

Creature Lab: How Far Can a Body Bend?

Ages 9-14 · about 45 minutes, in one sitting

Your child watches a fish, a snake and a lizard swim in tight circles and finds out why the fish is the only one that cannot close its ring. Under the skin each body is a chain of joints, and each joint can bend only so far, so the bends add up like angles. By the end your child has changed the fish until it curls all the way around.

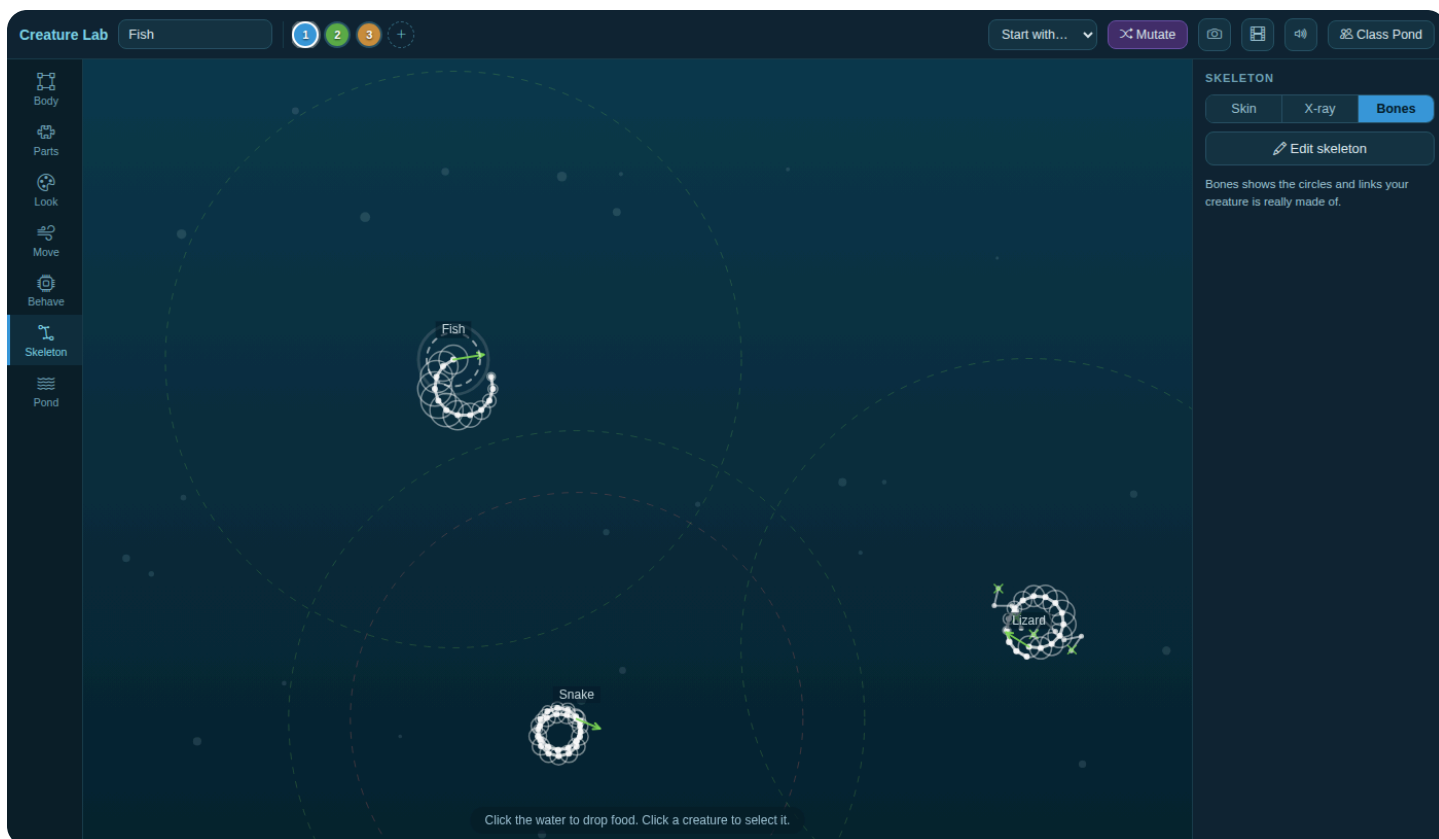
What you need

- A computer or Chromebook with a current browser.
- The lesson link: mytekdev.com/try/creaturelab?lesson=how-far-can-a-body-bend&ref=fam-creaturelab-1. No account, no email and nothing to install.
- Optional: the activity sheet at the end of this plan, printed, and a pencil. It has the table of degrees for the Flexibility slider.

Before you start: try it once yourself

Close the fish's ring yourself once before you start, about ten minutes.

1. **Open the lesson.** Go to mytekdev.com/try/creaturelab?lesson=how-far-can-a-body-bend&ref=fam-creaturelab-1.
 1. A fish, a snake and a lizard swim in tight circles. The selected creature's name is in the box at the top left, next to the numbers 1, 2 and 3; the fish is 1.
2. **Look under the skin.** Open **Skeleton** in the rail on the left and pick **Bones**. The snake's chain coils inside itself, the lizard's just closes, and the fish's stays a C.
3. **Make it floppier.** With the fish selected, open **Body** and drag **Flexibility** to about seven tenths of the way along. The view stays on Bones, and the fish's chain now closes into a ring.
4. **Try length instead.** Drag **Flexibility** back to two fifths of the way along, where it started. Then drag **Length** right a little at a time, counting the dots, until there are 16. The ring closes again.



Bones view with the starter: only the fish cannot close its ring.

If you see something else: if `Length` and the width sliders are missing from Body, `Edit skeleton` was pressed, which swaps the sliders for a hand-built skeleton; press `Reset to sliders`. Body changes only the selected creature, so check the name box says Fish. Clicking the water drops food; clicking a creature selects it.

The ideas, in plain words

Each creature's body is a chain of joints. The head goes where the brain steers it, and every joint behind it follows one simple rule: stay the same distance behind the joint ahead. Nobody animates the tail; it falls into place because the rule repeats down the whole chain. Game and animation programmers use this same follow-the-leader trick for snakes, tentacles and ropes.

Each joint can also bend only so far from the line of the joint ahead, and the Flexibility slider sets that limit, from about 13 to about 42 degrees. Bends between joints add up, so the whole body can curl at most the number of bends times the limit. A full circle is 360 degrees. A body with too little total bend makes a C however hard it turns. A long body can close a ring even when each joint is stiff, because many small bends add up: that is how a real snake, with more than 200 vertebrae, coils.

YOUR CHILD MIGHT ASK

A GOOD ANSWER

Why not just tell the fish to turn harder?

Its brain already turns as hard as the app allows. What stops the ring is the body: how far each joint can bend, times how many bends there are.

YOUR CHILD MIGHT ASK	A GOOD ANSWER
Why 11 bends and not 12?	A bend is the gap between two joints. Twelve dots have eleven gaps.
Why does the snake overlap itself?	Its bends add up to about two full circles, more than one ring needs, so it wraps around on itself.
Is the worksheet's total exact?	Close, not exact. The degrees on the worksheet are rounded, and the app measures the fish at 269 degrees, against 264 on paper.

Do it together

1. Open mytekdev.com/try/creaturelab?lesson=how-far-can-a-body-bend&ref=fam-creaturelab-1 together. A fish, a snake and a lizard swim in tight circles, each one curving as hard as it can. A short guide runs along the bottom; follow it together. It opens **Skeleton** in the rail on the left and picks **Bones**.

You'll know it worked when: Each creature is a chain of dots: the snake's coils inside itself, the lizard's just closes, and the fish's stays a C.

2. Ask: all three swim in a tight circle, so why can't the fish make a ring? Then say the rule together: every dot follows the dot ahead and stays the same distance behind it. Nobody animates the tail; the rule, repeated down the chain, moves the whole body.

You'll know it worked when: Your child can say the rule in their own words: follow the dot ahead and stay the same distance behind it.

3. Each joint can bend only so far. Open **Body** and find **Flexibility**: it runs from about 13 degrees per joint at the left to about 42 at the right. Work the fish together: 12 joints make 11 bends, each about 24 degrees, and $11 \times 24 = 264$ degrees.

If you get stuck: If the answer is $12 \times 24 = 288$, the joints were counted instead of the bends. The bends are the gaps between the dots, so there is one fewer bend than joints.

You'll know it worked when: Your child says 264 is less than the 360 degrees of a full circle, so the fish cannot close a ring however hard it turns.

4. Now predict before looking. The snake has 26 joints at about 29 degrees, and the lizard 16 joints at about 26. Your child works out each total and writes yes or no for a full ring, then checks in **Bones**.

You'll know it worked when: The snake's $25 \times 29 = 725$ is about two circles, so it wraps around on itself. The lizard's $15 \times 26 = 390$ is just over one, so it just closes its ring.

5. Close the fish's ring. Select the fish (click it, or the 1 at the top), open **Body** and change one slider at a time: **Flexibility** to the right, or **Length** for more joints. After each change, count the dots in Bones, work out the new total, and check it.

If you get stuck: If **Length** has disappeared from Body, **Edit skeleton** was pressed, which hides the simple sliders; press **Reset to sliders**. If the snake or the lizard changed instead, Body changes only the selected creature: click 1 at the top and check the name box says Fish.

You'll know it worked when: The fish's chain closes into a ring: with **Flexibility** about seven tenths of the way along ($11 \times 33 = 363$), or with about 16 joints ($15 \times 24 = 360$).

6. The real question, without trying it: would a stiff snake still make a ring? Why?

You'll know it worked when: Your child says yes, because a long body has many small bends, and many small bends add up past 360. That means they see that the angles add and that the rule repeats down the chain.

7. Finish with the big question: how can one small rule make a whole body move?

You'll know it worked when: Your child says that one rule, follow the joint ahead and bend no more than so far, repeated for every joint, makes swimming, slithering and coiling.

Talk about it

Ask these while you work together. A child who has understood the lesson can answer them without help:

- What is the one rule every joint follows?
- Why does a fish with 12 joints have only 11 bends?
- How far can the whole fish bend? Is that a full circle?
- Which slider did you change, and what total did you work out?
- Without trying it: would a stiff snake still make a ring? Why?

The last one is the real test. A child who works out that a long body can make a ring even when each joint is stiff, because many small bends add up, understands that the angles are additive and that the rule is repeated down the chain.

For younger and older kids

Younger: For ages 7 and 8, do the sums together, side by side, and keep to the prediction and the check in Bones.

Older: For teens, work out the flexibility a ring needs as a formula, $\text{degrees per joint} = 360 / (\text{joints} - 1)$, and compare it with the slider. Then read the chain code, a for loop over the joints, in the free walkthrough at

Keep going

- Find the shortest snake that still coils into a ring at its flexibility.
- Give the fish legs in Parts and look in Bones: what keeps each foot planted while the body moves?
- Open Program the brain in Behave and switch to Code. Change `turn(20)` to `turn(5)`, then to `turn(60)`. `turn(5)` makes a wider circle, but `turn(60)` circles exactly like `turn(20)`. Why? (A creature can turn at most 6 degrees each moment, so anything bigger is the same as 6: a body has limits, whatever the brain asks for.)

Bring it into other subjects

- Science: real snakes have more than 200 vertebrae. Why can they coil so tightly? (Many small bends add up, just like the chain.)
- Math: a fish has 11 bends. What is the smallest bend per joint that makes a full circle? ($360 / 11 =$ about 33 degrees.)
- Art: draw a creature as a chain of circles of different sizes, as the X-ray view in Skeleton shows them.
- Computer science: open Program the brain in Behave to see the program that steers the head.

For your records

Ready to copy into an hour log, a portfolio or a transcript.

LESSON	Creature Lab: How Far Can a Body Bend?
SUBJECTS	Math, Computer science
TIME	45 minutes
WHAT WE DID	Explored animated creatures whose bodies are chains of joints, each following the joint ahead and bending only so far. Added the bend at every joint to predict which bodies could curl into a full circle, checked the predictions in the app, and changed a fish until it closed its ring.
SKILLS PRACTICED	angles as additive; multiplying to find a total; predicting, then testing; one rule repeated down a chain

Activity sheet (optional)

Name: _____ Date: _____



Open the app: scan the QR code, or go to mytekdev.com/try/creaturelab?lesson=how-far-can-a-body-bend

Essential question: How can one small rule make a whole body move?

Bends = joints - 1. Total bend = bends x degrees per joint. A full circle is 360 degrees. Count the joints as the dots in Bones.

Flexibility slider: all the way left = 13 degrees per joint, a quarter = 20, halfway = 27, three quarters = 35, all the way right = 42.

CREATURE	JOINTS	BENDS	DEGREES PER JOINT	TOTAL BEND	FULL RING? (PREDICT)	BONES SAYS
Fish	12		24			
Snake	26		29			
Lizard	16		26			
My fish 1:						
My fish 2:						

1. **Look under the skin.** Open **Skeleton** in the rail on the left and pick **Bones**.
2. **Change one thing.** Pick the fish, open **Body**, change **Flexibility** or **Length**, then work out the new total.

1. What is the one rule every joint follows?

Quick check

Name: _____

1. A creature has 10 joints. How many bends does it have? (A) 10, (B) 9, (C) 11.
 2. A creature has 20 bends, and each can bend 20 degrees. Can it curl into a full circle? (A) yes: 400 degrees is more than 360, (B) no: 40 degrees is too little, (C) no: 20 is less than 360.
 3. A fish cannot close its ring. Name two different changes that could help, and say why each one works.
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Answers

Measured in the app with the starter's three creatures circling as tightly as they can: the fish curls 269 degrees, the lizard 372, the snake 712. The worksheet's rounded degrees give 264, 390 and 725: close, because the slider's degrees are rounded to whole numbers.

CREATURE	BENDS	TOTAL BEND	FULL RING?
Fish	11	$11 \times 24 = 264$	No
Snake	25	$25 \times 29 = 725$	Yes, and it wraps around on itself
Lizard	15	$15 \times 26 = 390$	Yes, just

Closing the fish's ring: Flexibility about seven tenths of the way along (about 33 degrees per joint: $11 \times 33 = 363$), or Length up to about 16 joints at the same flexibility ($15 \times 24 = 360$), or a mix of both.

QUESTION	ANSWER	WHY
1	B	The bends are the gaps between joints, so there is one fewer bend than joints.
2	A	$20 \times 20 = 400$ degrees, more than 360, so the body can curl all the way around.
3	Any two of: more flexibility (each bend is bigger); more length or joints (more bends to add up)	Two changes, each with a reason about the total bend.

If your state or umbrella school asks, this lesson covers Common Core Math 4.MD.C.7, CSTA 2017 1B-DA-07, Common Core Math 4.NBT.B.5, NGSS 3-5-ETS1-3.

Creature Lab's chain and animal rigging are ported from animal-proc-anim by argonautcode, open source under the MIT License.

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The app this lesson uses is free and runs in the browser, with nothing to install and no account needed. It is at mytekdev.com.

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