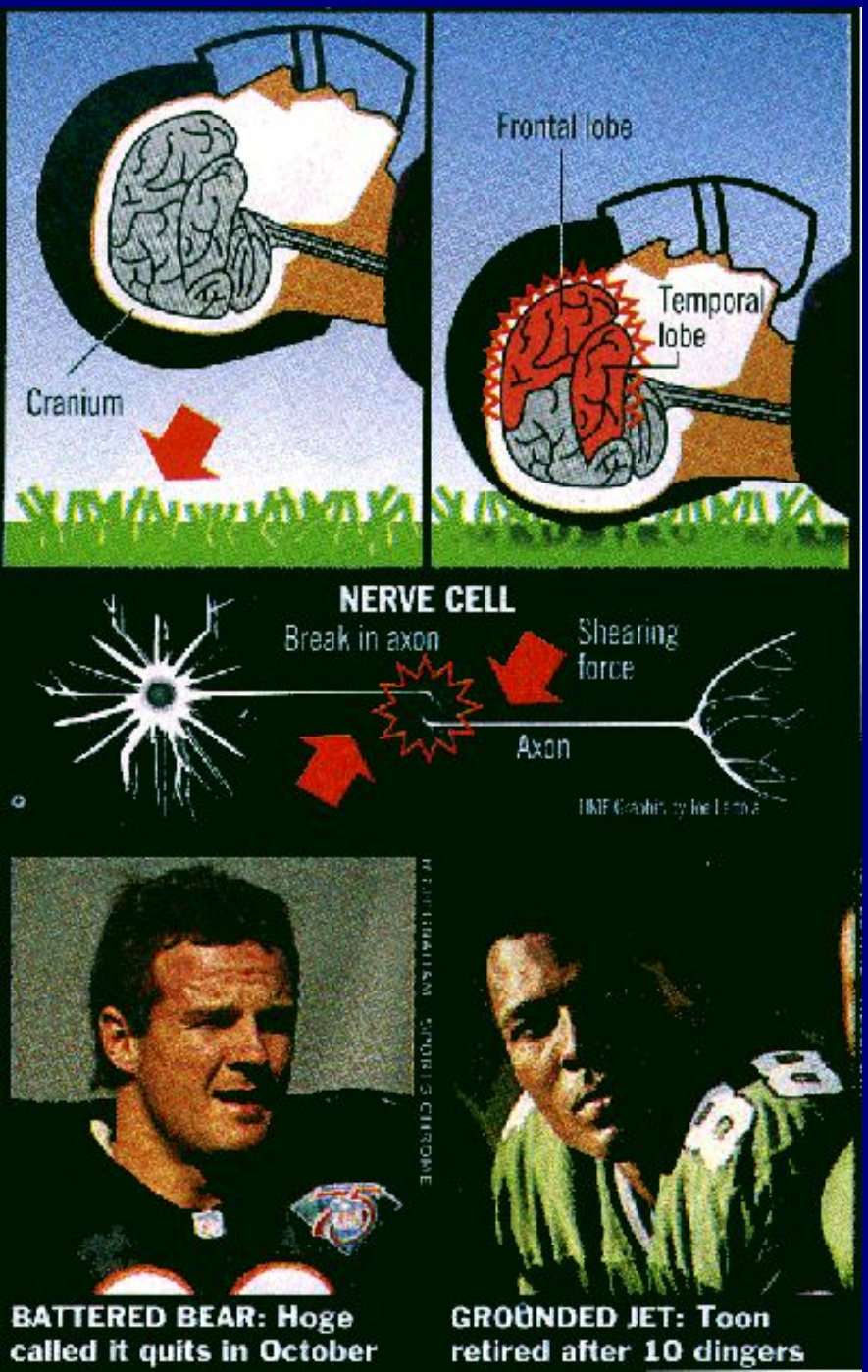
The Double Edge Sword



IMPORTANT TAKE HOME MESSAGE:
Prevention Is The Best Treatment

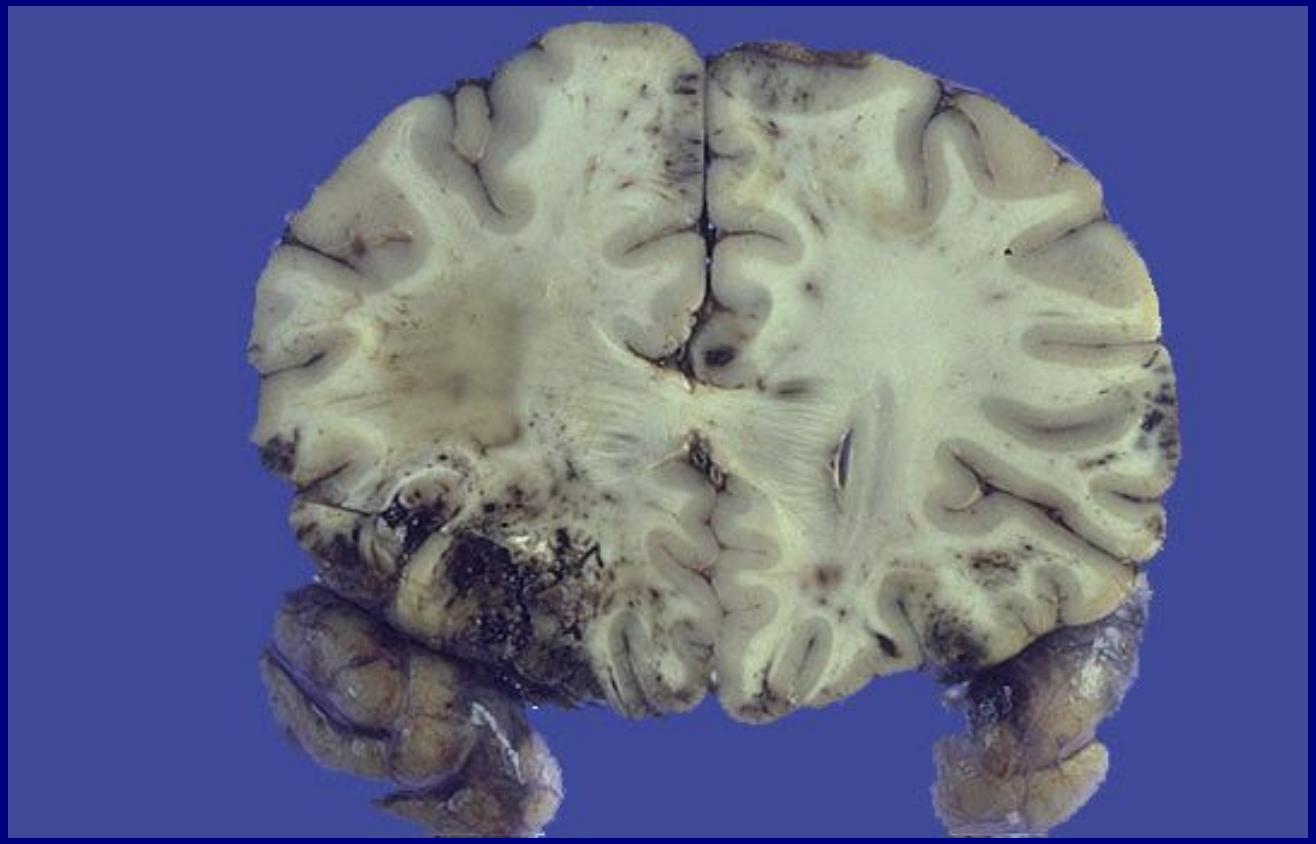
"IT TAKES VERY LITTLE ENERGY TO SCRAMBLE AN EGG, AND ALL OUR SCIENCE IS INCAPABLE OF REVERSING THAT TRANSACTION!" *RICHARD FEYNMAN,*

END



- A concussion is a temporary loss of consciousness caused by a blow to the head. The brain shifts violently, sometimes smashing into the skull. Many nerves cells may break, producing such symptoms as headaches, slurred speech and loss of balance or memory

  – *Time Magazine 12/12/94*



Schema of Degeneration

