

The following information applies to all parts.

1. Molecules known as dinucleoside polyphosphates, a type of nucleotide, are signaling molecules that accumulate in plant cells during dry or stressful conditions.

Part A

Describe the three structural components of a nucleotide.

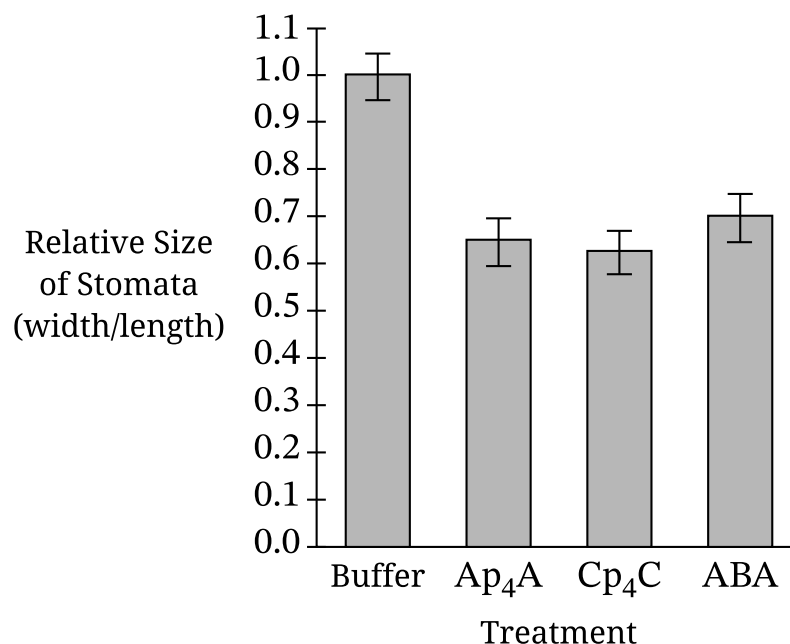
The following information applies to parts B, C, and D.

Stomata are pores on the surface of leaves that open when exposed to light and regulate the flow of carbon dioxide, oxygen, and water vapor in and out of a plant. In response to dry environmental conditions, many plants close their stomata, which reduces water loss.

Scientists hypothesized that the dinucleoside polyphosphates Ap_4A and Cp_4C bind to DORN1 receptors on the plasma membrane of plant cells and initiate signaling cascades that cause stomata to close. The scientists exposed plants to light to open the stomata and then placed samples of the leaves in buffer alone or in buffer containing one of three different compounds: Ap_4A , Cp_4C , or abscisic acid (ABA), a molecule that causes stomata to close.

The scientists measured the size of the stomata in each sample and calculated their sizes relative to the size of the stomata in the sample kept in buffer alone, as shown in Figure 1.

Figure 1. Effect of Ap_4A , Cp_4C , and ABA on Relative Stomatal Size
(Error Bars Represent $\pm \text{SE}_{\bar{x}}$)



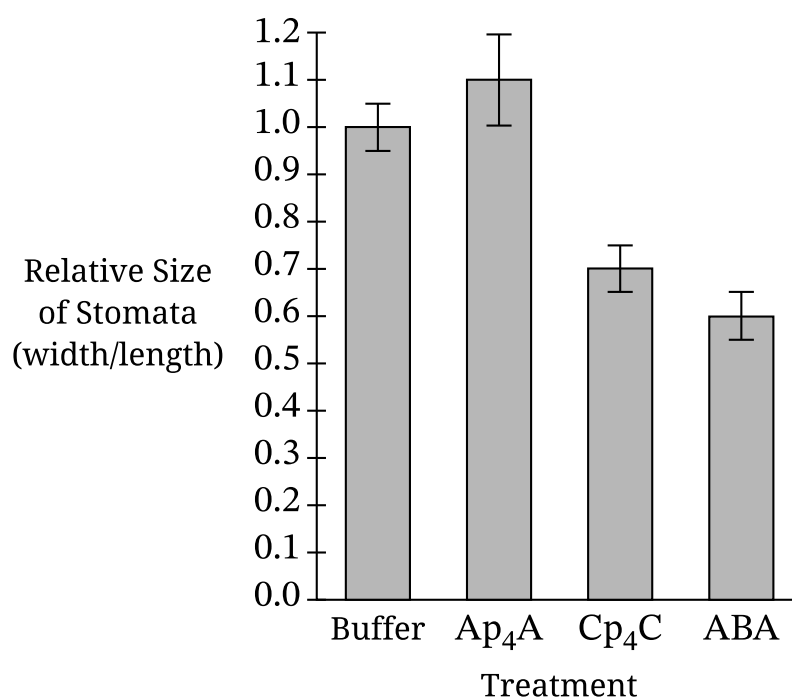
Part B

- i. **Identify** the dependent variable in the scientists' first experiment.
- ii. Based on Figure 1, **describe** the relative size of the stomata in the Cp_4C treatment group as compared with the size of the stomata in the group treated with buffer alone.
- iii. **Justify** the use of buffer alone as a control in the scientists' experiments.

Part C

In a second experiment, the scientists used plants that were identical to those in the first experiment except that the gene encoding the DORN1 receptor was mutated. The scientists repeated the procedure of the first experiment. Their results are shown in Figure 2.

Figure 2. Effect of Ap_4A , Cp_4C , and ABA on Relative Stomatal Size in DORN1 Mutants (Error Bars Represent $\pm \text{SE}_{\bar{x}}$)



- i. **Justify** the scientists' treating one sample of leaves with ABA in the experiments.
- ii. Based on Figure 2, **describe** the difference between the effects of Ap_4A and Cp_4C treatments on the size of stomata in plants with mutated DORN1 receptors.
- iii. Activation of DORN1 receptors induces plant cells to produce certain molecules that cause the stomata to close. Based on the data in Figures 1 and 2 for cells treated with Ap_4A , **predict** the relative production of the molecules by DORN1-mutated cells in comparison to the production by nonmutated cells.

Part D

The DORN1 receptor transmits signals that result in an increase in the transcription of genes involved in plant defenses. The scientists then developed DORN1-mutant plants in which the DORN1 receptor lacked most of its intracellular domain.

- i.

In cells homozygous for this mutation, **predict** the effect of Ap_4A treatment on transcription of the genes involved in plant defenses relative to the effect of Ap_4A on nonmutated cells.
- ii.

Justify your prediction.

2. Many insects rely on pheromones (chemical signals) that are released by the females to find mating partners. Scientists hypothesize that, in a certain type of moth, the behavior of male moths in response to pheromones is regulated by the extracellular signaling molecule 20E.
- A. Many receptors are embedded in the plasma membrane. **Describe** the polarity of the portion of the receptor that is inside the membrane.

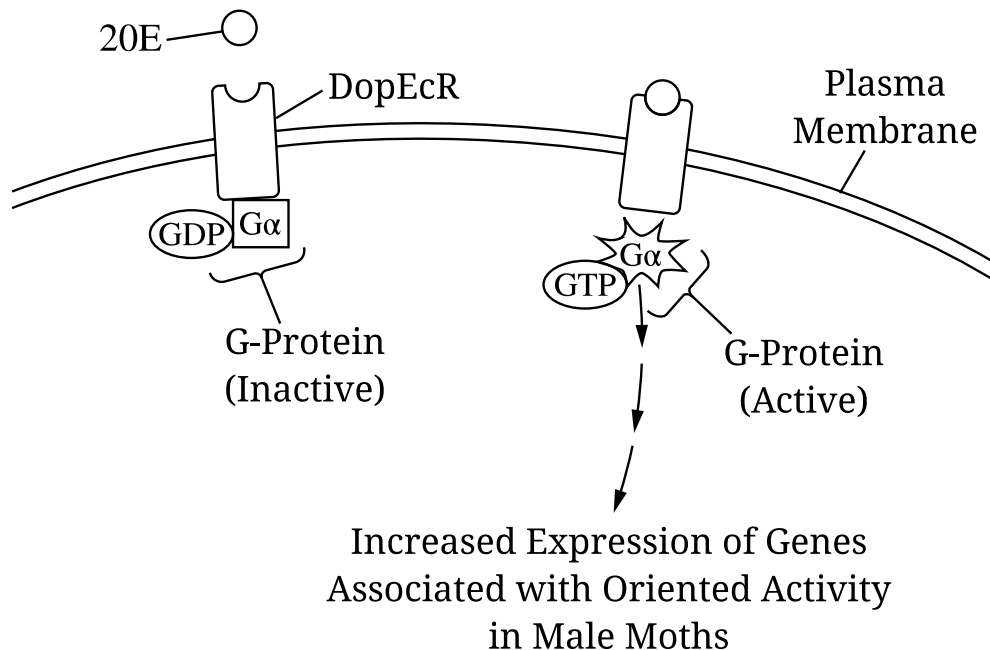
To investigate whether the binding of 20E to its receptor, DopEcR, affects behavior in moths, scientists injected male moths with saline (control solution) or with small interfering RNA molecules (siRNAs) that inhibit the expression of the gene encoding DopEcR. The scientists then exposed the moths to the pheromone and determined the percent of total time observed that the moths engaged in general activity, defined as movement in any direction. The scientists also determined the percent of the general activity time that the moths spent in oriented activity, defined as movement toward an area of high pheromone concentration (Table 1).

Table 1. Average General and Oriented Activity in Male Moths Injected With Saline or siRNA Molecules

Treatment	General Activity (percent of total time observed, average $\pm 2SE_{\bar{x}}$)	Oriented Activity (percent of general activity, average $\pm 2SE_{\bar{x}}$)
Male moths injected with saline (control solution)	95 ± 5	60 ± 4
Male moths injected with siRNAs that inhibit expression of the gene encoding DopEcR	90 ± 8	25 ± 6

DopEcR is a G protein-coupled receptor. When 20E binds to DopEcR, GTP displaces the GDP bound to the G protein, and a signaling pathway is activated. The scientists hypothesize that this leads to the transcription of genes associated with the oriented activity observed in the male moths (Figure 1).

Figure 1. A simplified model of a signaling pathway activated by the binding of 20E to its receptor, DopEcR



B.

- Using the template in the space provided for your response, **construct** an appropriate type of graph that represents the data in Table 1. Your graph should be appropriately plotted and labeled.
- Based on the data in Table 1, **determine** the type of activity that was affected by inhibiting the expression of the DopEcR receptor.

C.

- Based on Table 1, **identify** the treatment group in which the oriented activity was greater than 50% of the general activity.
- The scientists studied some moths with a mutation in the gene encoding the G protein. The mutation prevents GTP from displacing the GDP bound to the G protein. Based on Figure 1, **predict** the effect of this mutation on the oriented activity in male moths exposed to the pheromone.

Expression of the gene encoding DopEcR is low in the male moths during their first few days as adults, when they are sexually immature. Gene expression rapidly increases as the moths reach sexual maturity. The scientists claim that this increase in gene expression increases the likelihood of males finding females with whom to mate.

D.

- Use evidence from the information provided to **support** the scientists' claim.
- Based on Figure 1, **explain** how an inhibitor of the DopEcR pathway might serve as an effective chemical to protect crops from moth damage.

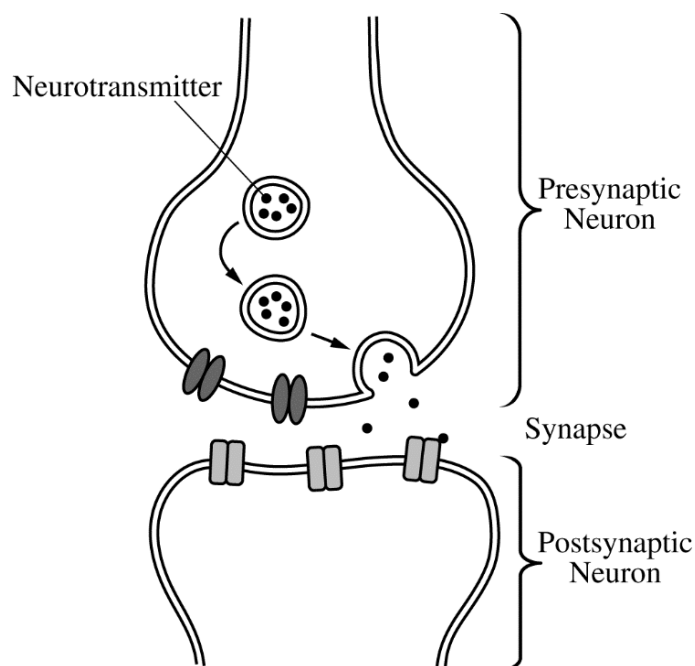


Figure 1. Release of neurotransmitters into the synapse in response to an action potential

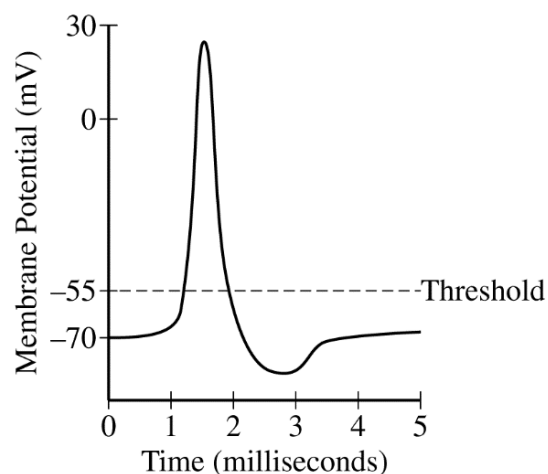


Figure 2. Model of a typical action potential in a neuron

4. Acetylcholine is a neurotransmitter that can activate an action potential in a postsynaptic neuron (Figures 1 and 2). A researcher is investigating the effect of a particular neurotoxin that causes the amount of acetylcholine released from presynaptic neurons to increase.
- (a) **Describe** the immediate effect of the neurotoxin on the number of action potentials in a postsynaptic neuron. **Predict** whether the maximum membrane potential of the postsynaptic neuron will increase, decrease, or stay the same.
- (b) The researcher proposes two models, A and B, for using acetylcholinesterase (AChE), an enzyme that degrades acetylcholine, to prevent the effect of the neurotoxin. In model A, AChE is added to the synapse. In model B, AChE is added to the cytoplasm of the postsynaptic cell. **Predict** the effectiveness of EACH proposed model. **Provide reasoning** to support your predictions.

8. Acetylcholine receptor (AChR) proteins are found at the synapse between neurons and skeletal muscle cells. Acetylcholine released from neurons binds to a specific site on the receptor proteins, which causes an ion channel in the receptors to open and allow sodium ions (Na^+) to enter muscle cells. The resulting depolarization of muscle cells initiates muscle contractions. Another molecule, nicotine, can also bind to certain types of AChR proteins and activate the receptors.

A researcher is investigating two different types of AChR proteins: type 1 and type 2. To determine which stimuli activate the receptors, the researcher exposes muscle cells expressing the different types of receptor proteins to stimuli and observes the results indicated in Table 1.

TABLE 1. RESPONSE OF AChR PROTEINS TO DIFFERENT STIMULI

AChR Protein Type	Acetylcholine	Nicotine
Type 1	+	+
Type 2	+	–

+ indicates activation

– indicates no activation

- (a) **Describe** the difference in the structure AND function between AChR type 1 and AChR type 2.
- (b) Acetylcholinesterase is an enzyme that breaks down acetylcholine in the synapse. **Describe** the effect of inhibiting acetylcholinesterase on the muscle cells with AChR type 2.

STOP

END OF EXAM

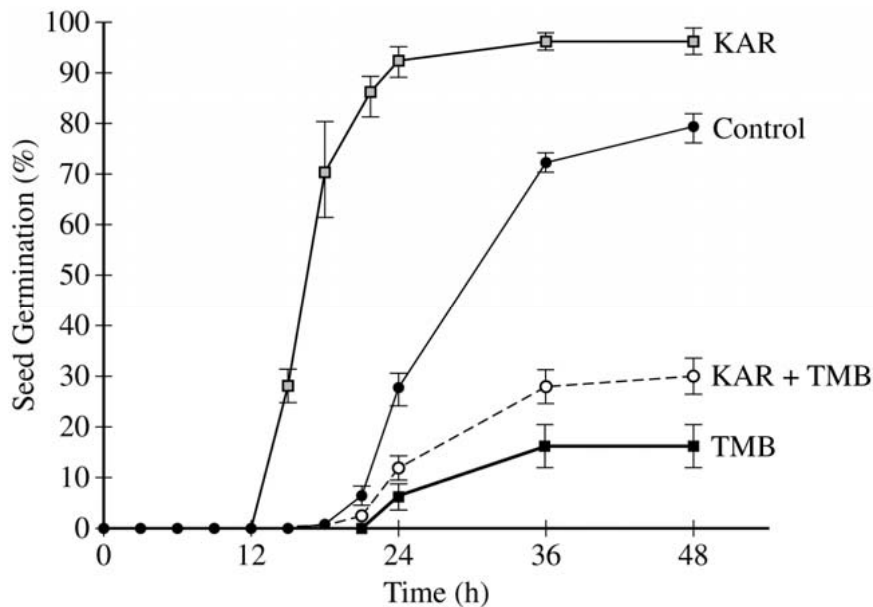


Figure 1. The effect of karrikins (KAR) and trimethylbutenolides (TMB) on seed germination in *Lactuca* plants. Error bars represent $\pm 2SE_{\bar{x}}$.

2. Fires frequently occur in some ecosystems and can destroy all above-ground vegetation. Many species of plants in these ecosystems respond to compounds in smoke that regulate seed germination after a major fire. Karrikins (KAR) and trimethylbutenolides (TMB) are water-soluble compounds found in smoke that are deposited in the soil as a result of a fire. KAR and TMB bind to receptor proteins in a seed. In a study on the effects of smoke on seeds, researchers recorded the timing and percent of seed germination in the presence of various combinations of KAR and TMB. The results are shown in Figure 1.

In a second investigation into the effect of available water on seed germination after a fire, researchers treated seeds with KAR or TMB. The treated seeds were then divided into two treatment groups. One group received a water rinse and the other group received no water rinse. The seeds were then incubated along with a group of control seeds that were not treated. The results are shown in the table.

EFFECT OF CHEMICAL TREATMENT AND WATER RINSE ON GERMINATION

Treatment Group	Chemical Treatment		Water	Germination Result
	KAR	TMB		
1 (control)	–	–	–	Control result
2	+	–	–	Different from control
3	–	+	–	Different from control
4 (control)	–	–	+	Control result
5	+	–	+	Different from control
6	–	+	+	Same as control

- (a) The researchers made the following claims about the effect of KAR and the effect of TMB on seed germination relative to the control treatment.

- KAR alone affects the timing of seed germination.
- KAR alone affects the percentage of seeds that germinate.
- TMB alone affects the timing of seed germination.
- TMB alone affects the percentage of seeds that germinate.

Provide support using data from Figure 1 for each of the researchers' claims.

- (b) **Make a claim** about the effect of rinsing on the binding of KAR to the receptor in the seed and about the effect of rinsing on the binding of TMB to the receptor in the seed. Identify the appropriate treatment groups and results from the table that, when compared with the controls, **provide support** for each claim.
- (c) There is intense competition by plants to successfully colonize areas that have been recently cleared by a fire. **Describe** ONE advantage of KAR regulation and ONE advantage of TMB regulation to plants that live in an ecosystem with regular fires.
8. Estrogens are small hydrophobic lipid hormones that promote cell division and the development of reproductive structures in mammals. Estrogens passively diffuse across the plasma membrane and bind to their receptor proteins in the cytoplasm of target cells.
- (a) **Describe** ONE characteristic of the plasma membrane that allows estrogens to passively cross the membrane.
- (b) In a laboratory experiment, a researcher generates antibodies that bind to purified estrogen receptors extracted from cells. The researcher uses the antibodies in an attempt to treat estrogen-dependent cancers but finds that the treatment is ineffective. **Explain** the ineffectiveness of the antibodies for treating estrogen-dependent cancers.

STOP

END OF EXAM