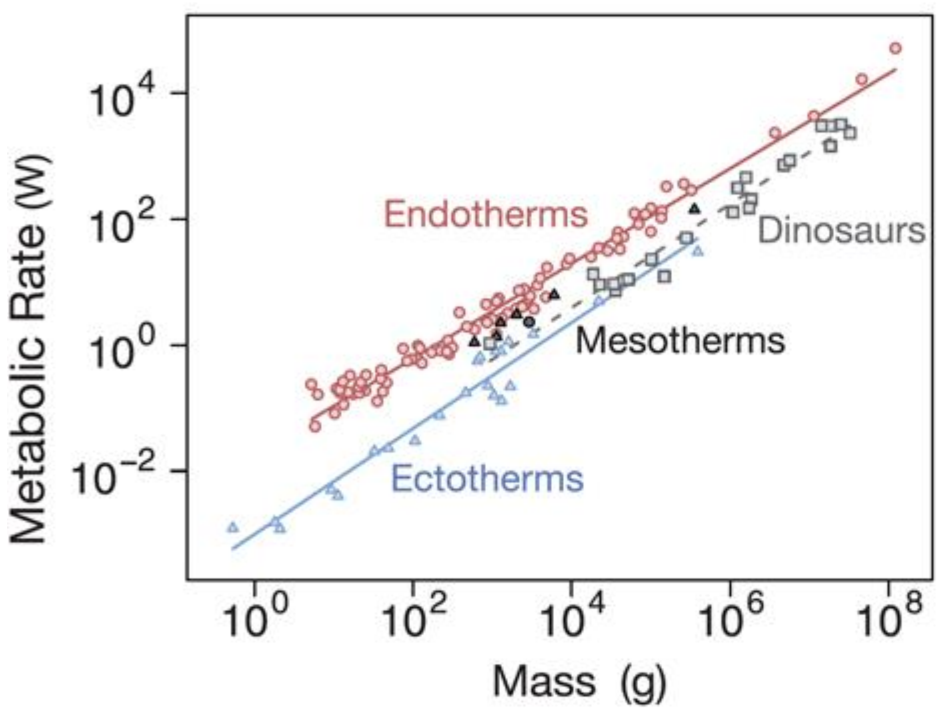
HOW TO USE THIS RESOURCE

Show the figure below to your students along with the caption and background information. The "Interpreting the Graph" and "Discussion Questions" sections provide additional information and suggested questions that you can use to guide a class discussion about the characteristics of the graph and what it shows.



Caption: Resting metabolic rates (in watts) of 381 living vertebrate species and 21 extinct dinosaur species plotted against their body masses (in grams). Endotherms are red, mesotherms are black, ectotherms are blue, and dinosaurs are gray. Regression lines through the points show the best fit between body mass and metabolic rate for endotherms, ectotherms, and dinosaurs, but not for mesotherms.

BACKGROUND INFORMATION

Most animals are able to thermoregulate, or regulate their internal body temperature, in order to survive temperature changes in the environment. Thermoregulation strategies range from ectothermy ("cold-blooded") to endothermy ("warm-blooded"). Ectotherms can tolerate a range of body temperatures, but they regulate their body temperature to avoid extremes by using behavioral strategies like basking in the sun. Endotherms, such as birds and mammals, generate internal heat from their metabolism to maintain a constant body temperature. Mesotherms—a relatively small group of animals that includes leatherback turtles, bluefin tuna, and great white sharks—use their metabolism to raise or lower their body temperature above or below that of their environment, but they do not maintain a constant body temperature. Metabolic rates also drive growth rates, so endotherms tend to grow faster than ectotherms. So where do dinosaurs fit?

Dinosaurs were once thought to be slow-growing ectotherms: lumbering animals with slow metabolisms similar to modern reptiles. But evidence from growth rings in fossil bones suggests that their growth rates were quite high and more closely matched those of endotherms. To shed more light on the type of thermoregulation that dinosaurs used—ectothermy, endothermy, or mesothermy—John Grady and colleagues compared fossil evidence with growth and metabolic rates of 381 living animal species. Because metabolic rate can vary with outside temperature, they selected only species that live in warm environments with temperatures similar to those in the Mesozoic Era. Determining the metabolic rates in extinct species, however, is not that easy. First, they used growth rings and the dimensions of fossil dinosaur bones to estimate growth rate and body mass (respectively) of 21 species of extinct dinosaurs. Then, using the correlation between growth rate and metabolic rate across clades of living species, they predicted the dinosaurs' metabolic rates. This study provides important evidence for mesothermy in dinosaurs, but additional lines of evidence will be critical as scientists continue to test the mesothermy hypothesis.

INTERPRETING THE GRAPH

Figure 3B shows the correlation between observed body mass and resting metabolic rate for 381 living species with three different thermoregulatory strategies: endothermy (red), ectothermy (blue), and mesothermy (black). The solid red and blue lines show similar positive correlations between body mass and metabolic rates for endotherms and ectotherms. The red line is higher than the blue line, meaning that for a given body mass, endotherms have a higher metabolic rate than ectotherms. The black shapes fall between endotherms and ectotherms, showing that their metabolic rates fall between those of endotherms and ectotherms for a given body mass. The gray squares show the estimated body mass and predicted metabolic rates of 21 species of dinosaurs. The dashed gray line shows the correlation between these two variables, which most closely matches that of mesotherms. Note that both mass and metabolic rates are plotted using a logarithmic scale, which allows for comparison of straight regression lines.

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

- Graph Type: Scatter plot with lines of best fit
- *X*-axis: Body mass in grams on a logarithmic scale. For dinosaurs, body mass was estimated using dimensions of fossil bones.
- *Y*-axis: Resting metabolic rate in watts on a logarithmic scale. For dinosaurs, metabolic rate was predicted using an estimated correlation between growth rate and metabolic rate.

DISCUSSION QUESTIONS

- What does this graph tell you about the relationship between body mass and metabolic rate in general?
- How does metabolic rate differ between endotherms, mesotherms, and ectotherms of the same body size? Justify your answer using evidence from the graph.
- How did researchers determine the body mass of dinosaurs?
- How did researchers predict the metabolic rates of dinosaurs?
- Why did researchers have to compile and analyze data for living species to help them determine the metabolic strategy of dinosaurs?
- Based on this data, are dinosaurs closest to endotherms, ectotherms, or mesotherms? Provide evidence to support your claim.
- Why is it necessary to show metabolic rate in relation to body size and not just metabolic rate?
- Why was it necessary for researchers to control for external temperature when selecting living organisms to compare with dinosaurs?
- For a given body mass, which requires more food, endotherms or ectotherms? Why?
- What are the advantages and disadvantages of being an endotherm versus an ectotherm?
- What does the thermoregulatory strategy of dinosaurs tell us about the way they lived?

SOURCE

Figure 3B from:

Grady, J. M., Enquist, B. J., Dettweiler-Robinson, E., Wright, N. A., and Smith, F. A. Evidence for mesothermy in dinosaurs. *Science*. 2014. 344: 1268-72.

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