Cell Communication: Effect of Assorted Drugs on Heart Rate of *Daphnia magna*

**Abstract**

*Daphnia magna* specimen were exposed to nicotine, caffeine, and epinephrine and monitored for changes in heart rate. This experiment was completed in order to study the physiological changes resultant of ligand binding in *D. magna.* The average basal heart rates of three *Daphnia magna* (D1, D2, and D3) were taken for each trial. Organisms were then exposed to one of the three drugs, and heart rate was measured again in duplicate for each organism. Basal and induced heart rate was measured for n=9 *D. magna total*, with 3 organisms allotted for each trial. Caffeine, an agonist ligand, was determined to increase the average heart rate of the specimen, implying that it promoted a signal transduction that increased heart rate. Nicotine and epinephrine, also agonist ligands, decreased the average heart rate. Deviations from known agonist function to increase heart rate were attributed to experimental error.

**Introduction**

Cell communication is vital to all living creatures. Multicellular organisms make use of cell-surface receptors, which are responsible for detecting extracellular signals, called ligands. These receptors have a critical role in the reception and transduction of outside signals that eventually lead to a change in cell function or behavior (1). The three steps of cell communication are reception, transduction, and response. Reception refers to the actual binding of the ligand to the receptor. Such binding may induce a conformational change in the receptor, unveiling a binding site or promoting enzymatic activity. Transduction involves the relay of information received from the signal via a cascade of an assortment of molecules and their associated proteins. The response refers to the actual change in cellular behavior that occurs as a result of the reception of the signal (1).

Common drugs are comprised of two types of ligands: agonists and antagonists. Agonists are ligands that bind to a receptor a mimic an internal object, such as a neurotransmitter (2). Antagonists also bind to the receptor, but they inhibit the function of the agonist. In this lab, nicotine, and epinephrine serve as agonists. Nicotine binds to nicotinic receptors, causing a conformational change. This change opens the associated ion channel for a brief period of time, causing depolarization of the membrane and excitation of the cell. The uptake of nicotine also promotes the release of neurotransmitters like epinephrine, dopamine, serotonin (3). Responses to nicotine intake may vary and depend on the amount consumed. This is because nicotine stimulates both the sympathetic and post sympathetic divisions of the nervous system (4). Epinephrine and Caffeine increase heart rate. Epinephrine does so by binding to adrenergic receptors, resulting in increased levels of calcium ion, which leads to the increase of contractile force in the heart (5). The uptake of caffeine leads to increased levels of the cAMP molecule in cells, increasing contraction rates in the heart (3).

This laboratory activity served to observe the direct physiological changes that occur on *Daphnia magna*, the water flea, as different ligands are introduced. The use of *Daphnia magna* as a model organism allows for the clear visualization of the changes in heart rate. The hypothesis for this experiment was that the addition of all three drugs would increase the heart rate of the specimen.

**Materials and Methods**

Three drug solutions were chosen for the purpose of testing their effects on the heart rate of the *Daphnia magna*: Nicotine, Caffeine, and Epinephrine. A single *Daphnia* specimen was obtained from the culture jar. One drop of Detain solution was placed in the center of a depression slide. Then, the *Daphnia* specimen was placed in the center of the drop for immobilization purposes. The dorsal heart of the specimen was located using a light microscope under the 4x objective setting. A resting heart rate (in beats per minute) for the specimen was determined by counting the number of heartbeats in 15 seconds and then multiplying the value by four. Observation time under the microscope was limited to minimize harm to specimen due to heat. This measurement was taken twice and then averaged to obtain the average basal heart rate.

A spatula was used to lift the specimen out of the Detain and into a depression well with fresh water. This allowed the specimen to clean itself of the resin and to regain its agility. Next, one drop of Nicotine was placed in a depression well. The specimen was moved from the fresh water well to the well containing the drug. After allowing one minute to pass for the drug to effect the *Daphnia,* the specimen was then placed in a drop of Detain on a depression slide as before. The dorsal heart was again located. The heart rate under the influence of the drug was observed and counted for 15 seconds as before. This value was multiplied by four to obtain the rate in beats per minute. The heart rate was measured twice and the average of the two was taken. Two more *Daphnia* specimen were tested in this manner for the effect of Nicotine. This entire process was then repeated for Caffeine and Epinephrine.

**Results**

**Table 1: Effect of Nicotine on *Daphnia* Heart Rate**

|  |  |  |
| --- | --- | --- |
|  | Basal Heart Rate (beats/min) | Nicotine Induced Heart Rate (beats/min) |
| D1 | 204 | 88 |
| D2 | 188 | 140 |
| D3 | 200 | 188 |
| Average | 197 | 139 |

**Table I.** D1, D2, D3 indicate the three individual *Daphnia magna* specimen that were tested. The “basal heart rate column” gives the value in beats per minute of the heart rate of the *Daphnia* before the addition of Nicotine. The “Nicotine Induced Heart Rate” column gives the heart rate of the *Daphnia* after the addition of Nicotine. Averages were taken for both columns to provide general idea of trend.

**Figure 1.** **Effect of Nicotine on *Daphnia* Heart Rate.** The heart rate of three *Daphnia magna* specimen (D1, D2, and D3) was measured before and after the addition of Nicotine. For basal heart rate, data shows the mean =197 bpm and standard deviation of 8. For induced heart rate, data shows the mean= 139 and standard deviation =50.

Table II: **Effect of Caffeine on *Daphnia* Heart Rate**

|  |  |  |
| --- | --- | --- |
|  | Basal Heart Rate (beats/min) | Caffeine Induced Heart Rate (beats/min) |
| D1 | 212 | 232 |
| D2 | 208 | 224 |
| D3 | 236 | 200 |
| Average | 218 | 219 |

**Table II.** D1, D2, D3 indicate the three individual *Daphnia magna* specimen that were tested. The “basal heart rate column” gives the value in beats per minute of the heart rate of the *Daphnia* before the addition of Caffeine. The “Caffeine Induced Heart Rate” column gives the heart rate of the *Daphnia* after the addition of Caffeine. Averages were taken for both columns to provide general idea of trend.

**Figure II.** **Effect of Caffeine on *Daphnia* Heart Rate.** The heart rate of three *Daphnia magna* specimen (D1, D2, and D3) was measured before and after the addition of Caffeine. For basal heart rate, data shows the mean = 218 bpm and standard deviation of (+/-) 15. For induced heart rate, data shows the mean= 219 and standard deviation = (+/-) 16.

**Table III: Effect of Epinephrine on *Daphnia* Heart Rate**

|  |  |  |
| --- | --- | --- |
|  | Basal Heart Rate (beats/min) | Epinephrine Induced Heart Rate (beats/min) |
| D1 | 220 | 204 |
| D2 | 248 | 12 |
| D3 | 212 | 128 |
| Average | 227 | 115 |

Table III. D1, D2, D3 indicate the three individual *Daphnia magna* specimen that were tested. The “basal heart rate column” gives the value in beats per minute of the heart rate of the *Daphnia* before the addition of Epinephrine. The “Epinephrine Induced Heart Rate” column gives the heart rate of the *Daphnia* after the addition of Epinephrine. Averages were taken for both columns to provide general idea of trend.

**Figure III.** **Effect of Epinephrine on *Daphnia* Heart Rate.** The heart rate of three *Daphnia magna* specimen (D1, D2, and D3) was measured before and after the addition of Epinephrine. For basal heart rate, data shows the mean = 227 bpm and standard deviation of (+/-) 19. For induced heart rate, data shows the mean = 115 and standard deviation = (+/-) 97.

**Figure IV: Effect of Various Drug Solutions on *Daphnia magna* Heart Rate.** The average basal and induced heart rates for the tested specimen are shown across all three drug solution treatments.

**Discussion**

As mentioned above, the purpose of this experiment was to observe cell communication in *Daphnia magna*, by observing the changes in heart rate that occur when nicotine, caffeine, and epinephrine are added. All three drugs were hypothesized to increase the heart rate of the specimen. The experiment demonstrated the effects of ligand binding accurately to an extent, as there were some deviations from the hypothesized results. In the experiment, the addition of nicotine decreased the heart rate of the specimen on average. Though nicotine is expected to increase heart rate, it is possible that it also induced a slower heart rate. This is because nicotine stimulates both the sympathetic and parasympathetic divisions of the nervous system (“Influence”). Thus, nicotine can either increase or decrease heart rate, the latter of which most likely occurred in the experiment. Factors that could have affected nicotine uptake include concentration of nicotine in solution and size of *Daphnia* specimen because they concern how much drug is taken into the body. The addition of Caffeine, an agonist, sped up the heart rate of the Daphnia specimen on average. This result is in accordance with the hypothesis. Epinephrine was predicted to speed up the heart rate of the Daphnia specimen. The experiment, however, showed a decrease in average heart rate upon addition of epinephrine. The deviation of this result from the hypothesized result must have to do with experimental error, most likely from extended observation of *Daphnia* under the microscope, thus causing the organism to overheat. Another source of error could be from an overdose of Detain resin, which could negatively impact the organism.

To reduce error in future experiments, *Daphnia* specimen of about the same size should be chosen for each trial in order to reduce large disparities in basal and induced heart rates. Observation time of organisms under the microscope should be minimized even more to avoid adverse effects on the organism. Specimen should also be given a small amount of detain in order to reduce the possibility of negative effects on the organism. In addition, in order to reduce the possibility of mortality, the specimen should be given an increase amount of time in fresh water to completely clean themselves of Detain resin and regain mobility.

*Daphnia* serve as simple models for cell communication and thus give true insight to the various physiological changes that occur as a result of ligand binding. They demonstrate how one ligand can influence a multitude of cells, causing an observable physiological change. As simple models, they can be used to predict possible signal responses in larger, more complex organisms.

References

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