1. Polycystic kidney disease (PKD) is an inherited disease that causes water loss from the body and affects cell division in the kidneys. Because water movement across cell membranes is related to ion movement, scientists investigated the role of the Na^+/K^+ATPase (also known as the sodium/potassium pump) in this disease. Ouabain, a steroid hormone, binds to the Na^+/K^+ATPase in plasma membranes. Individuals with PKD have a genetic mutation that results in an increased binding of ouabain to the Na^+/K^+ATPase. The scientists treated normal human kidney (NHK) cells and PKD cells with increasing concentrations of ouabain and measured the number of cells (Figure 1) and the activity of the Na^+ / K^+ATPase (Figure 2) after a period of time. The scientists hypothesized that a signal transduction pathway that includes the protein kinases MEK and ERK (Figure 3) may play a role in PKD symptoms.

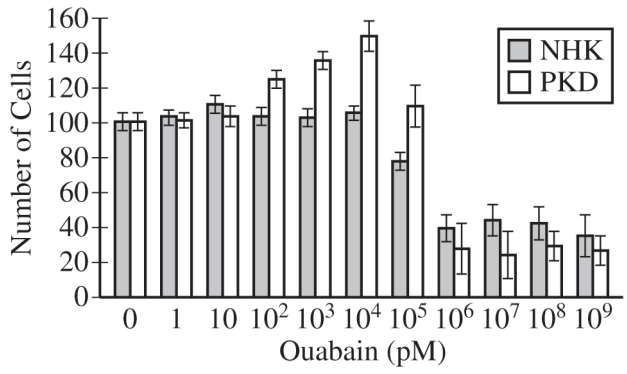

Figure 1. Cell number compared with the number of cells at 0 pM ouabain. Normal human kidney (NHK) cells and polycystic kidney disease (PKD) cells were treated with increasing concentrations of ouabain. Error bars represent $\pm 2SE_{\bar{x}}$.

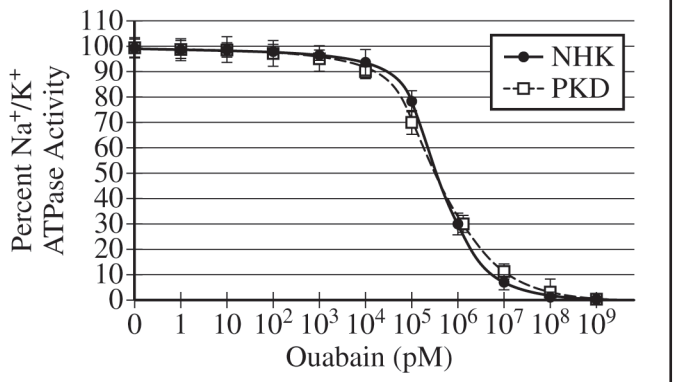

Figure 2. Percent Na^+/K^+ATPase activity of NHK and PKD cells treated with increasing concentrations of ouabain. Error bars represent $\pm 2SE_{\bar{x}}$.

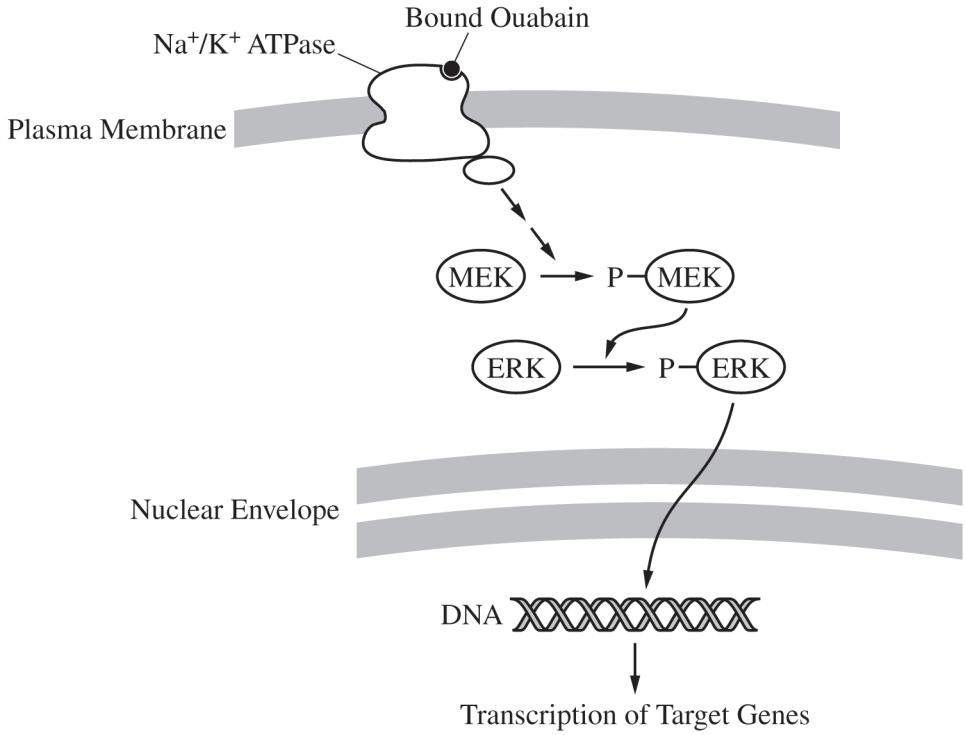

Figure 3. Signal transduction pathway hypothesized to play a role in the increased number of PKD cells

(a) **Describe** the characteristics of the plasma membrane that prevent simple diffusion of Na^+ and K^+ across the membrane. **Explain** why ATP is required for the activity of the Na^+ / K^+ATPase.

(b) **Identify** a dependent variable in the experiment represented in Figure 1. **Justify** the use of normal human kidney (NHK) cells as a control in the experiments. **Justify** the use of a range of ouabain concentrations in the experiment represented in Figure 1.

(c) Based on the data shown in Figure 2, **describe** the relationship between the concentration of ouabain and the Na^+ / K^+ ATPase activity both in normal human kidney (NHK) cells AND in PKD cells. The scientists determined that Na^+ / K^+ATPase activity in PKD cells treated with 1 pM ouabain is 150 units of ATP hydrolyzed/sec. **Calculate** the expected Na^+ / K^+ATPase activity (units/sec) in PKD cells treated with 10^6 pM ouabain.

(d) In a third experiment, the scientists added an inhibitor of phosphorylated MEK (pMEK) to the PKD cells exposed to 10^4 pM ouabain. Based on Figure 3, **predict** the change in the relative ratio of ERK to pERK in ouabain-treated PKD cells with the inhibitor compared with ouabain-treated PKD cells without the inhibitor. Provide reasoning to **justify** your prediction. Using the data in Figure 1 AND the signal transduction pathway represented in Figure 3, **explain** how the concentration of cyclin proteins may increase in PKD cells treated with 10^4 pM ouabain.

Write your responses to this question only on the designated pages in the separate Free Response booklet.

GO ON TO THE NEXT PAGE.

(a) **Describe** a cause of logistic growth of the ragweed population.

(b) Based on the representation in Figure 1, **explain** why the scientists claim that plot B would be more resilient than plot A in response to a sudden environmental change.

(c) In a third group of plots, the researchers removed all seedlings of all plants that germinated before June 1. All plants that germinated after June 1 were left untouched. Using the template in the space provided for your response and the symbols shown in Figure 1, **represent** the expected plant species that would be found in this third group of plots three months later. Draw no more than 12 symbols. Assume all other environmental conditions are the same as for the initial study described.

(d) **Explain** how an invasive species such as ragweed affects ecosystem biodiversity, as illustrated in Figure 1.

Write your responses to this question only on the designated pages in the separate Free Response booklet.

GO ON TO THE NEXT PAGE.

(a)

Describe the characteristics of the plasma membrane that prevent simple diffusion of Na^+ and K^+ across the membrane. **1 point**

Accept one of the following:

- The interior of the plasma membrane is hydrophobic/nonpolar.
- The phospholipid tails are hydrophobic/nonpolar.
- The exterior of the plasma membrane is hydrophilic/polar.
- The phospholipid heads are hydrophilic/polar.

Explain why ATP is required for the activity of the Na^+/K^+ ATPase. **1 point**

- The Na^+/K^+ ATPase pumps ions against their concentration gradients. This requires an input of (metabolic) energy.

Total for part (a) 2 points

(b)

Identify a dependent variable in the experiment represented in Figure 1. **1 point**

- The number of cells

Justify the use of normal human kidney NHK cells as a control in the experiments. **1 point**

Accept one of the following:

- It allows the scientists to determine the effect of PKD on the cells' responses to (various concentrations of) ouabain.
- It allows the scientists to compare the responses of PKD cells and normal cells (to ouabain).

Justify the use of a range of ouabain concentrations in the experiment represented in Figure 1. **1 point**

Accept one of the following:

- The scientists need to determine whether different concentrations have different effects on the cell numbers.
- The scientists did not know at which concentration of ouabain there would be an effect.

Total for part (b) 3 points

(c)

Based on the data shown in Figure 2, **describe** the relationship between the concentration of ouabain and the Na^+/K^+ ATPase activity both in normal human kidney (NHK) cells AND in PKD cells. **1 point**

Accept one of the following:

- Increasing concentrations of ouabain result in decreasing ATPase activity (in both types of cells).
- There is an inverse relationship/negative correlation between the concentration of ouabain and the ATPase activity (in both types of cells).

The scientists determined that Na^+/K^+ ATPase activity in PKD cells treated with 1 pM ouabain is 150 units of ATP hydrolyzed/sec. **Calculate** the expected Na^+/K^+ ATPase activity (units/sec) in PKD cells treated with 10^6 pM ouabain. **1 point**

- 45 (Accept between 40 and 50)

Total for part (c) 2 points

(d) In a third experiment, the scientists added an inhibitor of phosphorylated MEK (pMEK) to the PKD cells exposed to 10^4 pM ouabain. Based on Figure 3, **predict** the change in the relative ratio of ERK to pERK in ouabain-treated PKD cells with the inhibitor compared with ouabain-treated PKD cells without the inhibitor. **1 point**

Accept one of the following:

- Option 1: The ratio of ERK to pERK will increase in the cells with the inhibitor.
- Option 2: The ratio of ERK to pERK will stay the same in the cells with the inhibitor.

Provide reasoning to **justify** your prediction. **1 point**

- The justification must indicate that the pMEK inhibitor blocks further phosphorylation of ERK AND one of the following:

Option 1:

- The amount of pERK will not increase as it does in cells without the inhibitor.
- The amount of ERK will not decrease as it does in cells without the inhibitor.
- The cell continues to synthesize ERK.
- Phosphorylated ERK is being dephosphorylated to ERK.

Option 2:

- No additional ERK is synthesized/pERK is not being dephosphorylated.

Using the data in Figure 1 AND the signal transduction pathway represented in Figure 3, **explain** why the concentration of cyclin proteins may increase in PKD cells treated with 10^4 pM ouabain. **1 point**

- The cell number increases to a maximum at 10^4 pM ouabain. The signaling pathway stimulates transcription of genes involved in cell division. The target genes likely include those for cyclins because cyclins regulate the cell cycle.

Total for part (d) 3 points

Total for question 1 10 points