

Investigation: Concussions

Name: _____

Watch this video by Ted-Ed: <https://www.youtube.com/watch?v=xvjK-4NXRsM> ~ 6 minutes

PART 1: Video Information

1. What natural protections does your brain have against damage caused by impacts? _____
2. a. A **concussion** can occur when someone receives a jolt to the skull... what actually happens to neurons in the brain when someone gets a concussion? _____

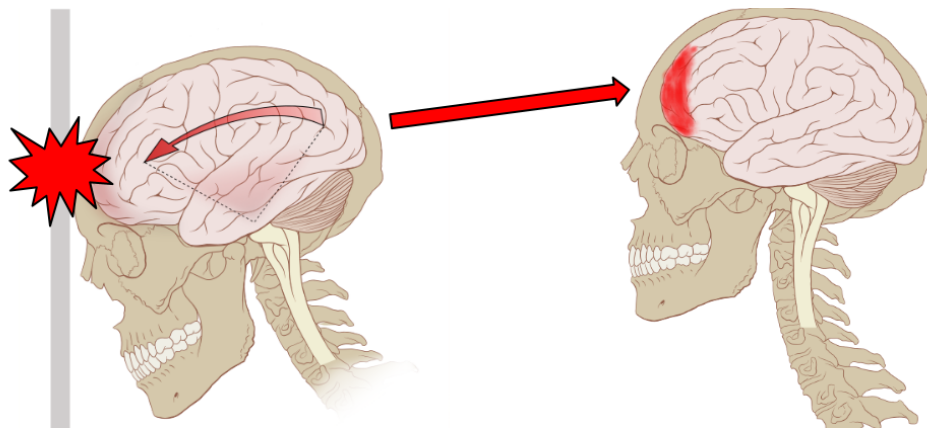
b. How many concussions have YOU had (that you are aware of)? _____

c. What are some common symptoms of concussion? _____

d. What is the standard treatment for a single concussion (what should someone do to heal from a concussion)? _____

e. How long does it usually take for a single concussion to fully heal (assuming someone follows the guidelines you described above)? _____
3. What do we call head injuries that don't cause full-on concussions *but* can still cause damage, especially if someone experiences many of these injuries? _____
4. a. What chronic condition can arise from accumulating multiple head injuries? *Provide both the full name and the commonly used acronym.* _____

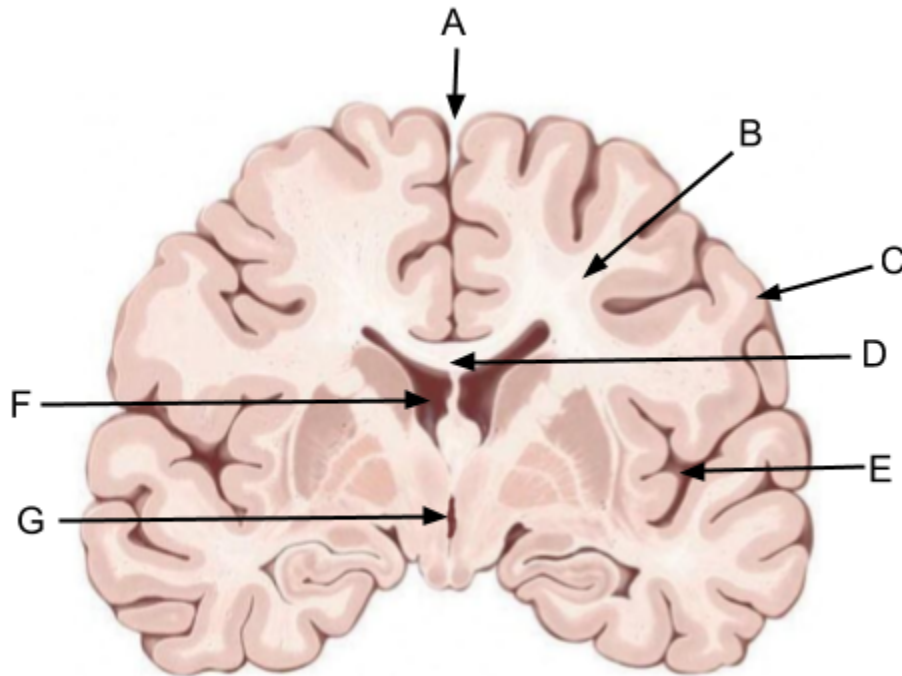
b. What are some common symptoms of this condition? _____
5. What is the relationship between TAU proteins and brain damage? _____



PART 2: Gross Pathology of CTE

6. What type of brain section is shown below (sagittal, coronal/frontal, or transverse)?

Go to Neuroanatomy.ca and view the brain slices to help you label the image below. Slide #11 will be the most useful, though it does contain many extra features.



Identify the following on the brain section above: Corpus callosum Gray matter White matter
Longitudinal fissure Lateral fissure Lateral Ventricle Third Ventricle

7. The image below shows two brain sections: one from a healthy, normal brain (left) and one from the brain of former University of Texas football player Greg Ploetz. Describe THREE significant differences you notice between the brain sections using proper anatomical terminology (use #5 as a guide for using proper terms).

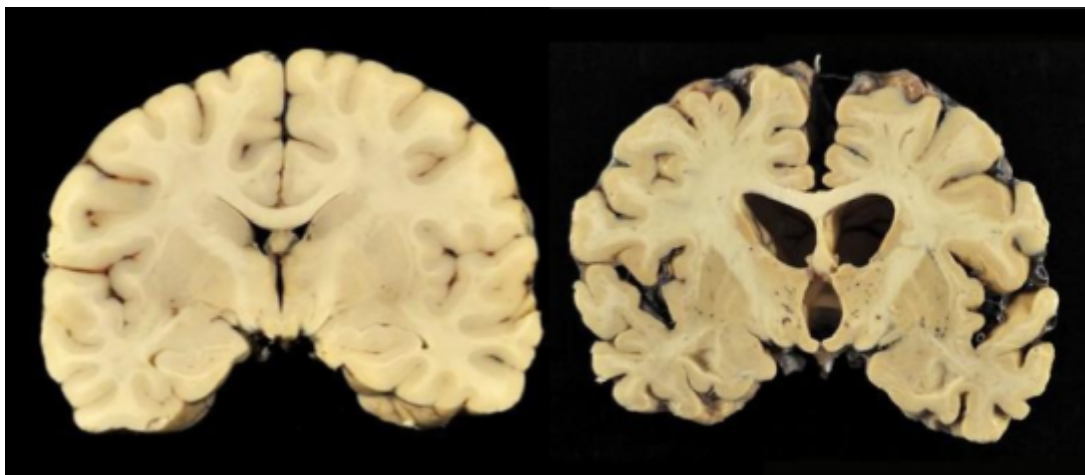
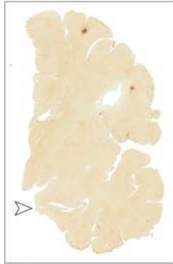
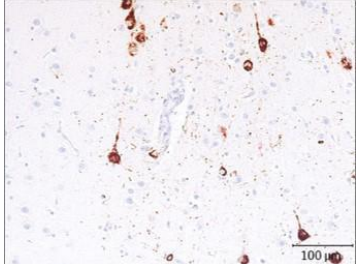
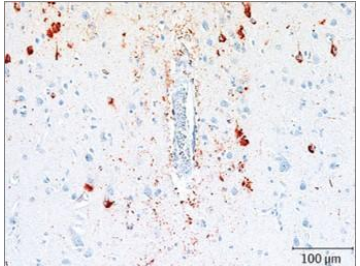
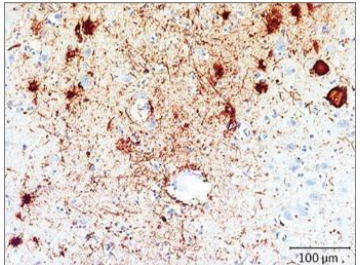
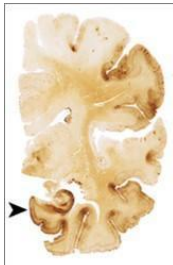
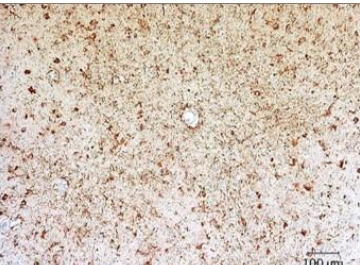


Photo: Ann McKee, MD / Boston University

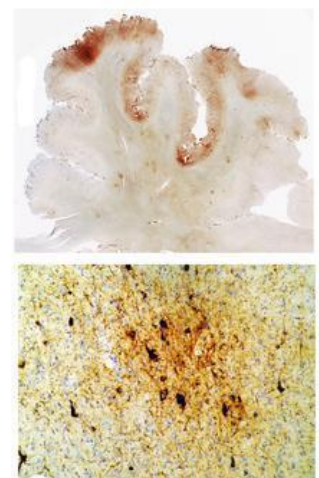
Dr. Bennet Omalu (whose research on the brains of NFL players was publicized in the 2015 film *Concussion*) was one of the first scientists to find tau tangles in the brains of athletes who had sustained multiple head injuries but did NOT have visible brain morphology differences – meaning that these athletes had CTE, even if their brains did not *look* structurally different. Based on Dr. Omalu’s work, researchers have classified CTE into 4 stages based on the extent of tau tangles.

CTE stage	Description	Brain section	Microscopic view
Stage I	A few hot spots of tau tangles appear in isolated areas of cortex		
Stage II	Multiple hot spots appear in cortical sulci; tau starts to migrate through brain		
Stage III	Tau hot spots start to blend with one another. Tau starts accumulating in the hippocampus and amygdala		
Stage IV	Dense tau tangles cover the brain’s cortex and appear in most brain regions, including the spinal cord		

Images: Mez J, Daneshavar DH, Keiman PT et al, 2017. Clinicopathological Evaluation of Chronic Traumatic Encephalopathy in Players of American Football. *Journal of the American Medical Association (JAMA)* 318(4):360-370.

8. Based on the information and images in the table, describe in one sentence what happens in the brain during the progression of CTE.

9. The images at right show a brain section (with tau staining) from a former NFL player. Did this individual have CTE when they died? If so, what stage? Justify your answer using specific information from the images.



Part 3: Brain Autopsies

A 2017 study examined the brains of 202 male players of American football and found that 177 of them had CTE, including 110 of 111 former NFL players. All of the brains studied had been voluntarily donated to a “brain bank” managed by several research institutions. Some brains were willed to the bank by the football players themselves before they died, while others were donated by the families of the players.

In most cases, brain donation was inspired by cognitive symptoms consistent with concussive damage and/or CTE. In several cases, symptoms were so severe that sufferers committed suicide – but being aware of the problem and the research being done, they intentionally chose methods of suicide that left their brains intact so that they could be studied.

The table below provides data about damage to specific regions of brains, organized by the stage of CTE at time of death. *Mean phosphorylated tau pathology* is a measure of the average relative buildup of tau proteins (tau tangles) in a given brain region. Examine the table and answer the questions that follow.

CTE Stage	No. of Donors	Brain region						
		Frontal	Temporal	Parietal	Amygdala	Hippocampus	Thalamus	Cerebellum
1	11	1.1	0.6	0.2	0.4	0.1	0.3	0
2	33	1.6	1.4	1.3	1.1	0.7	0.9	0.2
3	76	2.2	2.1	1.6	2.3	2.1	1.4	0.3
4	57	2.8	2.7	2.6	2.8	2.4	2.2	0.6

Mean phosphorylated tau pathology

0	1	2	3
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Selected data from: Mez J, Daneshmandi DH, Keimig PT et al, 2017. Clinicopathological Evaluation of Chronic Traumatic Encephalopathy in Players of American Football. Journal of the American Medical Association (JAMA) 318(4):360-370.

10. What would motivate a family to donate the brain of a deceased loved one?

11. Tau tangles are known to interfere with brain function. Based on the data above, which TWO brain regions had the most advanced tau pathology and what types of symptoms do you think individuals are most likely to experience? Justify your answer using information from class about brain regions and their functions. You may need to look up or review the role of the brain areas in cognitive function.

12. Which brain region consistently showed the *lowest* levels of tau pathology (compared to other brain regions) in brains at ALL stages of CTE and what cognitive function is the least affected?

PART 4: SYMPTOMS AND CORRELATIONS

The table below provides data about clinical features (symptoms) reported by 111 male players of American football diagnosed as having CTE. Examine the data and answer the questions that follow:

Clinical feature	Found in what % of mild CTE cases (n = 27)	Found in what % of severe CTE cases (n = 84)	Found in what % of ALL CTE cases (n = 111)
Headache	30	14	18
Cognitive symptoms:	85	95	93
Memory problems	73	92	86
Executive functioning	73	81	79
Attention	69	81	78
Language	39	66	59
Visuospatial	27	54	47
Dementia	33	85	72
Behavioral/mood symptoms:	96	89	91
Impulsivity	89	80	82
Depressive symptoms	67	56	59
Explosivity	67	45	51
Apathy	50	52	51
Anxiety	52	50	51
Hopelessness	69	46	52
Verbal violence	63	34	41
Social inappropriateness	48	32	36
Physical violence	52	28	34
Paranoia	41	31	34
Motor symptoms:	48	75	68
Gait instability	26	66	56
Slowness	19	50	42
Coordination difficulties	26	45	41
Falling	15	46	39
Tremor	19	39	34
Difficulty swallowing	11	18	16
Slurred speech	19	13	14
Diagnosed conditions:			
Motor Neuron Disease (ALS)	4	4	4
Parkinson's disease	4	6	6
Alzheimer's disease	4	25	20

Selected data from: Mez J, Daneshavar DH, Keiman PT et al, 2017. Clinicopathological Evaluation of Chronic Traumatic Encephalopathy in Players of American Football. Journal of the American Medical Association (JAMA) 318(4):360-370.

13. What percent of ALL individuals diagnosed with CTE in this study reported cognitive symptoms?
 What was the most commonly reported cognitive symptom?
 This indicates dysfunction of what part of the brain?
 What was the SECOND most commonly reported cognitive symptom? This indicates dysfunction of what part of the brain?
14. What % of all individuals diagnosed with CTE in this study reported dementia?
 What % of all individuals diagnosed with CTE in this study reported behavioral/mood symptoms?
 What % of those with mild CT report anxiety? What % of those with severe CTE?

15. Several of the individuals whose brains were studied had a history of perpetrating (committing acts of) domestic abuse... based on the data in the table, could this be related to CTE? *Use at least TWO specific pieces of data from the table to justify your answer.*

16. What % of all individuals diagnosed with CTE in this study reported motor symptoms?

What was the most commonly reported motor symptom (among ALL CTE cases)? This indicates dysfunction of what part of the brain?

17. What % of individuals in the group with severe CTE were diagnosed with Alzheimer's disease? How does this compare to the general population rate of 1 in 10 Americans over the age of 65?

18. Which symptoms (or categories of symptoms) were generally reported more often by individuals with mild CTE than those with severe CTE?

Propose a reason for this difference?

The table below provides additional data about 177 male players of American football diagnosed as having CTE. Examine the data and answer the questions that follow:

Characteristic	Mild CTE cases (n = 44)	Severe CTE cases (n = 133)	Combined total CTE cases (n = 177)
Mean concussion count (range)	90 (22-150)	50.5 (12-163)	70
Mean duration of football play (years)	13	15.8	15.1
Highest level of football play:			
Youth	0%	0%	0%
High School	7%	0%	2%
College	48%	20%	27%
Semiprofessional	9%	4%	5%
Canadian Football League (CFL)	2%	5%	4%
National Football League (NFL)	34%	71%	62%
Cause of death:			
Neurodegenerative	16%	47%	39%
Cardiovascular disease	11%	22%	19%
Suicide	27%	5%	10%
Cancer	5%	8%	7%
Motor Neuron Disease (ALS)	9%	5%	6%

Selected data from: Mez J, Daneshmandi DH, Keimig PT et al, 2017. Clinicopathological Evaluation of Chronic Traumatic Encephalopathy in Players of American Football. Journal of the American Medical Association (JAMA) 318(4):360-370.

19. a. What was the *minimum* number of lifetime concussions reported by anyone in this study?
b. What was the mean (average) number of lifetime concussions for all individuals in the study?

20. What impact does continuing a football career from college to the NFL have on CTE? Justify your answer using specific data from the table.

21. What was the most common cause of death in individuals found to have severe CTE?
What was the most common cause of death in individuals found to have *mild* CTE?
How does this number (your answer to part b) compare to the U.S. national average?
[Look up the most recent data for the U.S.](#) – and convert to % if needed.

22. Critics of the 2017 study claim that the data do not accurately reflect the incidence of CTE in the wider population of football players because the data set is inherently biased. Considering the information about the brains used for this study, what do you think? Justify your answer.

What should researchers do if they want to obtain a less biased data set?

23. Based on what you know about concussions and CTE, name FIVE other sports and/or careers in which you would expect to find a high rate of CTE.

24. FINAL SYNTHESIS

In 2015, the United States Youth Soccer Association banned heading the ball for ages 10 and under. ([Article by NBC](#)). Some opposed the new restriction and some say that the ban didn't go far enough and should have been extended to all ages. Based on what you know about concussions and CTE, state a claim (position) about the new policy against heading the ball and provide evidence (support) for your position from what you have learned in this investigation. (2-3 sentences)