PART 3

How does a blue whale feed?

By Polly Shulman

All animals have to eat. But few do it as dramatically as rorquals. Their dining strategy—lunge feeding—is unique to rorquals. In fact, it's what makes a rorqual a rorqual.

Lunge feeding is one type of filter feeding. Baleen whales use several kinds of filter feeding. Some non-rorquals, such as right whales and bowheads, use a feeding method called "continuous ram filtration." They swim through areas with a lot of prey areas with their mouths partly open, taking in food and water. The movement rams the water through a complex arrangement of lip features and baleen (**Fig. 1**). Then the water shoots out through jetport-like openings at the corners of their mouths just beneath their eyes. Food gets caught on their baleen.

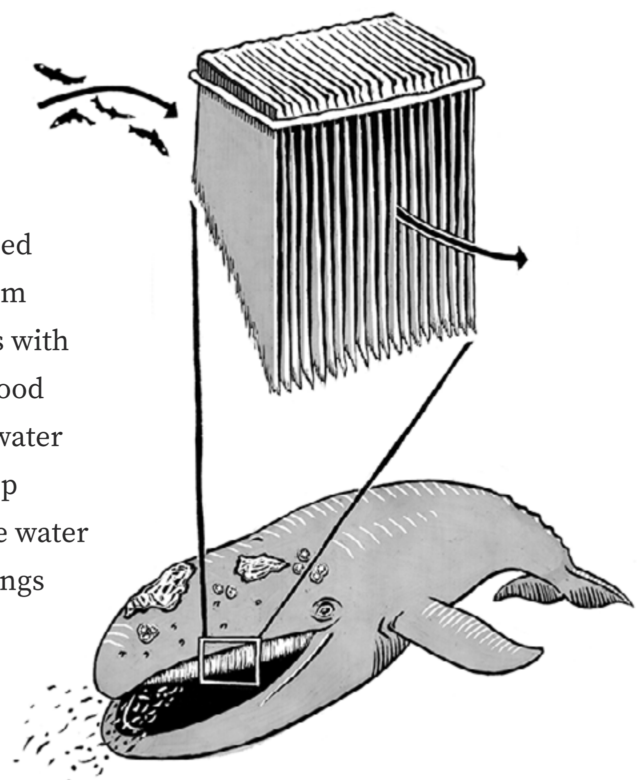

Figure 1: Gotcha! When baleen whales feed, water flows out through the spaces in between the baleen plates. But food like fishes and krill is too big to get through. It gets caught on one side of the baleen. Illustration by Alex Boersma

Rorquals can't do that because they're too big. They would not be able to keep their vast bodies fed in the areas where right whales forage. The food there is too spread out for rorquals. Instead, rorquals seek out patches where the prey animals are even more densely crowded together. They take a mouthful only when they've found a very big, very dense prey patch.

Rorquals' jaw anatomy helps them take a big gulp. Unlike ours, their lower jaws detach into two pieces. Feel the point of your chin? Rorquals have a gap in the bone there. When the whale opens its mouth to feed, the two halves pivot apart (**Fig. 2**). The pivoting motion makes the expanded pouch even bigger.

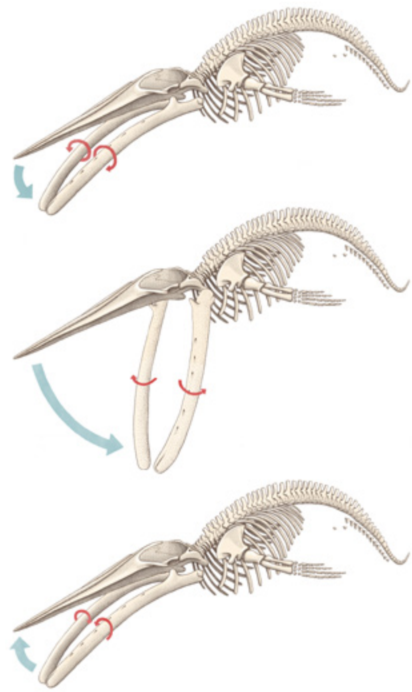

Figure 2. Pivoting jawbones.
As a rorqual opens its mouth, the two halves of its lower jaw separate slightly and pivot open. As it closes its mouth, the two halves pivot shut again. Illustration by Alex Boersma

Rorquals' lunge feeding has three phases: acceleration, engulfment, and filtering (**Fig. 3**). During the acceleration phase, the whale speeds up. It has to go fast enough for the water pressure to push its throat pouch open. Its typical speed is 1 to 2 meter per second (2.2 mph to 4.5 mph). It can accelerate to reach speeds of up to three or four meters per second (about 9 miles per hour). Next comes the engulfment phase. It lasts about five seconds. That's when the whale closes its mouth on a gigantic gulp of prey-filled water. Then comes the filtering phase. The whale must expel the water. It uses its baleen to retain the prey. During the feeding season, the whale repeats these three phases hundreds of times a day.

When it opens its mouth, the whale takes in a huge amount of water. It gulps up to 140 percent of its own weight! (This means a whale that weighs 200,000 pounds can gulp up to 280,000 pounds of water!) Adding the mass of the water to its own body mass slows the whale down. So does the change in the whale's shape. Usually the whale is streamlined. But the swollen pouch alters the flow of water around the whale's body. "Remember that these whales are very hydrodynamic," says marine biologist David Cade. "They're shaped like torpedoes going through the

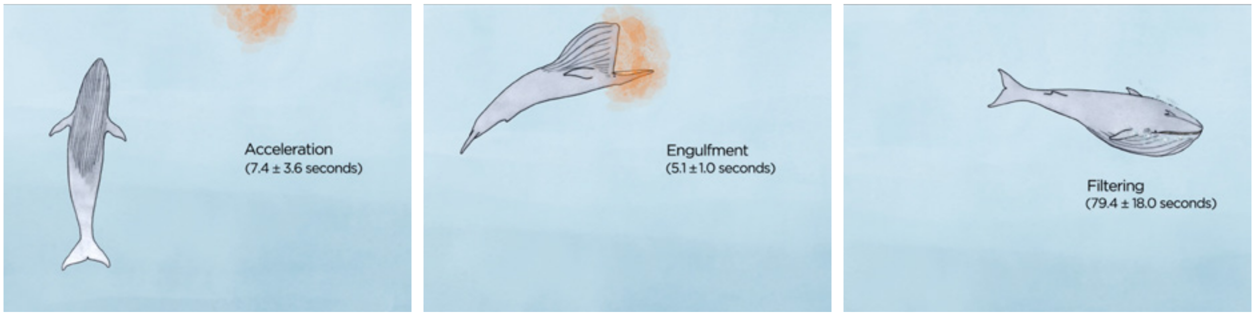

Figure 3. Lunge feeding. These images show a blue whale's movements as it performs the acceleration, engulfment, and filtering phases of its lunge. Illustration by

water. So they can go really fast with minimal drag. But as soon as they open their mouth and start inflating like a parachute, that's going to slow them way down. It's going to take a lot of energy to push against that."

And remember: the whales are performing these energetic acrobatics while holding their breath. They typically go 15 minutes at a time without breathing while they feed. "They're mammals, just like us," says Cade. "We need air to breathe. They need air to breathe. They can't get air from the water like a fish, so they have to return to the surface every so often. But the food is down deep."

When a blue whale dives for food, it needs to maximize its time feeding. Each visit to the surface comes with a cost in time, energy, and effort, explains Cade. The fewer times the whales have to return to the surface, the better. And the more they can get done on each dive, the better.

To feed efficiently, blue whales have to time each lunge carefully to take in as much krill as possible. Some other rorquals, such as humpback whales, are generalist feeders. They have lots of food choices. They don't prey only on slow-moving krill. They also prey on fishes like sardines and anchovies, which can swim away. These generalist whales have to gulp their prey suddenly before the prey can escape. But blue whales are specialist feeders. They eat only krill, which don't maneuver well. When blue whales go after krill, they're not worrying about catching animals that are trying to escape. Instead, they're trying to make sure they capture enough food to make their lunges worthwhile. If blue whales open their mouths too soon, they may engulf too much krill-poor water. That would waste energy on a skimpy mouthful. If they open them too late, they may miss part of the dense krill patch. They have to get the timing just right.

The value of efficiency

Feeding efficiently is extremely important to blue whales. That's because they have such high energy needs and eat only krill. It all comes back to how they got to be so big. "If you're a very large animal, you have a lot of body mass that you have to maintain," says marine biologist Jeremy Goldbogen. "That requires a lot of energy, so you have to be very efficient in how you feed. We think lunge feeding is the key to why we see blue whales as the largest animals of all time."

Krill "is only available on a very, very short time scale in the summer months," says Goldbogen. "When the patches get dense and abundant in the summer months, [blue whales] have to be incredibly efficient to make the most out of a very short feeding season."

Lunge feeding behavior has extremely high energetic costs—maybe the highest of any behavior on Earth! A blue whale must constantly weigh the cost and benefit of this movement. As the Goldbogen team gathered data on whales' behavior underwater, they had many questions. How do the whales vary their speed while diving down, feeding, and returning to the surface? Do they swim at top speed when traveling through a prey patch? How about during the descent? At which point during the feeding process do they open and close their enormous mouths?

The data showed that blue whales feeding on krill followed a distinct pattern of activity. They opened their mouths at top speed. Then they closed their mouths around the time they had lost enough momentum to return to normal speed. The researchers tested different computer models of feeding for blue whales. They found that this pattern gained the whales the most food for the energy they spent. It was the most efficient.

The data

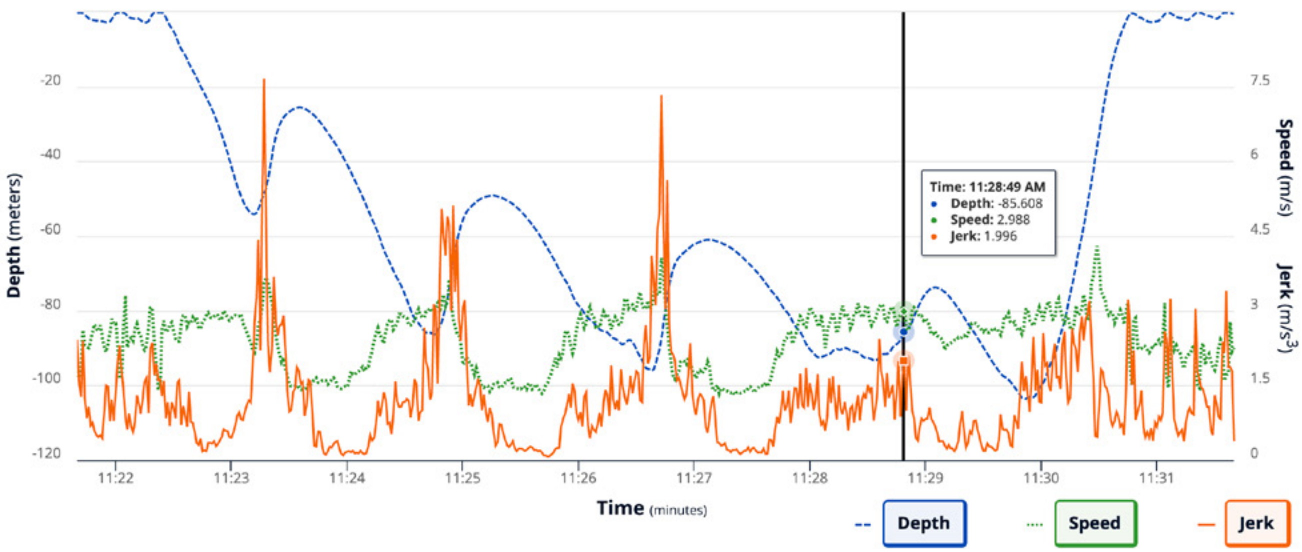

Figure 4. Data gathered from a tagged whale.

This graph (**Fig. 4**) shows data gathered from a tagged whale. The horizontal (x-axis) represents time. The vertical (y-axis) has different units depending on which of three variables (depth, speed, and jerk) is being considered. Because the three lines share the same x-axis, the graph shows how these three characteristics of the whale's motion and position change together over time.

The **dashed blue line** represents depth, which is how far below the ocean's surface the blue whale dove. Pressure increases the farther you descend into the ocean. Depth is measured by the tag's pressure sensor. The greater the water pressure, the greater the depth. Depth is given in meters.

The **dotted green line** represents speed, measured in meters per second (m/s). The researchers can't measure speed directly underwater, because that would require knowing the whale's exact position. But GPS doesn't work underwater. So they measure noise instead. The more noise, the faster the whale is going. "Imagine sticking your head out the window of a car and the wind's rushing by you. It gets louder as the car goes faster, and the dog's tongue is wagging a lot faster," says Cade. Similarly, the noise of the hydrophone and the shaking of the tag itself stand in for the whale's speed. Notice the longish periods when the whale is maintaining a constant speed. Cade calls this gliding. Also notice the brief periods when the whale speeds up and slows down.

The **solid orange line** represents jerk. (Yes, this is a real scientific term!) Cade describes jerk as "a measure of how much that animal is moving around at different times." Technically, jerk is the rate of change of acceleration. It is given in meters per second cubed (m/s^3).

Stop and Think

1. Review the single-dive data interactive. Can you spot the feeding behaviors that Dave Cade discussed?

2. Are there any new observations you were able to make? Describe them.