YOUR BRAIN
NEUROSCIENCE AND SOCIETY

# TRAUMATIC BRAIN INJURY CASE STUDIES

***Student Worksheet***

## Part 1: Read and annotate the following article.

Abridged from *Head to Head: The National Football League & Brain Injury*
NYU Langone's High School Bioethics Project

**Head Injuries in the NFL**
Over the past few years, concussions suffered by NFL players have been in the news. Many high-profile football players have been sidelined by severe head injuries. Although severe head trauma and brain injury have gotten much attention in the media, efforts to minimize these injuries have lagged. The NFL has only recently begun taking steps to protect its players in response to a torrent of criticism.

**Background on Chronic Traumatic Encephalopathy and Tau Protein**
In 2008, research surfaced that was gathered by neuropathologist Ann McKee, MD, from the Bedford VA Medical Center and CTE Center at Boston University Medical Center. After studying the brains of 12 former football players over a 2-year period, Dr. McKee found evidence of neurodegeneration. Each brain showed apparent signs of repeated trauma, the only cause of a condition known as CTE. CTE has been found to lead to depression, loss of judgment, inability to control impulse, rages, and memory loss, and can ultimately result in dementia. What's worse, these symptoms are not immediately apparent and can emerge up to 10 years after one stops playing football.

As Dr. McKee found, with every accumulation of brain trauma there is an increased effect on tau protein in the brain. Tau protein is a microtubule-associated protein (MAP) that plays a large role in microtubule stability. Microtubules transport nutrients and molecules within cells of the brain. In Alzheimer's disease, tau is altered chemically and begins pairing with other tau threads, becoming tangled, and a similar thing happens in CTE. These altered tau structures collapse, causing microtubules to disintegrate and the cells to die.

A survey by the Associated Press in November 2009 showed approximately 32 of the 160 NFL players surveyed—20 percent—replied that they have hidden or downplayed the effects of a concussion. Half said they have had at least 1 concussion, and 50 players—roughly 38 percent—missed playing time due to head injury. While players may currently hide their concussions in order to play, they may not be able to hide from

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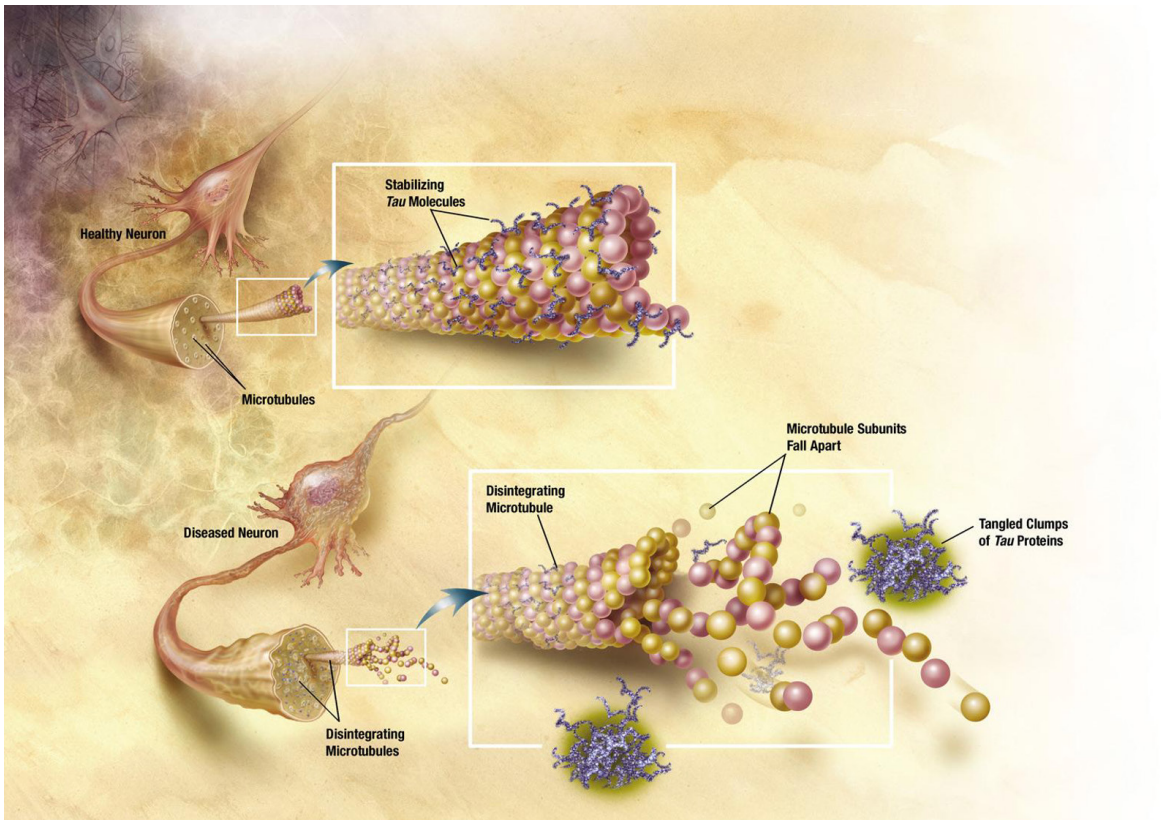
them in the future. In a 2009 study at the University of Michigan commissioned by the NFL, 6 percent of retired NFL players over the age of 50 had been diagnosed with Alzheimer's, dementia, or another memory-related disease. This study shows the much higher level of diagnoses in NFL players than in American men of a similar age who did not play professional football. The incidence in these men is only 2 percent.

**What Is Being Done, and Is It Enough?**




Altered tau structures collapsing, causing microtubules to disintegrate. *Image courtesy of the Alzheimer's Disease Education and Referral Center, a service of the National Institute of Aging.*

In 2007, the NFL mandated neuropsychological baseline tests and retests for players before they can return to play after sustaining head trauma. The NFL now prohibits players from returning to a game from which they were knocked unconscious and also established a hotline to report pressure to play against a doctor's advice. The hotline was created after New England Patriots coach Bill Belichick convinced former linebacker Ted Johnson to play too soon after a concussion, after which he sustained a more severe injury.

In 2015, the NFL released a new concussion poster to its players. It discloses more information about the effects of repeated head trauma than in previous information released to its players and, for the first time, acknowledges the serious long-term

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harm that concussions cause.

**How Do We Protect Our Future Athletes?**
Concussions are not uncommon to football played at all levels. In fact, they can be even more devastating to someone whose brain is still developing, as injuries can take longer to heal.

A major issue with concussions is they can be difficult to diagnose, and many student athletes return to play too soon. Many high schools lack the necessary medical personnel and equipment to examine athletes properly. A concussed athlete who returns to play before their brain is properly healed is more susceptible to sustaining an even worse injury known as second-impact syndrome—a condition in which the brain is vulnerable to another, often more severe, injury.

Making the proper diagnosis of a concussion and removing an athlete from play are hard enough when the symptoms are there. But the true danger lies in the inability to diagnose someone who demonstrates no symptoms. In fact, it is not always the severity of the hit that can cause brain trauma leading to CTE. The mere accumulation of hits can be just as devastating.

**Here are some figures to think about:**

- A high school lineman receives between 1,500 and 1,800 subconcussive hits each season
- Someone who plays four years of high school football can experience 6,000 to 7,200 subconcussive hits
- Playing 4 years of college football additionally doubles the amount of hits—12,000 to 14,400 hits to the head before a player has the opportunity to play in the NFL

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## Part 2: Analyze the three datasets below and answer the questions that follow each dataset.

**DATASET 1: John Grimsley**
The first deceased athlete examined by BU researchers was John Grimsley, former linebacker for the Houston Oilers and Miami Dolphins, who died in February 2008 at the age of 45 from an accidental gunshot wound. Examination of Mr. Grimsley's brain confirmed extensive CTE. In the photographs below, the brain tissue has been stained

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for tau protein, which appears as a dark brown color. It has also been treated with cresyl violet stain, which is commonly used as a general marker for neurons.

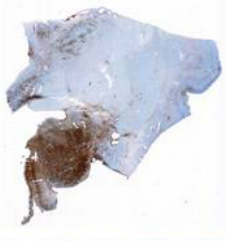
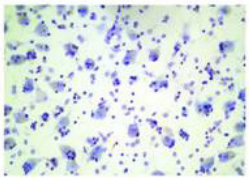
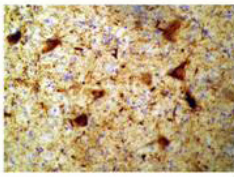
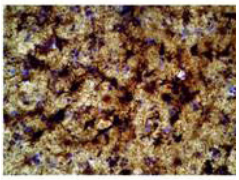
| | Control subject | John Grimsley | World champion boxer |
|---|---|---|---|
| **Whole brain section** |  |  |  |
| **Microscopic section of the amygdala** |  |  |  |

IMAGE CREDIT: BU SCHOOL OF MEDICINE.

**Questions:**

**1. How do pathologists look for tau tangles in the brain? How do they distinguish them from healthy brain cells?**

**2. What differences do you observe in tau tangle deposition between the healthy brain, Mr. Grimsley's brain, and the brain of a deceased world champion boxer?**

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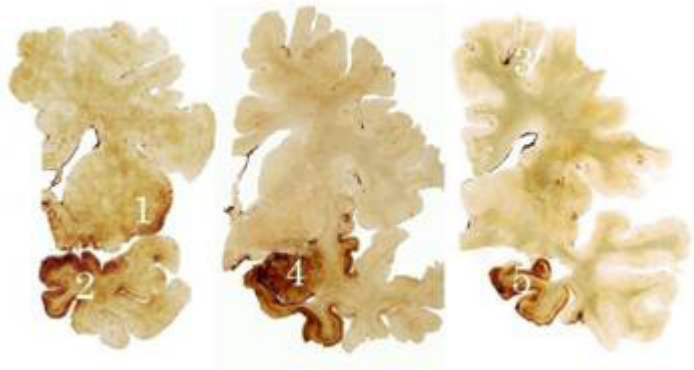
**DATASET 2: Lou Creekmur and Mike Borich**

Lou Creekmur, a former Detroit Lions lineman and eight-time Pro Bowl player, died in 2009 from dementia at age 82. BU researchers examined Mr. Creekmur's brain and found substantial evidence of CTE. There was no evidence of Alzheimer's disease or of any other neurodegenerative disease. Mr. Creekmur was the tenth former NFL player diagnosed with CTE and the most advanced case of CTE found in a football player at the time of analysis.

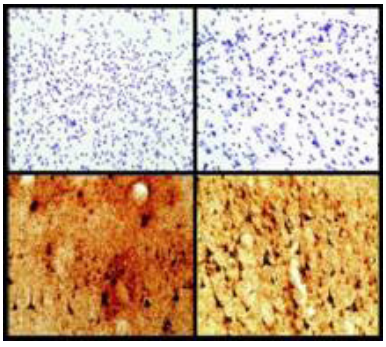
In the photographs below, the brain tissue has been stained for tau protein, which appears as a dark brown color.




**Whole brain sections of Lou Creekmur's brain, including the insula and temporal cortex (left), amygdala (center), and frontal cortex and hippocampus (right).**

Mike Borich, a former college football wide receiver, died of a drug overdose in February 2009 at age 42. Borich played for Snow College and Western Illinois University in the 1980s, and was later a football coach for the NFL's Chicago Bears and multiple division 1 college teams. Mr. Borich was the first advanced case of CTE discovered in a college football player who did not play professionally.  Mr. Borich also represents the first case of CTE diagnosed in a wide receiver.

**Whole brain section of Mike Borich's brain (right) compared to a control brain (left). Image credit: BU School of Medicine.**



**Microscopic sections of Mike Borich's brain (bottom) compared to a control brain (top). Image credit: BU School of Medicine.**

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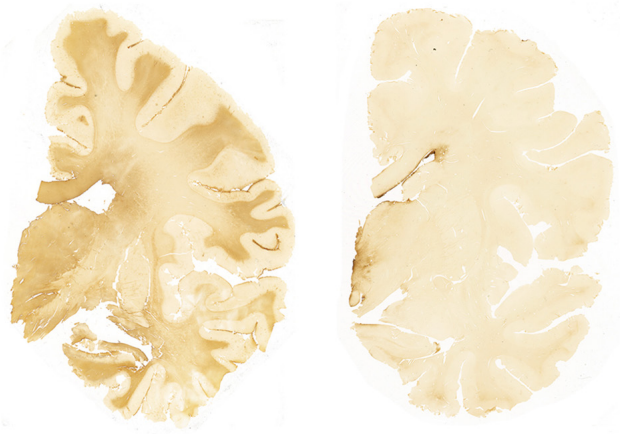
**Question:**

**1. What similarities do you observe between the pathologies of Lou Creekmur and Mike Borich, compared to John Grimsley?**

**DATASET 3: High School Football Players**

The problems with cognition, memory, and balance associated with concussions are symptoms of head injuries, but not all injuries result in concussions. In a study published in 2018, BU researchers performed post-mortem analyses of the brains of 8 teenage and young adult athletes. Four had sustained recent sports-related head impact injuries (1 day to 4 months prior to death), while the other four had no recent history of head impact injury. For example, Case 3 was a 17-year-old male high school American football and lacrosse player. He was diagnosed with two sports-related concussions during life, the last sustained 2 days before death. Case 8 was a 22-year-old male former high school American football player. He had suffered three concussions, all sustained more than 7 years before death.

In the photographs below, the brown stain does not identify tau tangles; it marks a different protein that indicates a widespread immune response, pointing to an abnormal increase in the number of astrocytes, a type of helper cell in the brain, due to the destruction of nearby neurons.



**Whole brain sections from Case 3 (left) and Case 8 (right). Image credit: BU School of Medicine.**

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**Questions:**

**1. Why do you think the researchers looked for signs of an immune response instead of tau tangles in this study, compared to the athletes in Datasets 1 and 2?**

**2. Scientists still do not know the direct cause of CTE. Identifying the cause is critical for developing methods of earlier diagnosis and treatment. Based on your observations of Dataset 3, should researchers focus their investigations on (a) the physical impact of an injury or (b) the cognitive impacts of concussions? Explain your answer.**

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