NEUROSCIENCE AND SOCIETY
Curriculum for High School Teachers

Unit 8: Wellbeing

Center for Neuroscience & Society, University of Pennsylvania

The Franklin Institute
Acknowledgments

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From sensing to moving to thinking to feeling, neuroscience explains how we perceive and interact with the world around us. This field provides a rich opportunity for high school students to explore fundamental science, framed within the context of everyday decisions and new challenges they will face as they enter adulthood.

Information about the intersection between neuroscience and society abounds online and in the media, yet many sources are unreliable. Meanwhile, there are few textbooks on neuroscience and its societal applications that are designed intentionally for high school students. This curriculum, therefore, is a curated collection of resources—reviewed by experts and tested by teachers—to help you bring this fascinating content into your classroom.

The curriculum is intentionally modular to provide flexibility. Each unit can stand alone, ready to be incorporated into an existing biology, psychology, or other course. Alternatively, multiple units can be linked together to create a semester-long elective course.

You can adapt the content to meet the readiness and capabilities of your class as needed. You can select certain topics and activities to match your students’ interest and skip others depending on time constraints.

The goal of the curriculum is to inspire excitement about and increase knowledge of neuroscience. The suggested activities include a variety of instructional approaches, and we encourage you to ask open-ended questions and guide conversations so students are interacting instead of being passive listeners. Students often find personal relevance in these topics, so feel free to extend activities and discussions.

If you feel you have reached the limit of your knowledge about a particular subject, don’t worry! Even scientists may not know the answer. Neuroscience is still a developing field and you can create opportunities for you and your students to think critically and learn together. Use the provided links and documents as a gateway to finding additional sources and evaluating their quality.

Your feedback is also welcomed, of course. Please contact the program administrator at neuroscience@fi.edu with comments and suggestions. Thank you for all your hard work!
Alignment with Next Generation Science Standards
The “Neuroscience and Society” curriculum supports Next Generation Science Standards in the following areas.

High School – Life Science
HS-LS1 From Molecules to Organisms: Structures and Processes
Disciplinary Core Ideas
   LS1.A: Structure and Function
   LS1.B: Growth and Development of Organisms

Science & Engineering Practices
   Developing and Using Models

Crosscutting Concepts
   Structure and Function
   Stability and Change

HS-LS3 Heredity: Inheritance and Variation of Traits
Disciplinary Core Ideas
   LS3.A: Inheritance of Traits
   LS3.B: Variation of Traits

Science & Engineering Practices
   Asking Questions and Defining Problems
   Analyzing and Interpreting Data
   Engaging in Argument from Evidence

Crosscutting Concepts
   Cause and Effect
   Systems and System Models
   Science is a Human Endeavor
So far we’ve seen the ways the brain can malfunction, leading to neurological problems (e.g. frontal lobe syndrome, prosopagnosia, Alzheimer’s disease) and psychiatric problems (e.g. depression, ADHD, schizophrenia, autism). But brain function can also make the difference between being merely healthy (no neurological or psychiatric diseases) and doing great—living a good life. In this section, we’ll be looking at what neuroscience knows about the good life, as opposed to just not feeling bad.

**LEARNING OBJECTIVES:**
Students will be able to …

- Give examples of how our level of mental wellbeing—whether we are happy and fulfilled, or just surviving free of mental disorders—depends on the brain.
- Compare and contrast the effects of loneliness and social interactions on the psyche and brain.
- List some of the benefits of physical exercise and what regions of the brain have been implicated.
- Explain mindfulness meditation and how it may influence well-being.
- Describe why generosity can be a pleasurable and positive experience.

**TABLE OF CONTENTS:**
A. Terms and Definitions
B. Topics:
   1. Friendship
   2. Physical Fitness
   3. Mindfulness
   4. Generosity and Empathy/Compassion
C. Annotated Resources by Topic (for further reading)
Meditation – A term used to describe many types of practices related to contemplation, reflection, and relaxation. This practice comes out of both Eastern and Western religious traditions.

Mindfulness Meditation – A type of meditation in which the person focuses on, but does not try to change, their thoughts, sensations, and emotions.

Empathy – The ability to understand and/or share the feelings of another person.

Compassion – A concern for the welfare of another person, often in situations of suffering.

Cortisol – A hormone that is released in response to stress.

**Key Points:**

- The presence of a friend reduces our overall stress response during stressful situations.
- Social interaction has been shown to generally improve health, including neurological health.
- Loneliness, on the other hand, has been shown to have detrimental effects on behavior and the brain.

**Resources and Discussion Questions:**

Recent neuroscientific research has shown that holding a loved one’s hand in the presence of the risk of an electric shock actually reduces stress responses in the body and brain (when compared to holding the hand of a stranger). Even just knowing that your loved one is present can reduce stress. See this summary from Psychology Today.

Other research suggests that the number of friends we have relates to our overall health, perhaps due to lowered stress and increased resilience to disease, damage, or other problems. One study suggests that there is a lower risk of dementia among women with larger social networks (see here). On the flip side, other researchers (see a summary here) have shown that loneliness/low social interaction is harmful to health. The study suggests that loneliness is...

- equivalent to smoking 15 cigarettes a day
- equivalent to being an alcoholic
- more harmful than not exercising
- twice as harmful obesity

Loneliness has also been shown to directly affect connections between brain regions:

- Research in mice showed that loneliness induces a reduction of myelin in brain regions associated with emotions (see the Neurons Unit for a review of white matter, gray matter, and the role of myelin).
- The same research also showed that when the mice were reintroduced into social situations, this
effect was reversed. (See an overview of the study from the Daily Mail.)

- *Scientific American* also has a description of a number of studies that look at the effects of loneliness/social isolation on white matter and myelination. It contains a review of gray and white matter.

**Classroom Activities:**

**Activity #1 – Quotes**
Get students thinking about differences between just getting by and living a good life. What role do things like friendship, spirituality, helping others, gratitude, mindfulness, and physical health play in well-being?

- Hand out or display a selection of quotes: “What makes for a good life?”
- Ask students to pick one they like or to provide their own quotes.
- Have students discuss the quote they picked and why it reflects their values.

**Activity #2 – Friendship in the Brain**
Have students brainstorm which cognitive and emotional processes are active when we interact with a friend.

- Have students point to or list brain regions that are associated with each of those processes. (e.g. listening: auditory cortex, remembering: hippocampus, upset or sadness: amygdala).
- Have students recall a time a friend provided comfort before, during or after a stressful experience. Which regions of the brain may be most affected?
- Which of the processes may be most associated with positive health?

**PHYSICAL FITNESS**

**Key Points:**

- Exercise has a beneficial effect on cognition in general, and these effects can be seen in the brain.
- One of the main findings of neuroscientific research on exercise is that it has been shown to boost learning and memory.
- In children, exercise has also been shown to increase executive function, which relates to the ability to plan, exhibit self-control, and hold things in memory.

**Resources and Discussion Questions:**
Exercise has been shown to substantial benefit our ability to learn and remember information (see this link for a summary of these two studies from BrainFacts.org).

- Monkeys who ran on a treadmill for an hour a day for five months learned twice as fast as monkeys who did not exercise.
- Older human adults who began walking regularly showed an increase in hippocampus volume, rather than a decrease in volume experienced by another group of adults who did only strength and balancing training.

An article in *The New York Times* also discusses the benefits of exercise on general cognition. In particular, researchers placed mice into one of four environments, some containing toys, some containing an exercise wheel, and some containing both. All mice that had access to the exercise wheel showed increased performance on cognitive tests.
One study suggests that even 30 minutes of exercise increases plasticity in the brain during the time just after exercising.

While many studies point to the effect of exercise on memory, one recent study also showed that 8 and 9-year-old students showed better executive control after being enrolled in a year-long after school exercise program. (See a New York Times article here.)

Classroom Activities:
Activity #1 – School Physical Education
Many schools are cutting recess and physical education classes. Why might this be a bad idea, based on what we know from neuroscience?

• Have students read (or summarize) this New York Times article about funding cuts to PE classes. (Alternatively, find an article on the state of recess/PE in your city.)
• In class or as a take home project, have students compose a letter to the governor/school board arguing for expansion of sports, recess, and/or physical education opportunities, making sure to include supporting scientific evidence.
• Discuss these letters in class, and talk about your own school. Should there be more opportunity for exercise? Different kinds of exercise? Incorporate into the discussion what has been learned from neuroscience research.

MINDFULNESS

Key points:
• Mindfulness meditation involves the practice of “mindfulness”: focusing on current thoughts, sensations, and emotions—not trying to change them, just being aware of them.
• Mindfulness meditation is known to reduce stress, and increase mood and sustained attention.
• Our use of technology can influence stress, mood, and attention both positively and negatively.
• In brain imaging studies, the positive benefits of meditation are often related to changes in networks in the brain (not just single regions or small groups of neurons), such as networks related to attention and emotional processing.

Resources and Discussion Questions:
Scientific American has a video that summarizes some of the psychological and neuroscientific research on mindfulness meditation.

The New York Times has an editorial on some recent research on meditation.

• After 5 weeks of meditation training, there was a leftward shift in frontal asymmetry, meaning that there was greater activity in the left half of the frontal cortex than in the right. The researchers associated this with “positive, approach-oriented mental states”.
• Other research has shown that people “multitask” (shift between tasks) better after an 8-week meditation course.
• Finally, regular meditators have increased default network connectivity, a brain network that has been associated with internal awareness and introspection.

Studies have also shown that meditation can have an impact on gene expression, which can result in lowered stress and inflammation in experienced meditators.

A press release from MIT describes research that shows after weeks of meditation, people showed neural signals related to increased ability to focus on bodily sensations, and they also reported less overall stress than a group who did not practice meditation.

Bloomberg Business has a very basic overview of some current research on the effects of meditation on stress. The Huffington Post summarizes a study that showed a reduction in the stress hormone cortisol after a meditation retreat.

Anderson Cooper from 60 Minutes has reported on the impact of technology on the brain. For instance, this video (4:42) demonstrates how his cortisol levels increase whenever he receives a text notification.

This short excerpt from The Organized Mind by Daniel Levitin discusses how various technology habits affect the brain. Refer back to Drugs & Addiction (Unit 4) for more information on the brain’s reward pathway.

This article summarizes research on video games that are being designed to improve cognitive function.

**Classroom Activities:**

**Activity #1 – Mindfulness Meditation**

What is mindfulness meditation? Many students will not have experienced meditation, and the best way to understand it is to try it out. Try this 10-minute guided mindfulness meditation or a longer 30-minute track that has been used by neuroscience researchers studying the effect of mindfulness meditation and compassion meditation (see next section) on the brain at the University of Wisconsin-Madison. After the 10 minutes are over, lead a discussion on students’ response.

• Is this what you were expecting?
• Did you enjoy the experience?
• Do you feel more relaxed or different in any way?
• What were the important elements of this exercise? What were you instructed to do and think?
• How do you think this helps your brain?

**Activity #2 – Technology Design for the Brain**

Have students choose an app or game that they use regularly. What features of the app or game are designed to attract attention? What features elicit a sense of reward? Are there opportunities for social interaction? What features motivate you to keep coming back? Have students review neuroanatomy and function to decide which regions of the brain are likely to be activated by each feature.
Key points:
- Giving and generosity can evoke pleasure by means of the same brain circuits that are also active when receiving good things (e.g. food, money).
- People’s level of generosity has been associated with the size and activity of a number of brain regions.
- “Compassion training” has been associated with decreased stress and increased empathy, both of which have also been related to changes in the brain.

Resources and Discussion Questions:

Pleasure of Giving
One neuroscience study reports that the same reward-related brain regions that are active when someone receives money are also active when someone gives money. See this write-up on the study from the NIH.

A 5-min NPR interview summarizes research shows that in many cases, people experience more happiness when giving to others, not keeping for themselves. This is shown even in young children, suggesting that happiness in giving may be “hard-wired.”

Generosity and the Brain
An article in the LA Times reports on research that showed that kidney donors have larger volume of their right amygdala than controls, and that the size of this region correlated with a more active response to facial expressions. (The question, of course, is whether greater volume in the amygdala led to greater generosity, or whether the practice of generosity led to greater amygdala volume.)

An EEG study showed that brain activity while children watch moral/non-moral animations relates to the child’s generosity in a later task. See this summary.

LifeScience discusses a case of a man in Brazil who, after suffering a stroke, developed “pathological generosity.”

Compassion and the Brain
A type of meditation called Loving-Kindness meditation has been shown to reduce stress responses and increase empathy and compassion. Neuroscientific studies have also associated LKM with changes in brain regions associated with those traits. See this summary from the Huffington Post.

Can people be trained to be more compassion? This article summarizes a recent psychological and neuroscientific study that suggests that Loving-Kindness meditation influenced adults to become more altruistic and sensitive to human suffering.

For a longer form article on the Dalai Lama, meditation, compassion, and the brain, this article from the Atlantic is excellent.
Assignment Ideas:
Assignment #1 – Empathy Self-Reflection
What is empathy, exactly? Use the self-reflection guide and have students record their positive and negative interactions over the course of a day, then reflect on their practice of empathy. This assignment is adapted from an activity developed by the Ashoka Changemaker Schools Network.

ANNOTATED RESOURCES
Note: Articles published by the Dana Foundation are written specifically for a wide readership and therefore the easiest to read among the below list.

General
A Cognitive Neuroscience Hypothesis of Mood and Depression
Trends in Cognitive Science/Moshe Bar
This paper is quite specific in its hypothesis that mood directly relates to the degree to which people think broadly or narrowly (associative processing). It offers a lot of interesting neuroscience and psychology research in support, and so may be of interest to those specifically interested in the neuroscience of mood disorders.

Hardwired for Happiness
Dana Foundation/Silvia Helena Cardoso
This is a broad overview of the scientific study of happiness, including both psychological and neuroscientific research. It’s a bit long and could have been better edited, but still has interesting information.

Stress and Immunity: From Starving Cavemen to Stressed-out Scientists
Dana Foundation/Fabienne Mackay
This is a helpful overview of the biology of stress and sickness. It does a relatively good job of defining the biological terms and concepts used to explain the research. Unfortunately, there are some editing errors that make some paragraphs hard to read.

One of Kind: The Neurobiology of individuality
Dana Foundation/Richard J. Davidson
This review goes into a fair amount of experimental detail, but gives good examples of research on the importance of experience in shaping brain function and emotion.

Towards a Functional Neuroanatomy of Pleasure and Happiness
Trends in Cognitive Science/Morten L. Kringelbach, Kent C. Berridge
This clearly written article focuses mostly on the neuroscience of pleasure, “hedonia”, and how this is distinguished from “wanting” in the brain.

Friendship
Perceived Social Isolation and Cognition
This article lists the many ways in which loneliness affects cognition, mood, and health. There is good discussion of related neuroscience research without getting bogged down in the details.
Can We Improve Our Physical Health by Altering Our Social Networks  
*Perspectives in Psychological Science* | Sheldon Cohen, Denise Janicki-Deverts
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This is a short paper on the current state of what we know about the effects of social networks on health. Easy to read and interesting.

Physical Fitness  
The Anxiolytic Effects of Resistance Exercise  
*Frontiers in Psychology* | Justin C. Strickland, Mark A. Smith
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This is a good review of the research on the positive cognitive and affective effects of strength training. It is clearly written and primarily contains basic statistics of what populations are affected by what kind of strength training.

“Shift-and-Persist” Strategies: Why Being Low in Socioeconomic Status Isn’t Always Bad for Health  
*Perspectives in Psychological Science* | Edith Chen, Gregory E. Miller
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This is quite a long article, but worth reading the abstract and scanning for points of interest.

Generosity and Empathy/Compassion  
With a Little Help from our Friends: How the Brain Processes Empathy  
Dana Foundation | Peggy Mason
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This article lays out some of the theories of why we are empathetic and describes interesting evidence that we also see empathy in other animals.

Toward a Cross-species Understanding of Empathy  
*Trends in Neurosciences* | Jaak Panksepp, Jules B. Panksepp
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A bit more detailed of a review containing theories of empathy and more examples of studies on empathy across species.

Compassion: An evolutionary analysis and empirical review  
*Psychological Bulletin* | Jennifer L. Goetz, Dacher Keltner, Emiliana Simon-Thomas
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This is a very long (though interesting) article with only a short section on neuroscience at the end. It may be worth a skim for sub-topics of interest.

Mindfulness  
Attention Regulation and Monitoring in Meditation  
*Trends in Cognitive Science* | Antoine Lutz and others
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A clear, short description of the cognitive and neural processes involved with two meditation styles.

Mindfulness Meditation and Explicit and Implicit Indicators of Personality and Self-concept Changes  
*Frontiers in Psychology* | Cristiano Crescentini, Viviana Capurso
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This article does not focus on neuroscience research, but contains insightful research on the positive effects of mindfulness meditation.
Focused attention, open monitoring and loving kindness meditation: effects on attention, conflict monitoring, and creativity – A review
Frontiers in Psychology/Dominique P. Lippelt, Bernhard Hommel, Lorenza S. Colzato
A relatively short article following in the steps of the Lutz article (above) that describes psychology and neuroscience research related to different types of meditation.

Brain Development in a Hyper-Tech World
Dana Foundation/Brenda Patoine
This briefing paper is from 2008, but it remains relevant in describing many of the questions that scientists are studying today.

The dark side of smartphone usage: Psychological traits, compulsive behavior and technostress
Computers in Human Behavior/Y-K Lee and others
This article is a fairly lengthy study on the psychology of smartphone use, but the survey questions in Appendix A may be useful in guiding students to reflect on technology and stress in their personal lives.

Paving the Way for Apps in Mental Health Care
Dana Foundation/Kayt Sukel
This article reviews the potential for apps and mobile technologies to actually improve mental health.