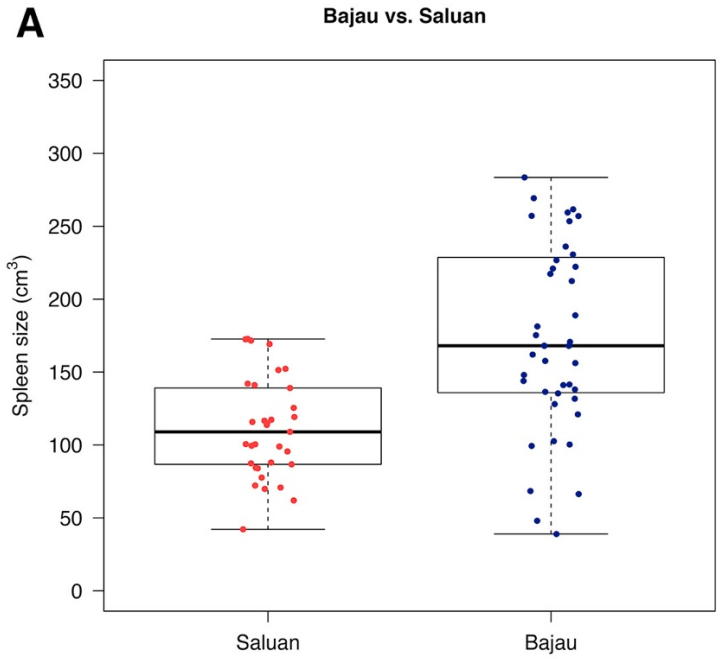
HOW TO USE THIS RESOURCE

Show the following figure and caption to your students. The accompanying Student Handout provides space below the image caption for Observations, Notes, and Questions and space next to the "Background Information" for Big Ideas, Notes, and Questions. The "Interpreting the Graph" and "Discussion Questions" sections provide additional information and suggested questions that you can use to prompt student thinking, increase engagement, or guide a class discussion about the characteristics of the graph and what it shows.



Caption: *Distributions of spleen sizes in two Southeast Asian populations: the Saluan and the Bajau (Sea Nomads). The red dots on the left represent 33 Saluan individuals, and the blue dots on the right represent 43 Bajau individuals. The thick black horizontal lines inside the boxes indicate the medians. The bottom and top sides of the boxes indicate the 25th and 75th percentiles, respectively.*

BACKGROUND INFORMATION

Over the course of evolutionary time, humans have established populations in a variety of extreme environments, including mountains, deserts, and polar regions. The conditions in these environments may lead to natural selection for certain traits. One example of natural selection in humans may come from the Bajau people of Southeast Asia, who are sometimes called Sea Nomads. For over 1,000 years, the Bajau have lived off the seas, traditionally gathering food and other resources through freediving (diving that requires holding your breath underwater instead of using an oxygen tank). Bajau freedivers spend 60% of their working time underwater and may dive as deep as 230 feet.

In this study, scientists investigated whether the Bajau's freediving abilities are due partly to selection for certain genetic adaptations or are due solely to practice and training within the Bajau culture. The scientists compared the Bajau population to a nearby population, the Saluan, who do not traditionally do freediving. They measured the spleen sizes of individuals in both of these populations using an ultrasound machine.

The scientists were interested in spleen sizes because of the spleen's role during diving in mammals. All mammals have a spleen, which is an organ that normally stores a reserve of red blood cells. When many mammals (including humans) dive, their spleens contract and release the stored red blood cells into the circulatory system. These cells are rich in oxygen, which may help the mammals hold their breath and stay underwater longer. In a population of diving seals, for example, scientists found that the seals with the largest spleens could dive the longest. Before this study, however, it was not clear whether larger spleens could help humans dive longer too.

INTERPRETING THE GRAPH

The figure is a boxplot, also known as a box-and-whisker plot, which provides a useful way of comparing distributions of data among multiple groups. (In particular, a boxplot does not require that the data are normally distributed, which is an assumption for using standard deviation or standard error.) In this figure, the plots represent key values in the data sets as follows:

- The **minimum** is represented by the lowest tip of the whisker (horizontal line below the box).
- The **maximum** is represented by the highest tip of the whisker (horizontal line above the box).
- The **median** (value below which 50% of the data fall) is represented by the thick black horizontal line inside the box.
- The **25th percentile** (value below which 25% of the data fall) is represented by the bottom of the box.
- The **75th percentile** (value below which 75% of the data fall) is represented by the top of the box. The box therefore contains the middle 50% of the data points.

In general, the figure shows that the Bajau individuals (Sea Nomads) have larger spleens than the Saluan individuals do. For example, over 75% of the Saluan individuals have spleen sizes below the median spleen size of the Bajau. The median spleen size of the Saluan is also less than that of the Bajau. The scientists used a type of *t*-test to show that the difference in the populations' means is statistically significant. They found that the difference remains significant even after accounting for other factors (such as gender, age, weight, height, and whether the individuals practiced freediving) through additional statistical analyses. The scientists also found that the spleen size difference between Bajau divers and Bajau nondivers is *not* statistically significant. In other words, Bajau nondivers generally still have larger spleens even though they do not do freediving themselves.

Overall, these results suggest that there is a significant anatomical difference in size (volume) between the spleens of the Bajau and the Saluan, one that cannot be explained by freediving practice alone. Based on this and related research, the scientists hypothesized that the Bajau have evolved over time to have larger spleens as an adaptation for freediving. A larger spleen would likely be advantageous for freediving because it can store more red blood cells, which boost oxygen availability when the spleen contracts during diving.

By performing genetic analyses on the individuals in the study, the scientists also discovered that the larger spleens of the Bajau are associated with a specific mutation. Namely, there is a strong positive correlation between spleen size and a SNP near a gene called *PDE10A*. *PDE10A* plays a role in signal transduction, including the regulation of thyroid hormone levels. Because the thyroid affects the production of red blood cells during development, the scientists hypothesized that the Bajau have an allele of *PDE10A* that results in the production of more red blood cells and therefore a larger spleen.

Teacher Tip: Prompt your students to explain the parts of the graph as applicable:

- Graph type: Boxplot, also known as a box-and-whisker plot
- *X*-axis: Population, Saluan or Bajau (Sea Nomads)
- *Y*-axis: Spleen size or volume (cm^3), calculated from ultrasound measurements

- Other key characteristics of the boxplots are summarized in the "Interpreting the Graph" section above. Outliers are not shown.

DISCUSSION QUESTIONS

- Compare the data points in red to the data points in blue. What do you observe about their similarities and/or differences?
- What do the rectangular boxes represent? Why is the box on the left shorter than the box on the right?
- What do the whiskers above and below the boxes represent? Why are the whiskers on the left shorter than the whiskers on the right?
- What do the thick black horizontal lines inside the boxes represent? How does the line in the first box compare with the line in the second box?
- How do the spleen sizes of the Bajau and the Saluan differ? Use data from the figure to support your response.
- How do the *ranges* of spleen sizes for the Bajau and the Saluan differ? Use data from the figure to support your response. Why do you think these ranges differ in the way you described?
- What selective pressures in the environment may have led to the patterns that you see in the figure?
- Does the figure provide any data that supports the hypothesis that large spleen size is a genetic adaptation? If so, describe that data. If not, what other data would be needed to support this hypothesis?
- How might a larger spleen provide a selective advantage for the Bajau? In what other environments might a larger spleen provide a selective advantage?
- In addition to a larger spleen, what other physiological adaptations might the Bajau have evolved in order to survive in their environment?
- Can you think of other situations besides diving in which scientists would want to study responses to low oxygen levels? How might this research be applied to other fields, such as medical science?
- Can you think of any other adaptations to extreme environments found in humans or other animals? How do those adaptations compare to the adaptation being studied here?

KEY TERMS

adaptation, box-and-whisker plot, boxplot, diving reflex, diving response, hypoxia, oxygen, red blood cell, spleen, thyroid hormone

SOURCE

Figure 1a from:

Ilardo, Melissa A., Ida Moltke, Thorfinn S. Korneliussen, Jade Cheng, Aaron J. Stern, Fernando Racimo, Peter de Barros Damgaard, *et al*. "Physiological and Genetic Adaptations to Diving in Sea Nomads." *Cell* 173, 3 (2018): 569–580. https://doi.org/10.1016/j.cell.2018.03.054.

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