

Part II — Feedback

Loops That Amplify, Loops That Correct

Online, with a lab for each exercise: thinking-in-diagrams.aryehnielsen.com

Causal loops Part II · Feedback · Chapter 4 of 12 · the first of two chapters on causal loops

Why do some changes snowball while others settle? A causal loop diagram shows the loops a change runs around, and whether each amplifies the change or corrects it.

Signals you need this diagram

- A change seems to feed itself.
- Something keeps drifting back to where it was, however hard anyone pushes on it.
- A fix worked for a while, then stopped, or began working against you.
- An explanation's *because*s run in a circle.
- People disagree about what causes what, and arguing hasn't settled it.

A week of short nights

A deadline costs you two nights' sleep. Foggy on Wednesday afternoon, you have a coffee at three, finish the job, and lie awake until one. On Thursday, foggier, you have a double at two. By Friday the caffeine has you sleeping five hours a night.

At the weekend, noticing how tired you are, you go to bed at nine two nights running, and by midweek you're yourself again.

One change fed itself: less sleep, more coffee, less sleep. The other corrected itself: the further behind you fell, the harder you caught up, until there was nothing left to catch up on.

What the notation expresses

Variables

Every name on the diagram is a **variable**: a quantity that can rise or fall, such as *sleep debt* or *hours slept*.

That rules out actions and events. Test a name by putting *more* in front of it: *more afternoon caffeine* makes sense; *more drink coffee* doesn't. Naming a variable as an action is the bad diagram's mistake.

CHECK YOUR UNDERSTANDING

Which of these names could be a variable on a causal loop diagram?

- a go to bed early
- b hours slept
- c the deadline
- d tiredness increases

Feedback: Answers, chapter 4

Polarity

An **effect** means that a change in one variable causes a change in another; its **polarity** shows which way. A + effect means they move in the same direction: more sleep debt, more afternoon caffeine. A – effect means they move in opposite directions: more afternoon caffeine, fewer hours slept.

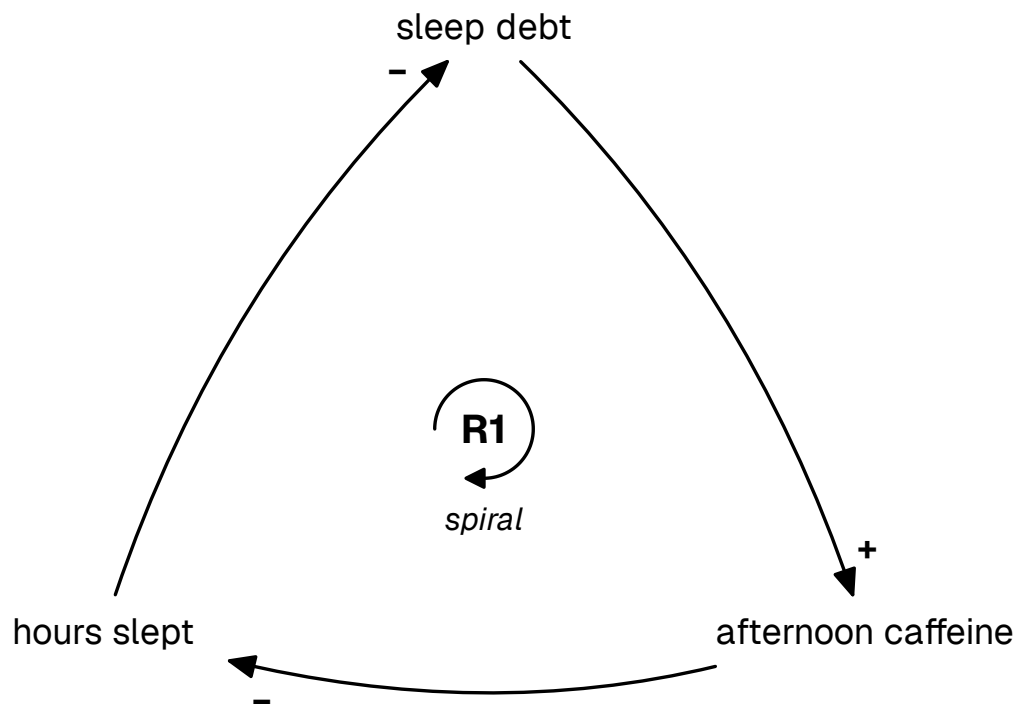
+ doesn't mean *good* and – doesn't mean *bad*, and neither gives size: caffeine might cost ten minutes of sleep or two hours.

In a causal loop diagram every effect carries a polarity; an influence claim

thinking-in-diagrams.aryehnielsen.com/framing/surfacing-influences/#influence-claims, drawn in an influence map, carries none until it is upgraded to a causal claim.

Loops

Sleep debt raises afternoon caffeine, caffeine cuts hours slept, and fewer hours slept raise sleep debt. A closed path of effects like this is a **loop**. A chain shows how one thing affects another; a loop shows how a thing ends up affecting itself.



A **reinforcing loop** makes a change snowball, in whichever direction it starts: debt brings coffee and more debt, but a good night likewise brings less coffee and another good night. A **balancing loop** makes a change settle, moving a variable toward a target and opposing any push away from it: the further behind on sleep you fall, the harder you try to catch up.

Each loop's label, drawn inside it with a curved mark showing which way it circulates, is its kind and a number: R1, R2 for reinforcing loops, B1, B2 for balancing ones. Its name describes what it *does*, not what it's about: *spiral*, not *coffee*.

The parity rule

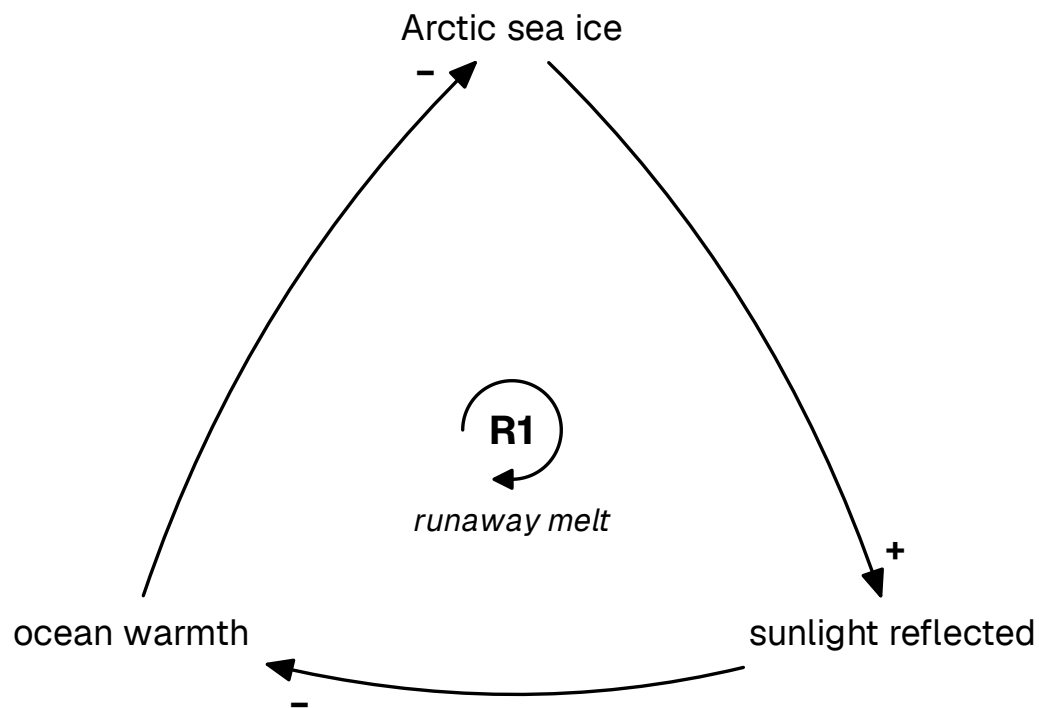
The parity rule: a loop with an even number of – effects is reinforcing, and one with an odd number is balancing. Zero counts as even.

Each – effect reverses a change passing through it. Two reversals cancel, so the change comes back pointing the way it set out, and grows; one or three leave it pointing against itself, and it shrinks.

For the spiral, the lab's check gives this working:

R1 (spiral) has 2 – effects (afternoon caffeine → hours slept, hours slept → sleep debt): an even number, so it is reinforcing, as declared.

At planetary scale, less Arctic sea ice reflects less sunlight, so the ocean warms, and warmer water melts more ice: again two – effects, so reinforcing.



CHECK YOUR UNDERSTANDING

A loop has four effects. Three are + and one is -. What kind of loop is it?

- a** Reinforcing, because most of its effects are +
- b** Balancing
- c** It depends on which effect carries the -
- d** You can't tell without knowing what the variables are

Feedback: Answers, chapter 4

The gap

A balancing loop closes a **gap**: the difference between the value someone wants and the value they have. Here it's *sleep debt*, the sleep you need minus the sleep you get.

Draw it as its own variable, fed by the target from outside the loop. That shows the loop's target, and raises two questions about any balancing loop: who set it, and could it move?

In a feedback control diagram, the words *target*, *gap* and *measured value* (the reading the target is compared with) are written above the names of the variables in those parts, and a person chooses the target: chapter 8's target and gap thinking-in-diagrams.aryehnielsen.com/control/sense-compare-correct/#target-and-gap.

Delays

A **delay**, two short strokes across an effect, means that the change arrives later than the cause: late enough to change what the loop does. Sleep debt builds for days before anyone acts on it, so the effect from sleep debt to early nights carries a delay, and the spiral, whose changes arrive within a day, gets a head start.

In a balancing loop with a delay, the correction continues after the gap closes; the variable overshoots its target and oscillates instead of settling.

In a stock & flow diagram, a delay on a flow holds material in transit and a delay on a signal holds a reading of the material: chapter 7's material and signal delays

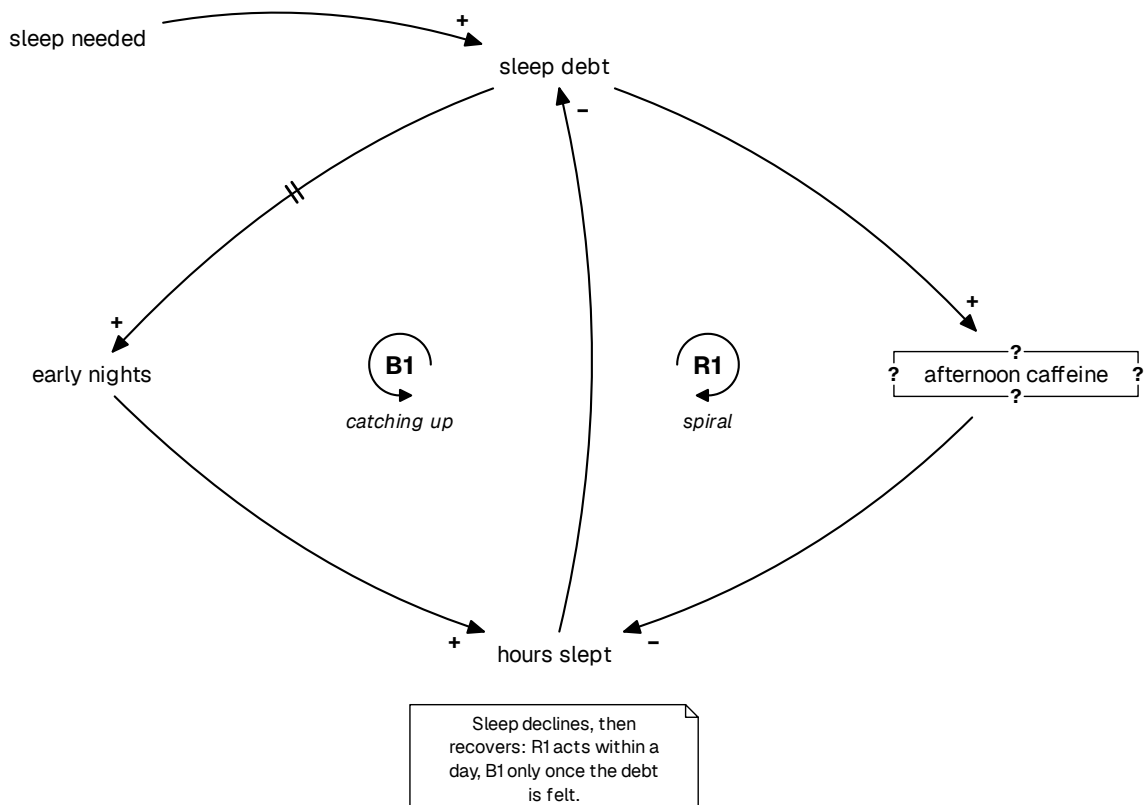
thinking-in-diagrams.aryehnielsen.com/accumulation/stocks-inside-feedback/#material-and-signal-delays.

Behavior notes

A **behavior note** names, on the diagram, the behavior you expect the structure to produce: *oscillation*, *overshoot*, *decline*, *then recovery*. It makes the diagram a prediction: if what happens differs, the structure you drew is missing something.

Coupled loops

Loops that share a variable are coupled: a change in one loop changes the other. In the full sleep diagram, the spiral and catching up share sleep debt, hours slept and the effect between them.



Which loop dominates depends on which is stronger at the time: early in the week, the spiral; once the debt is felt, catching up.

Leverage points

A **leverage point** is a variable proposed as the place to intervene, drawn as a box with a question mark on each side. In the sleep diagram it's *afternoon caffeine*: cutting it weakens the spiral and leaves the slow balancing loop less to correct.

It's a hypothesis, not a proven fix: someone else might propose *early nights*, arguing that noticing the debt sooner would help more. Either proposal can be tested against the diagram.

What stays informal

A causal loop diagram shows structure only, not **size**: when amounts decide the question you need numbers, which chapter 6's stocks begin to supply.

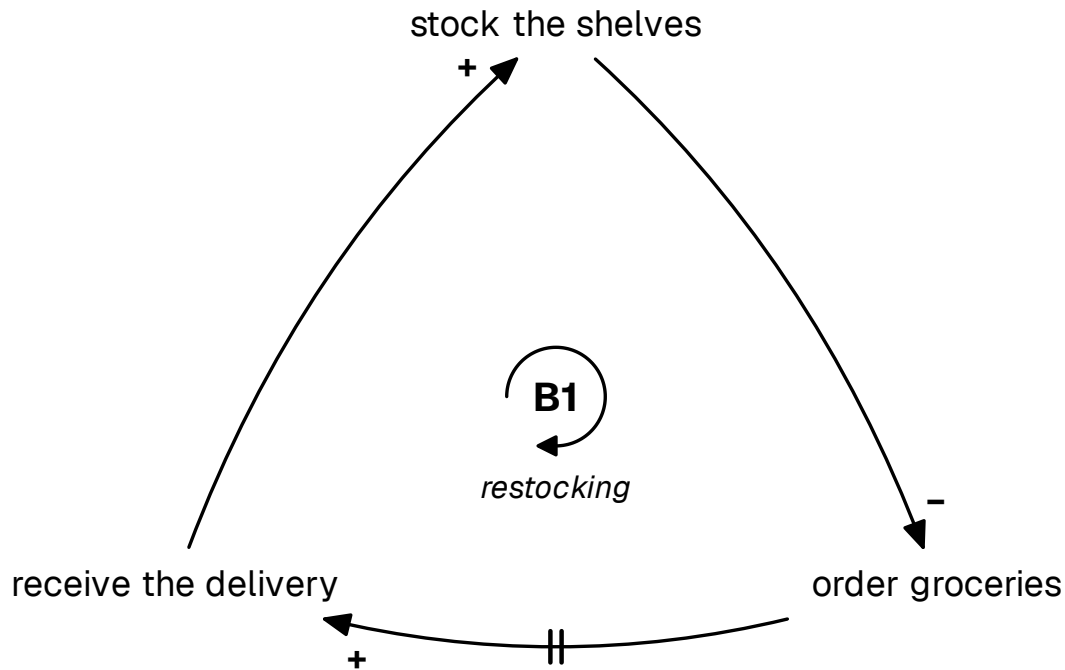
Nor does it show **sequence**: for the order in which things happen, use a numbered list. A loop diagram of a sequence is the bad diagram's mistake.

Nor **everything**: the sleep diagram leaves out stress, exercise and the deadline, keeping only the loops that explain the behavior in question.

When nothing feeds back, a sentence does the job.

The bad diagram

What's wrong with this diagram of keeping a household pantry stocked?

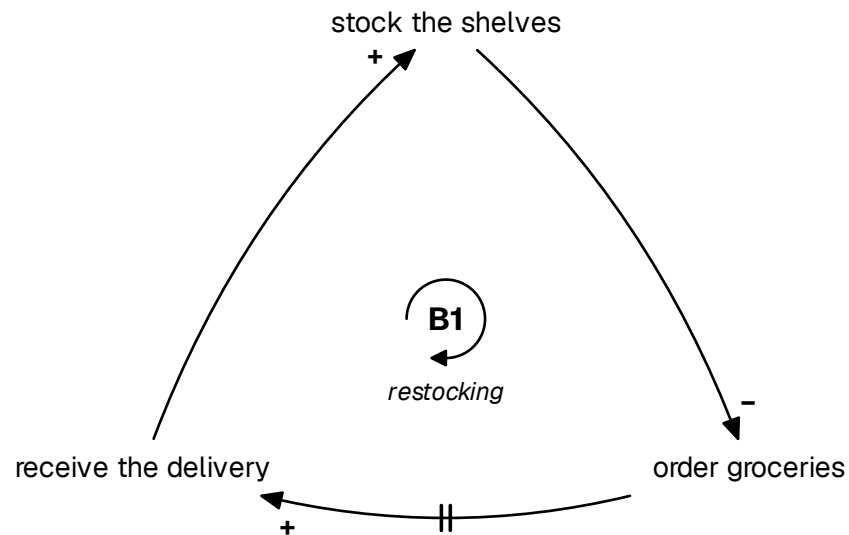
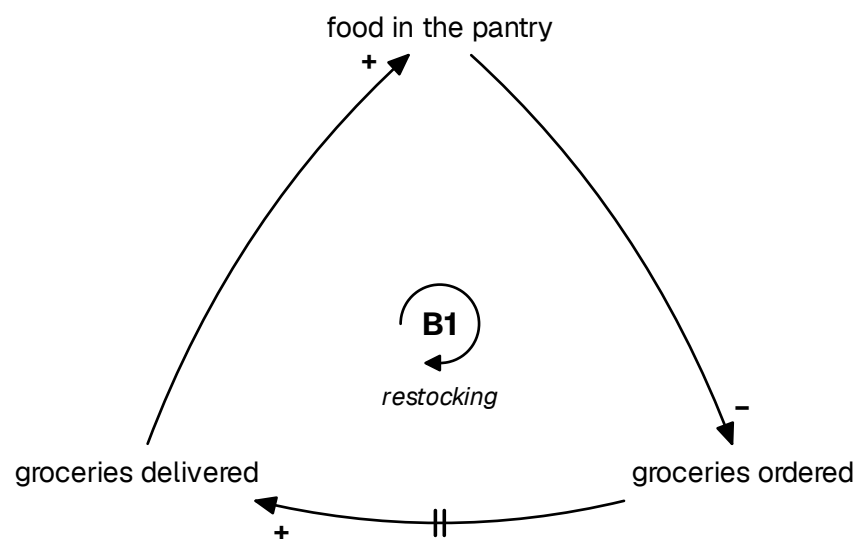


Its structure is sound: a closed loop, one – effect, labeled B1, a delay on the right effect. But its names, *stock the shelves*, *order groceries* and *receive the delivery*, are actions done in order and fail the *more* test, so the diagram is a to-do list bent into a circle, and its polarities mean nothing: what would *more receive the delivery* cause?

In the lab it passes every check, with a notice on each of its three names.

The corrected diagram

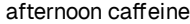
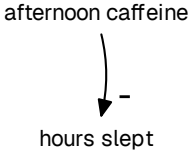
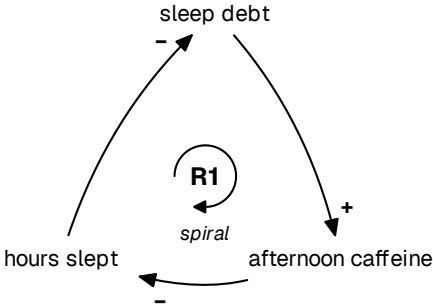
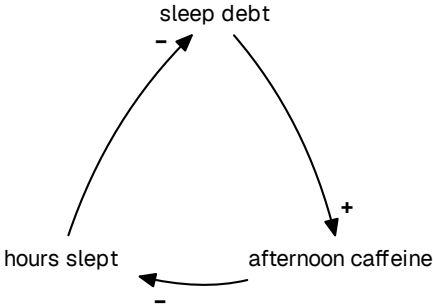
The correction keeps every effect, every polarity, the delay and the loop, and renames the three variables as quantities.

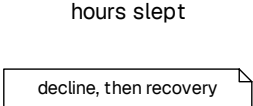
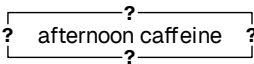
Bad diagram**Corrected diagram**

Changed: 3 labels. Effects unchanged.

Now each effect is a checkable claim: more food in the pantry, fewer groceries ordered (-); more ordered, more delivered a few days later (+, delayed); more delivered, more food in the pantry (+). One - effect, so the loop is balancing: it holds the pantry near full. With the delay: reorder before the first delivery arrives and the pantry overfills.

Notation moves

Notation move	When	What it shows	Example
Name a variable as a quantity		What rises or falls	<i>afternoon caffeine</i> , not <i>drink coffee</i>
 afternoon caffeine			
Mark an effect + or -		Which way each change runs	afternoon caffeine → hours slept is -
 afternoon caffeine hours slept			
Close a loop and label it	A chain returns to its start	How a change comes back to itself	R1 <i>spiral</i>
 sleep debt hours slept afternoon caffeine R1 spiral			
Count the - effects	Before labeling a loop	The loop's kind	two - effects, so reinforcing
 sleep debt hours slept afternoon caffeine			

Notation move	When	What it shows	Example
Draw the gap as a variable	A balancing loop has a target	What the loop closes, and its target	<i>sleep debt</i> , fed by <i>sleep needed</i>
			
Mark a delay	The change arrives late enough to alter the loop's behavior	Where a correction can overshoot	<i>sleep debt</i> → <i>early nights</i>
			
Add a behavior note	You expect a pattern over time	A prediction to check	<i>decline, then recovery</i>
			
Propose a leverage point	You choose where to intervene	A hypothesis to test	<i>afternoon caffeine</i>
			

Check your understanding

CHECK YOUR UNDERSTANDING

You're warming a pan of soup on an electric stove that takes several minutes to respond. Whenever the soup seems too cool you turn the heat up, and whenever it seems too hot you turn it down. What does the structure predict?

- a A smooth rise to the temperature you want
- b Swings between too hot and too cool before it settles
- c The soup getting hotter and hotter
- d Nothing: without numbers the diagram can't predict anything

Feedback: Answers, chapter 4

The diagram illustrates the following causal relationships:

- trauma and burnout of first responders** (+) → **overdoses**
- overdoses** (+) → **people with opioid use disorder**
- people with opioid use disorder** (-) → **overdose deaths**
- overdose deaths** (-) → **lives saved**
- lives saved** (+) → **calls to 911**
- calls to 911** (+) → **overdoses**
- calls to 911** (-) → **trauma and burnout of first responders**
- mistreatment of patients by first responders** (+) → **calls to 911**

Feedback loops identified:

- B1 (calls withheld):** A reinforcing loop involving **calls to 911** and **overdoses**.
- R1 (risk renewed):** A reinforcing loop involving **overdose deaths** and **lives saved**.

Panels a and b drawn as one diagram; the heavier red lines that pick out each panel's loop drawn like every other line; Overdose, Calling 911 and Saving a Life renamed as amounts; OUD spelled out; the two names about first responders shortened; each loop named; panel c, the whole model, left out

R1 runs from people with opioid use disorder through overdoses, calls to 911, lives saved and overdose deaths, and back. By the parity rule, what kind of loop is it?

- a Reinforcing: it has two – effects, an even number.
- b Balancing: any loop with a – effect in it is balancing.
- c Balancing: a call to 911 is made to bring overdose deaths down.

QUESTION 2 OF 3

B1 leaves overdoses through trauma and burnout of first responders, then mistreatment of patients, joins R1 at calls to 911 and follows it back. What kind of loop is it?

- a Reinforcing: it shares four effects with R1, which is reinforcing.
- b Balancing: it has three – effects, an odd number.
- c Reinforcing: burnout and mistreatment both rise as overdoses rise.

QUESTION 3 OF 3

Burnout among first responders keeps growing, so mistreatment keeps more people from calling 911. Which loop comes to dominate, and what happens to overdose deaths?

- a B1, and overdose deaths fall, since a balancing loop corrects the problem.
- b R1, since overdoses keep rising and R1 runs through them.
- c B1, and overdose deaths rise.

Feedback: Answers, chapter 4

Exercises

Passing the checks means meeting the brief, not being right.

CL 01 A riverbank cleanup that grows by word of mouth

One reinforcing loop

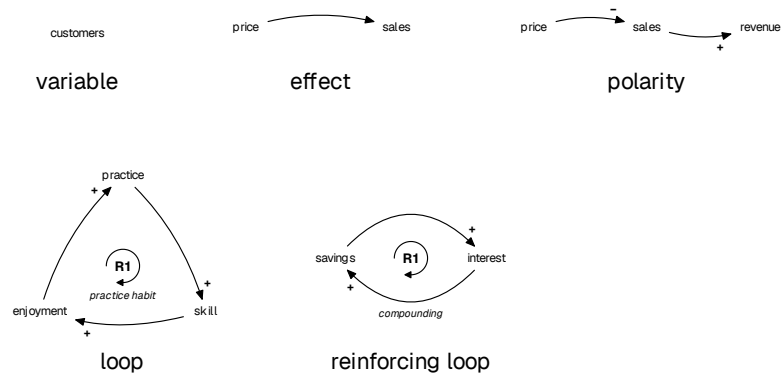
Reasoning ●○○○○ 1 of 5 Polish ●○○○○ 1 of 5

Neighbors meet one Saturday a month to clear litter from a city riverbank. Each cleared stretch shows from the footpath, and people who walk there talk about it. Some of them come to the next cleanup, and some of those keep coming. Show the smallest complete feedback explanation. Leave out the weather and the litter the river carries in.

The brief

- ☐ Use exactly four variables.
- ☐ Close one loop.
- ☐ Mark every effect + or -.
- ☐ Label the loop R1.
- ☐ Give the loop a short name.

Your palette



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CL 02 Hunger and eating

One balancing loop

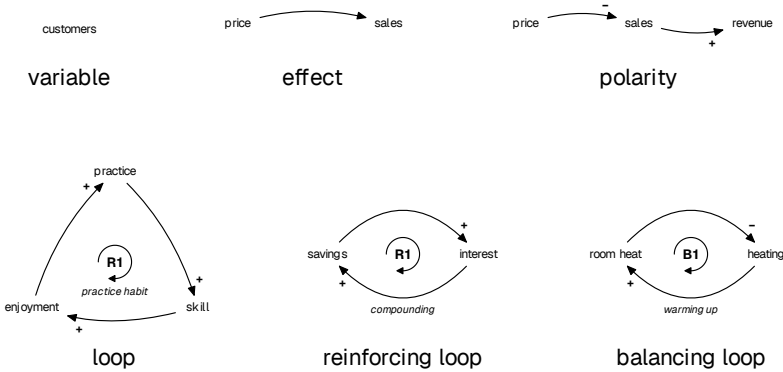
Reasoning ●○○○○ 1 of 5 Polish ●●○○○ 2 of 5

When hunger rises, a person eats. Food eaten fills the stomach, and as fullness grows, hunger falls. Once hunger is low, eating stops until it returns hours later. Show this correction as feedback, not as a sequence of meals. One effect reverses direction, and the loop's kind follows from it.

The brief

- ☐ Use three or four variables.
- ☐ Find the single – effect.
- ☐ Label the loop B1.
- ☐ Name its target-seeking behavior.

Your palette



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A large grid of dots for drawing the diagram.

CL 03 A housing shortage and the building boom that overshoots it

Balancing loop with delay

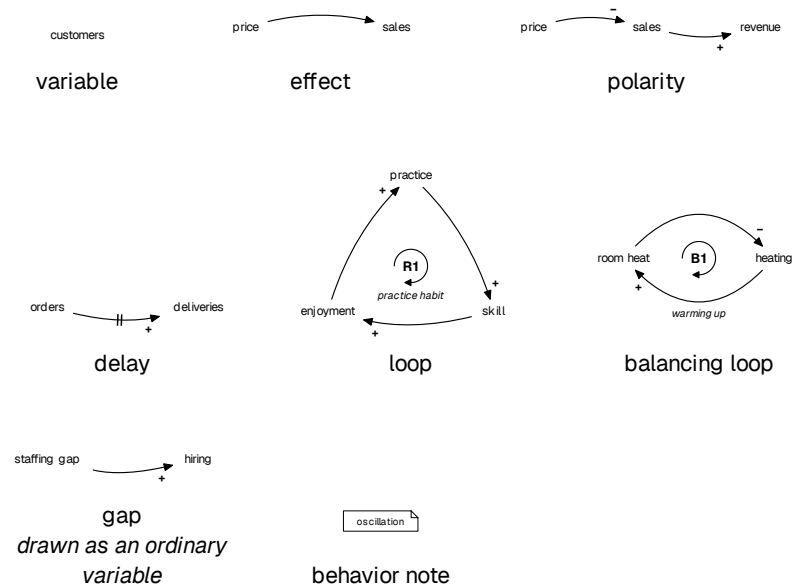
Reasoning ●●○○○ 2 of 5 Polish ●●○○○ 2 of 5

A growing city has fewer homes than its households need, and rents climb. High rents lead developers to start new buildings, which take two to three years to finish. Starts continue while rents stay high, so the homes arrive together and overshoot the need. Draw the intended correction, with the delay on an effect, not in a new variable.

The brief

- ☐ Show the homes needed, the shortage, building starts, and the housing stock.
- ☐ Put a delay on building starts → housing stock.
- ☐ Use one behavior note.
- ☐ Name the likely behavior in it: oscillation.

Your palette



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CL 04 A friendship group that grows until gatherings feel crowded

Coupled R and B loops

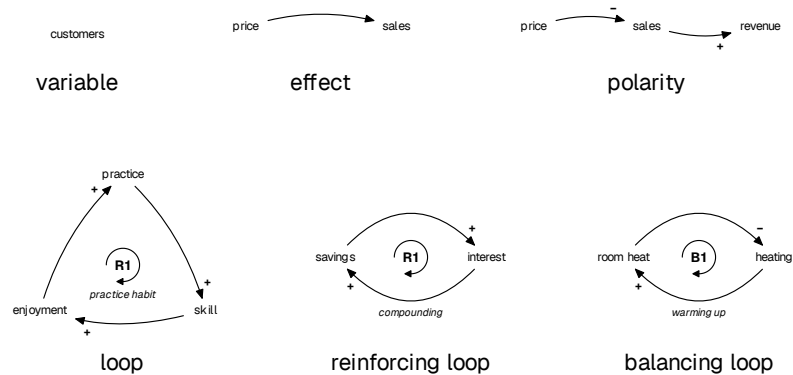
Reasoning ●●○○○ 2 of 5 Polish ●●●○○ 3 of 5

A group of friends meets every Friday evening, and members invite friends of their own; some of those stay. As the group grows, the gatherings get crowded, conversations split up, and members enjoy them less and invite fewer people. Build one reinforcing loop of growth and one balancing loop of crowding around the group's size, which they share.

The brief

- ☐ Create one R loop.
- ☐ Create one B loop.
- ☐ Share at least one variable between them.
- ☐ Place the variables so that no two effects cross.

Your palette



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CL 05 Borrowing to get to the end of the month

Short-term gain, long-term erosion

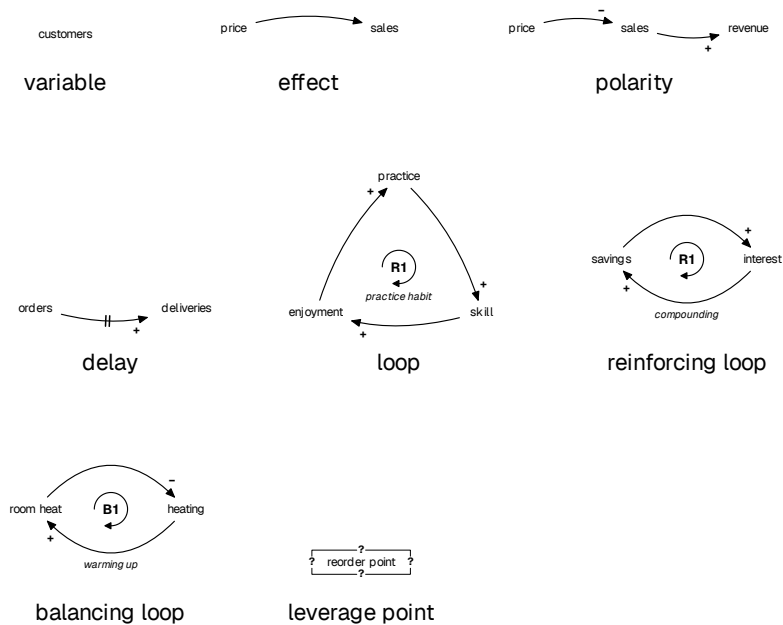
Reasoning ●●●○○ 3 of 5 Polish ●●●○○ 3 of 5

A household's bills outrun its income, and it covers the month's gap with a credit card. The cash closes the gap at once. Weeks later, repayments with interest start taking money from every month, and the gap reopens wider.

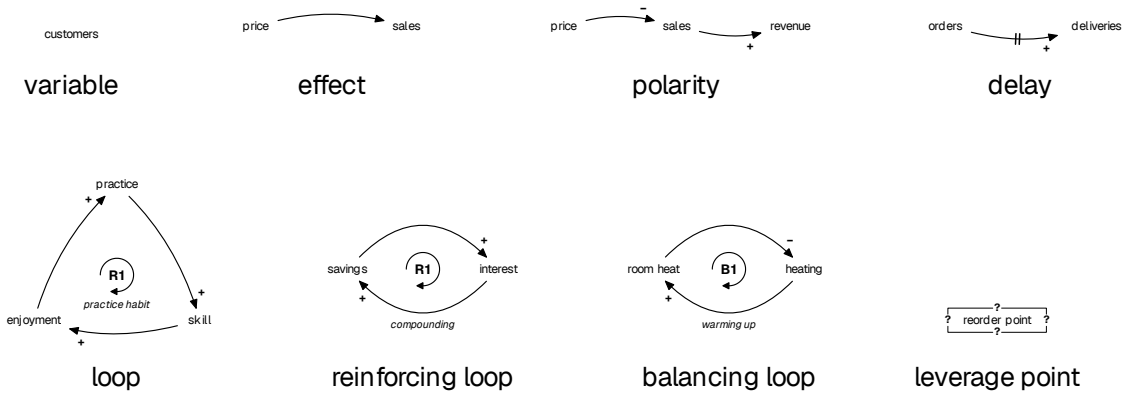
The brief

- ☐ Separate fast relief from slow consequence.
- ☐ Mark at least one delayed effect.
- ☐ Make the variable you would monitor first a leverage point.

Your palette



Draw here

CS 04 Kelsham Primary School: funding that follows its pupils**Your palette**

CS 04 Kelsham Primary School: funding that follows its pupils

Coupled loops, a delay and a leverage point

Reasoning ●●●○○ 3 of 5 Polish ●●●○○ 3 of 5

Kelsham Primary School is paid £4,800 a year for each pupil, set from the count each October and paid through the school year after it. In October 2020 it had 126 pupils in five classes. By October 2023 it had 108, the governors could pay for four teachers, and Years 3 and 4 became one class. Ruth Okafor, the head teacher, hears from some parents that mixed-age classes are why they chose Brayford Primary School, six miles away, where classes hold up to 30. Others stay because Kelsham's classes are smaller: 88 pupils in four classes in October 2026. Tom Hale, who chairs the governors, asks where the school could act. Draw both stories as loops through the pupils on roll, and mark the variable you would change first as a leverage point.

The brief

- ☐ Close one reinforcing loop through the school's funding and its teachers.
- ☐ Close one balancing loop through class size.
- ☐ Let the two loops share at least one variable.
- ☐ Mark the delay the October count makes.
- ☐ Make the variable you would change first a leverage point.
- ☐ Name each loop by what it does.

Your palette

On the page before this sheet.

Draw here

Sources

- Donella H. Meadows, *Thinking in Systems: A Primer* (Chelsea Green, 2008), chapter 1, on reinforcing and balancing loops, and chapter 2, on delays.
- Donella H. Meadows, *Leverage Points: Places to Intervene in a System*
donellameadows.org/archives/leverage-points-places-to-intervene-in-a-system/ (Sustainability Institute, 1999), on leverage points.
- John D. Sterman, *Business Dynamics: Systems Thinking and Modeling for a Complex World* (Irwin/McGraw-Hill, 2000), chapter 5, on causal loop diagrams: polarity, a loop's kind, delays, and naming variables as nouns rather than actions.
- John D. Sterman, "System Dynamics Modeling: Tools for Learning in a Complex World"
doi.org/10.2307/41166098, *California Management Review* 43, no. 4 (2001), a short introduction to the same ideas.
- George P. Richardson, "Problems with Causal-Loop Diagrams" doi.org/10.1002/sdr.4260020207, *System Dynamics Review* 2, no. 2 (1986), on what polarity does and doesn't mean.
- National Snow and Ice Data Center, Why sea ice matters
nsidc.org/learn/parts-cryosphere/sea-ice/why-sea-ice-matters, on why melting ice speeds further melting.

Answers

Chapter 4 · Loops That Amplify, Loops That Correct

Which of these names could be a variable on a causal loop diagram?

- a go to bed early
Not quite. That's an action: something you do, not something there can be more or less of. The quantity inside it is early nights, a count that rises and falls from week to week.
- b hours slept
Yes. It's a quantity that can rise or fall, and "more hours slept" makes sense. Every effect into or out of it can show which way it moves.
- c the deadline
Not quite. That's an event: it happens once, on a date. What rises and falls around it is something like work still to do, and that would be the variable.
- d tiredness increases
Not quite. The increase doesn't belong in the name: which way tiredness moves is what the effects' polarity shows. The variable is tiredness.

A loop has four effects. Three are + and one is -. What kind of loop is it?

- a Reinforcing, because most of its effects are +
Not quite. A + effect passes a change on unchanged, so only the - effects count, and one is an odd number.
- b Balancing
Yes. One - effect is an odd number. A change that goes around the loop comes back reversed, so the loop opposes it.
- c It depends on which effect carries the -
Not quite. Each - effect reverses a change wherever it sits, so only the number of reversals counts.
- d You can't tell without knowing what the variables are
Not quite. You need the variables to judge whether the diagram is true. You don't need them to know its kind: the parity rule works from the polarities alone.

You're warming a pan of soup on an electric stove that takes several minutes to respond. Whenever the soup seems too cool you turn the heat up, and whenever it seems too hot you turn it down. What does the structure predict?

- a A smooth rise to the temperature you want
Not quite. That's what a balancing loop does when nothing in it is delayed. Here the stove goes on heating for minutes after you turn it down, so the soup can't stop where you meant it to.
- b Swings between too hot and too cool before it settles
Yes. It's a balancing loop with a delay on the effect from the heat setting to the soup's warmth. Each correction goes on acting after the gap has closed, so the soup overshoots, and the next correction overshoots the other way. A behavior note would read oscillation.
- c The soup getting hotter and hotter
Not quite. That would take a reinforcing loop. Turning the heat down when the soup is too hot puts one – effect in the loop, an odd number, so the loop is balancing.
- d Nothing: without numbers the diagram can't predict anything
Not quite. Without numbers you can't say how large the swings are or how long they last. The structure alone still predicts that they'll happen.

QUESTION 1 OF 3

R1 runs from people with opioid use disorder through overdoses, calls to 911, lives saved and overdose deaths, and back. By the parity rule, what kind of loop is it?

- a Reinforcing: it has two – effects, an even number.
Yes. Lives saved → overdose deaths and overdose deaths → people with opioid use disorder are the two, and their reversals cancel. More calls to 911 save more lives, so fewer people die and more remain at risk of another overdose: the change comes back the way it set out.
- b Balancing: any loop with a – effect in it is balancing.
Not quite. Only an odd number of – effects makes a loop balancing. Each – effect reverses a change, and two reversals cancel.
- c Balancing: a call to 911 is made to bring overdose deaths down.
Not quite. A loop's kind comes from its effects' polarities, not from anyone's purpose. R1 has two – effects, so it is reinforcing, whatever each caller intends.

QUESTION 2 OF 3

B1 leaves overdoses through trauma and burnout of first responders, then mistreatment of patients, joins R1 at calls to 911 and follows it back. What kind of loop is it?

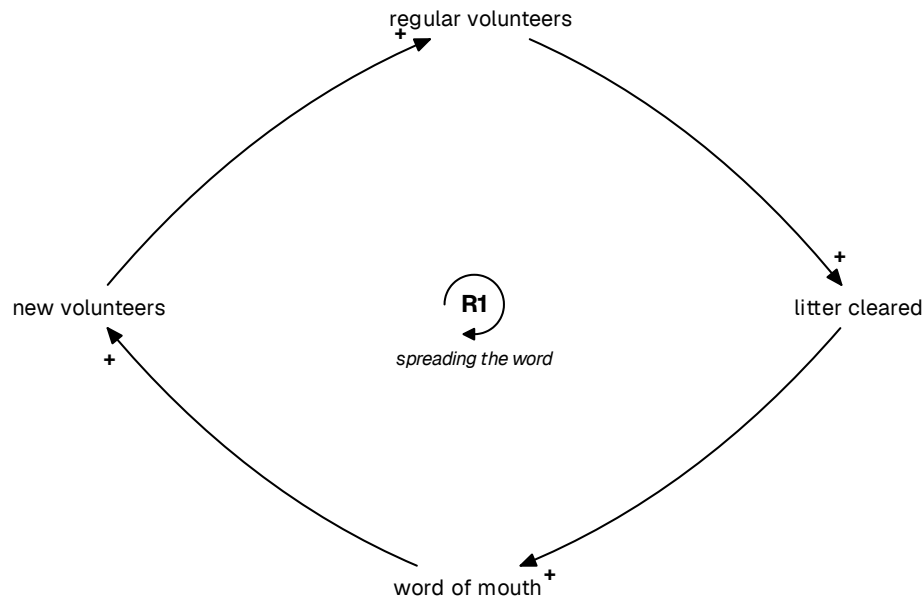
- a Reinforcing: it shares four effects with R1, which is reinforcing.
Not quite. Loops that share effects are coupled, but each has its own kind. B1's own path adds a – effect, mistreatment → calls to 911, which makes three.
- b Balancing: it has three – effects, an odd number.
Yes. Mistreatment → calls to 911 is the third, beside R1's two. More overdoses bring more burnout, more mistreatment and fewer calls, so fewer lives are saved, more people die, and fewer remain to overdose: the change comes back against itself.
- c Reinforcing: burnout and mistreatment both rise as overdoses rise.
Not quite. Those two effects are +, and a + effect changes no loop's kind. Its kind comes from the – effects counted around the whole loop: three, so balancing.

QUESTION 3 OF 3

Burnout among first responders keeps growing, so mistreatment keeps more people from calling 911.

Which loop comes to dominate, and what happens to overdose deaths?

- a** B1, and overdose deaths fall, since a balancing loop corrects the problem.
Not quite. B1 does come to dominate, but it runs through lives saved → overdose deaths, a – effect: fewer lives saved, more deaths. Balancing names what the loop does to a change, not whether the result is good.
- b** R1, since overdoses keep rising and R1 runs through them.
Not quite. Both loops run through overdoses. Growing burnout strengthens only the path through mistreatment, which B1 alone runs through, so B1 gains on R1.
- c** B1, and overdose deaths rise.
Yes. B1 strengthens through its own path, so it brings overdoses down, but by fewer calls, fewer lives saved and more deaths. A balancing loop makes a change settle; nothing in its kind makes the outcome welcome.

CL 01 A riverbank cleanup that grows by word of mouth

This is one defensible answer, not the only one. Yours can differ and still hold up: the lab's checks show whether it has the brief's structure.

Four variables close one chain of + effects. More regular volunteers clear more litter, the cleared riverbank gets talked about, and the talk brings new volunteers, so a change compounds in the direction it starts.

Why it works

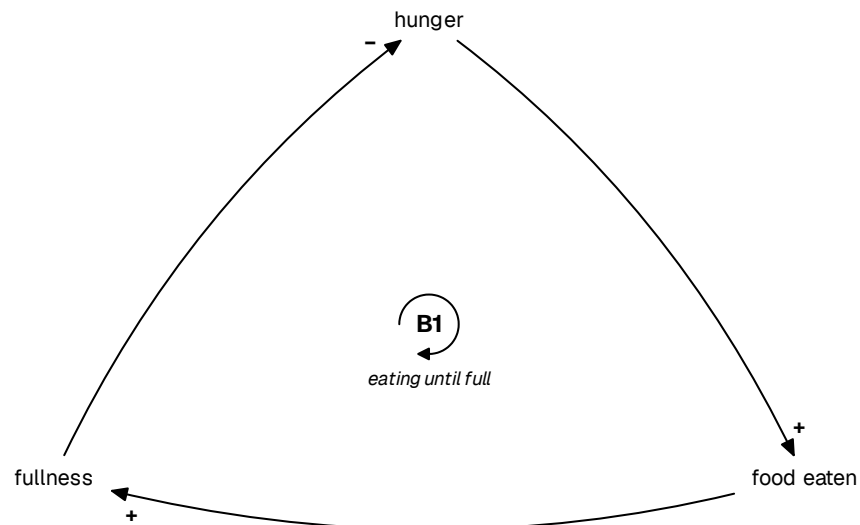
- Four quantities that can rise or fall
- Closed chain
- All effects +
- Loop named by its behavior

Step by step

1. Regular volunteers and litter cleared, the two quantities the paragraph opens with, and the + effect between them: more volunteers clear more litter.
2. Word of mouth, with a + effect into it from litter cleared: each cleared stretch shows from the footpath, and people who walk there talk about it.
3. New volunteers, with a + effect into them from word of mouth: some of the people who hear about the cleanup come to the next one.
4. The loop closes with a + effect from new volunteers back to regular volunteers, since some newcomers keep coming; with no – effect it is reinforcing, R1, named spreading the word.

What another defensible answer might vary

Another defensible answer might take a different step between the regular volunteers and the newcomers, such as invitations to friends in place of litter cleared, or start the chain at a different variable. What stays the same is four quantities that can rise or fall, closed into one loop of + effects.

CL 02 Hunger and eating

This is one defensible answer, not the only one. Yours can differ and still hold up: the lab's checks show whether it has the brief's structure.

Hunger raises the food eaten; food eaten raises fullness; fullness lowers hunger. One – effect makes the loop balancing: after each meal it brings hunger back down.

Why it works

- Hunger is a quantity
- One opposite-direction effect
- Closed correction loop
- No meal-by-meal steps

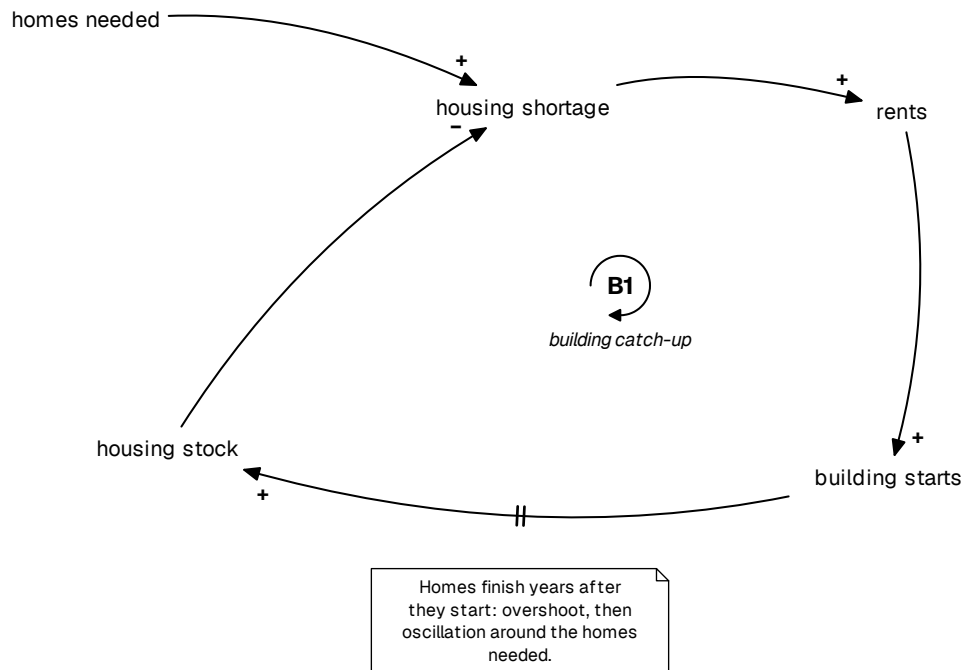
Step by step

1. Hunger and food eaten, with a + effect between them: when hunger rises, a person eats.
2. Fullness, with a + effect into it from food eaten, since food fills the stomach.
3. The loop closes with a – effect from fullness back to hunger, and its label goes on with it: balancing, B1, eating until full.

What another defensible answer might vary

Another defensible answer might add a fourth variable, as the brief allows, such as stomach stretch between food eaten and fullness, or start the chain at a different variable. What stays the same is a single – effect closing one balancing loop around hunger.

CL 03 A housing shortage and the building boom that overshoots it



This is one defensible answer, not the only one. Yours can differ and still hold up: the lab's checks show whether it has the brief's structure.

Rising rents draw new building that closes the shortage, but homes finish years after they start. Starts made during the delay overshoot the need, and building then falls off: oscillation.

Why it works

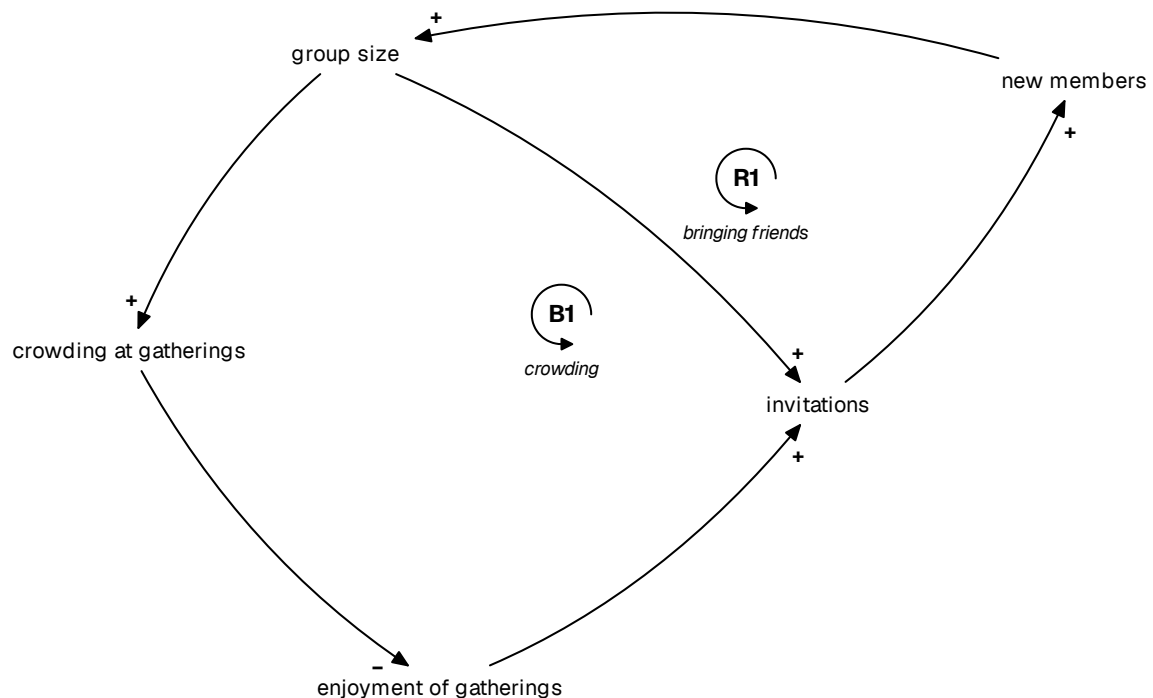
- Target and gap are separate
- Delay sits on building starts → housing stock
- Housing stock is a quantity, not an action
- Behavior note names oscillation

Step by step

1. Homes needed and the housing shortage, with a + effect between them: the need the city's households set, and how far the homes fall short of it.
2. Rents and building starts, with + effects from the shortage to rents and from rents to starts, the developers' answer to high rents.
3. Housing stock, with a + effect from building starts delayed by the two to three years a building takes, and a – effect back to the shortage that closes the loop: balancing, B1, building catch-up.
4. The behavior note, beside the loop once the loop and its delay are both drawn, since the overshoot it names comes from the two together.

What another defensible answer might vary

Another defensible answer might drop rents and let the shortage raise building starts directly, or split the housing stock into homes under construction and homes finished. What stays the same is the homes needed feeding the shortage from outside the loop, one balancing loop through the shortage, the delay on the effect that carries starts into the stock, and a note naming oscillation.

CL 04 A friendship group that grows until gatherings feel crowded

This is one defensible answer, not the only one. Yours can differ and still hold up: the lab's checks show whether it has the brief's structure.

Group size sits on two loops: invitations bring in new members and grow the group, while crowding lowers enjoyment of gatherings and, with it, the invitations.

Why it works

- Group size is shared
- R and B loops touch
- Crowding path is readable
- Crossings avoided

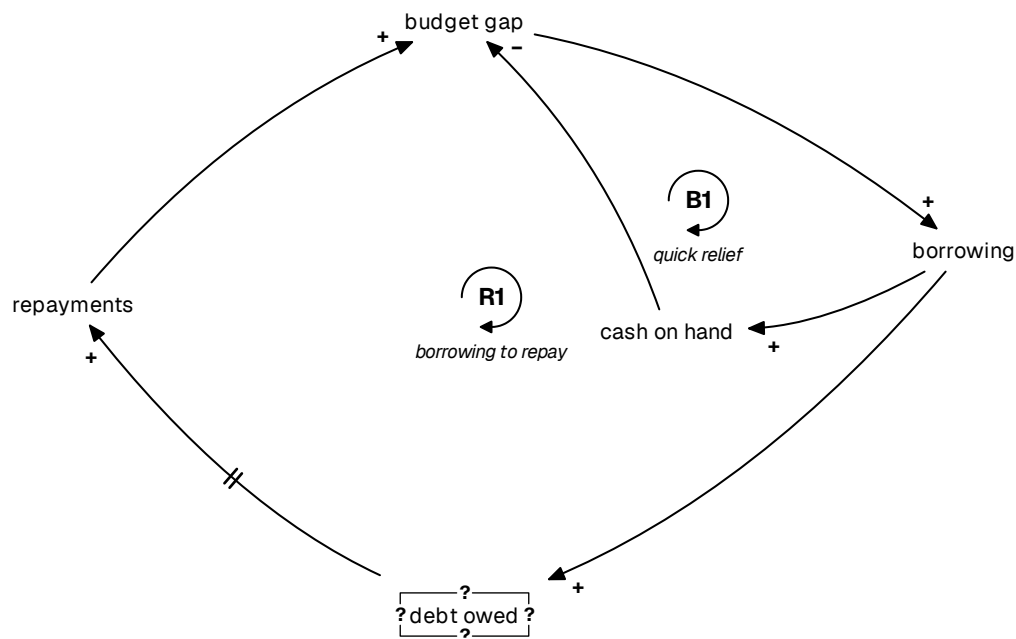
Step by step

1. Group size and invitations, with a + effect between them: members invite friends of their own.
2. New members, with + effects from invitations and on into group size, closing a loop with no – effect: reinforcing, R1, bringing friends.
3. Crowding at gatherings, with a + effect from group size, which both loops pass through.
4. Enjoyment of gatherings, with a – effect from crowding and a + effect into invitations, which closes a second loop through R1's invitations and new members: one – effect, so balancing, B1, crowding.

What another defensible answer might vary

Another defensible answer might carry the limit through a different quantity, such as time with each friend in place of enjoyment, or let crowding lower how many new members stay rather than the invitations. What stays

the same is one reinforcing and one balancing loop passing through group size, with the single – effect on the crowding path.

CL 05 Borrowing to get to the end of the month

This is one defensible answer, not the only one. Yours can differ and still hold up: the lab's checks show whether it has the brief's structure.

Borrowing closes this month's gap at once, while the debt it adds comes back as repayments in later months and widens the gap again.

Why it works

- Fast and slow paths separated
- Effect on repayments delayed
- Trap closes as a reinforcing loop
- Debt owed rises before repayments do: the leverage point

Step by step

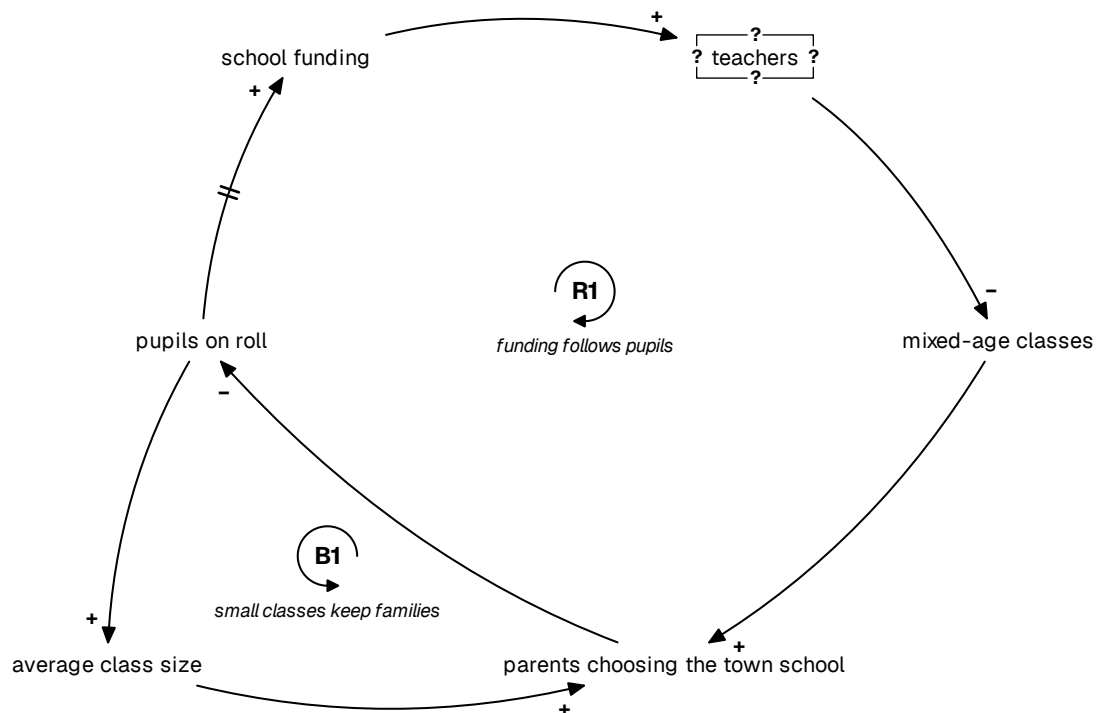
1. Budget gap and borrowing, with a + effect between them: the household covers the month's gap with a credit card.
2. Cash on hand, with a + effect from borrowing and a – effect back to the budget gap, closing the fast loop: balancing, B1, quick relief.
3. Debt owed, with a + effect from borrowing, marked as the leverage point, the variable to monitor first.
4. Repayments, with a + effect from debt owed delayed by the weeks before they start, and a + effect back to the budget gap, closing the slow loop: reinforcing, R1, borrowing to repay.

What another defensible answer might vary

Another defensible answer might put the delay on borrowing → debt owed, as interest builds, or make repayments the leverage point, since they show in the budget each month. What stays the same is a fast

balancing loop of relief and a slower reinforcing loop, through the debt, that reopens the gap.

CS 04 Kelsham Primary School: funding that follows its pupils



This is one defensible answer, not the only one. Yours can differ and still hold up: the lab's checks show whether it has the brief's structure.

The pupils on roll sit on two coupled loops. Through funding, teachers and mixed-age classes, fewer pupils bring fewer pupils still, a year behind each count; through average class size, fewer pupils make smaller classes, which keep some families from the town school and slow the fall.

Why it works

- Every name passes the more test: more pupils on roll, more mixed-age classes
- R1 has two – effects and B1 one, as the parity rule gives
- The delay on pupils on roll → school funding: the October count
- Both loops share pupils on roll, parents choosing the town school and the effect between them
- Teachers, the leverage point, sit on R1 only: holding their number up weakens R1 and leaves B1

Step by step

1. Pupils on roll, which both loops pass through, and school funding, joined by a + effect with a delay: each October's count sets the funding for the school year after it.
2. Teachers, with a + effect from the funding that pays them, marked as the leverage point: holding their number up cuts the path from the count to the classes.
3. Mixed-age classes, more of them as teachers fall (–), and parents choosing the town school, more of them as classes are mixed (+).
4. A – effect from parents choosing the town school back to pupils on roll closes R1: two – effects, an even number, so it is reinforcing, and a fall in pupils brings a further fall.

5. Average class size, rising with pupils on roll (+) and sending parents to the town school (+), closes B1 through the same – effect: one – effect, so it is balancing, and it slows the fall.

What another defensible answer might vary

Another defensible answer might propose mixed-age classes as the leverage point, keeping Years 3 and 4 apart with a teacher paid from the reserve, or parents choosing the town school, through what families hear about Kelsham. It might also draw a + effect from mixed-age classes to average class size, closing a second reinforcing loop. What stays the same is a reinforcing loop through funding and a balancing loop through class size, coupled at the pupils on roll, with the delay on the funding.