

The Campus Coffee Shop: Caffeine Conundrums

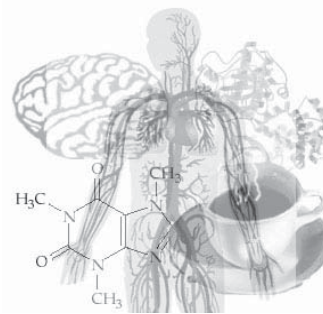
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Part I—Introduction

The rich, strong smell of coffee filled the newest coffee house in the small college town. The place was packed with students sitting at small art deco bistro tables. A hip-looking barista was busy taking customer orders behind the counter while a loud grinding sound purred from the espresso machine, followed by the gurgle of steaming milk. Students were glued to their laptops—coffee in one hand, mouse in the other. Sally, Alex, and Jenna were sitting together at one of the tables, discussing their latest biology project, “Science in Everyday Life.”

Taking a sip from her water bottle, Sally said, “It’s getting late and we still don’t have a topic and this project is due the day after tomorrow! Let’s get moving. We all have classes all day tomorrow and we are running out of time!”

“Don’t worry, Sally,” Alex said, after guzzling down his energy drink. “We’ll definitely get through it, we have plenty of time to finish and I’m not tired whatsoever.”

Jenna, gulping down her third espresso latte of the night, added, “Yeah, Sally, we’ll get through it, you just need some caffeine to keep you awake so we can finish it tonight. It will be the best project Professor Jackson has ever seen.”

“I don’t understand why you both need caffeine. Stress keeps me going,” Sally replied.

“I’m not addicted,” said Jenna. “Coffee just keeps me moving with all the demands of college life. I have at least one cup in the morning, one in the afternoon and two or more while studying in the evening. I’ve been drinking coffee since the first day of my freshman year, and it’s been working great.”

“I usually only need a quick boost every now and then before a deadline,” added Alex.

“That gives me a great idea... why don’t we focus our project on the effects of caffeine on the human body?” interjected Sally.

“Good idea, let’s go with it. Now, where should we start?” replied Alex.

Questions

1. List common foods/drinks that are sources of caffeine. How much caffeine is found in each?
2. What is the chemical structure of caffeine? What class of chemical molecules does caffeine belong to?
3. What are common physiological effects of caffeine consumption?
4. Where in the body does caffeine act?
5. Propose reasons why Alex and Jenna feel the need to consume caffeine while Sally does not. Why does Jenna feel that she needs more caffeine than Alex?



Part II—Cell Biology and Signal Transduction

Jenna wondered what all of the caffeine she drank was doing to her brain. Sally told her that was why she avoided all unnecessary chemicals, and caffeine was unnecessary. Alex said it depends on your definition of necessary. He followed up with “But what does caffeine do in the brain?”

The group began sifting through the websites they found while discussing the effects of caffeine that they noticed. “Well, for me, the main effect is that it keeps me alert. I don’t feel sleepy even when studying late if I’m drinking my coffee,” said Jenna.

“Yeah,” Alex interjected, “but too much and you get jittery. My hands start to shake and I can’t sit still. Does that ever happen to you?”

Sally sniffed in a superior way, but remained quiet.

“Yes, it does” Jenna agreed. “Does anyone see anything about the effects of caffeine on neurons on these websites?”

Sally looked up from her computer and asked “Has anyone ever heard of adenosine receptors? Adenosine seems to have something to do with sleep.”

“Hey, no fair coming up with new types of receptors,” Alex said. “And doesn’t adenosine have something to do with ATP? How can it have receptors?”

“ATP stands for Adenosine Triphosphate,” Sally reminded him.

“The energy source for the cell” they all chorused together, laughing at the memory of their studying together in their first biology course.

“Maybe adenosine gets to go out without its triphosphate. I’ll look it up in my neurobiology book.” Sally pulled her book out of her sack. “There are four types of adenosine receptors,” she reported. “They are G-protein coupled receptors. According to this book, caffeine seems to be an antagonist for these receptors.”

Questions

1. What are G-protein coupled receptors? Where are these receptors located in the cell? How do they work? Draw a diagram.
2. What is an antagonist for a receptor? What would an antagonist do? Draw a diagram to explain this.
3. How would caffeine binding to an adenosine receptor affect the activity inside the neuron? Refer to your diagram for Question 1.
4. Adenosine inhibits other neurons in the brain. Specifically, it inhibits the release of excitatory neurotransmitters and decreases the effect of dopamine. During the day, adenosine levels rise, and adenosine acts on its receptor to inhibit other neurons. Specifically, what effects would caffeine have?
5. How does caffeine get into the brain? Hint: Look at the chemical structure of caffeine.



Part III—Caffeine and Parkinson’s Disease

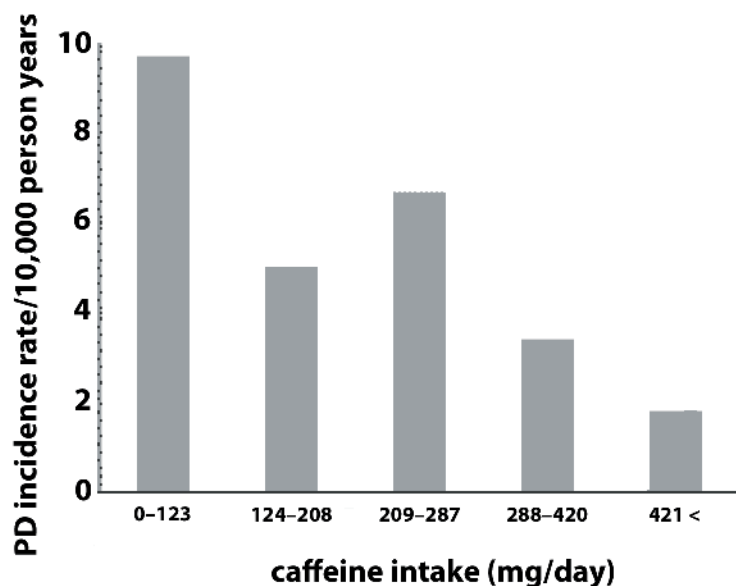
“I’ve been searching through all these scientific articles about caffeine and Parkinson’s Disease, there is a lot we can include in our biology project,” Alex said.

“I wonder, is there really a connection between caffeine and Parkinson’s Disease?” Jenna asked.

“My grandfather suffers from Parkinson’s Disease, maybe I could call him and get a first person perspective on the disease. Alex, skim through those articles and see if there is any useful information about a link between caffeine and Parkinson’s Disease while I call Granddad,” added Sally.

Questions

1. Describe the biological basis for Parkinson’s Disease (PD). Include specific molecules and cells involved in the pathogenesis of PD. What groups of people are most affected by PD? What treatments or cures are available for PD?
2. What questions could Sally ask her grandfather about PD that might be useful for the students’ biology project?
3. Based on the graph below, what do you conclude about Parkinson’s Disease? What other information would you need to properly assess the data? Propose additional ways of performing this experiment in a more controlled environment. What variables would you need to consider in your experimental design?



4. Generate hypotheses to explain your conclusion(s) above. Suggest experiments to test your proposed hypotheses. Be sure to include appropriate controls in your experiments.
5. Would caffeine be considered an effective treatment option for Parkinson’s Disease? Why or why not?



Part IV—Caffeine and the Cardiovascular System

“I tried drinking hot coffee once and my heart started beating faster and I felt energized, almost overstimulated. I stay away from the stuff. I asked my doctor about it and he said something about vasoconstriction,” Sally said.

“How about we do a little experiment and measure our blood pressures when we drink caffeine and include real data as part of our biology project,” proposed Jenna.

Alex exclaimed, “Hey, I found these equations... maybe we can use these to explain what’s going on when we drink caffeine...”

- Mean Arterial Pressure (MAP) = cardiac output \times total peripheral resistance
- cardiac output = heart rate \times stroke volume
- MAP = $\frac{1}{3}$ (systolic) + $\frac{2}{3}$ (diastolic)

Questions

1. Using the students as subjects, design an experiment that will help them determine the effects of caffeine on MAP over time. Predict the results for each student. Use the equations above to help explain the results.
2. What is vasoconstriction? If vasoconstriction is a result of caffeine signaling, describe the changes that would occur in MAP.
3. What is an average MAP reading? Calculate Jenna’s and Sally’s MAP (at rest and with caffeine) using the systolic and diastolic readings provided in the tables below.

Jenna	epinephrine levels	blood pressure
resting	290 pg/mL	120/80
with caffeine	291 pg/mL	120/81

Sally	epinephrine levels	blood pressure
resting	292 pg/mL	113/75
with caffeine	290 pg/mL	130/95

4. Propose biological and physiological differences between Jenna’s heart rate and Sally’s to help explain the data above.
5. Give examples of common catecholamines and describe how they work. If Sally was given a beta-blocker, what would you predict would happen to her heart rate? Why? What about for Jenna?
6. If catecholamines are involved in increasing heart rate, how do you explain the data in the chart provided? What alternative biological/molecular/cellular explanations can you provide to explain the data?
7. If hypertension is characterized by beta-receptor down-regulation, what will happen if someone who has hypertension consumes caffeine?



Part V—Caffeine and Addiction/Withdrawal

Jenna, Sally, and Alex worked for several hours at the coffee house on their project about the effects of caffeine on the human body. Even though the project was almost complete by night's end, they decided to meet in the library at seven o'clock the morning it was due to proofread it and put any last minute touches on it before the nine o'clock deadline. They said their goodbyes and parted for the night, promising to meet in the morning on the day after tomorrow.

Sally was the first to arrive at the library that morning. She was a few minutes early, so she waited for the others to arrive. Alex arrived promptly at 7:00. "Good morning, Sally. Have you seen Jenna yet?" Sally replied, "No. Let's give her a few minutes before we get started."

Fifteen minutes passed and still no Jenna. "You know, Alex," said Sally, "we should probably go ahead and get started. I'd hate to run out of time." So, Sally and Alex decided to finish the project.

Finally, at 7:45, Jenna arrived. She looked like she had just rolled out of bed. Jenna grumbled a hello to her partners. As they all began to work together, both Alex and Sally immediately noticed that Jenna was cranky and difficult to work with. Compared to two nights ago, Jenna was irritable, jumpy, and unable to concentrate.

Sally asked, "Jenna, are you okay?"

Jenna replied, "No, I'm really tired. I couldn't sleep well last night. I have a headache; I feel shaky, and I am nauseous. Maybe I am coming down with the flu or some virus."

Sally and Alex murmured something sympathetic even though they both simply wished Jenna would snap out of it and be helpful. Sally offered Jenna medication for her headache.

Jenna mused, "You know, I haven't felt right since we started working on this project. I thought about all of the coffee I drink, and I decided to try to go without it. Now, I am not sure it was a good idea."

Questions

1. Although she is unaware, Jenna is suffering from caffeine withdrawal. List common symptoms of caffeine withdrawal.
2. What is the timeframe for the onset of these symptoms? How long can they last?
3. Sally offers Jenna some medication to try to alleviate her headache, which is caused by dilation of blood vessels in the brain. Explain why you think many headache medications contain caffeine.
4. Compare and contrast "drug dependence" and "drug addiction." Based on this comparison, justify under which category you would place caffeine consumption.
5. Explain the mechanism by which adenosine contributes to caffeine dependence or addiction.
6. Explain how dopamine can contribute to caffeine dependence or addiction.

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