

Part V — Pattern and Judgment

Choosing the Diagram

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

All six diagram types Part V · Pattern and Judgment · Chapter 12 of 12 · the closing chapter

Which diagram, if any, answers your question? Each of the six diagram types answers its own kind of question, so you may draw several for one situation, and none for a question arithmetic answers.

Ana's two hives

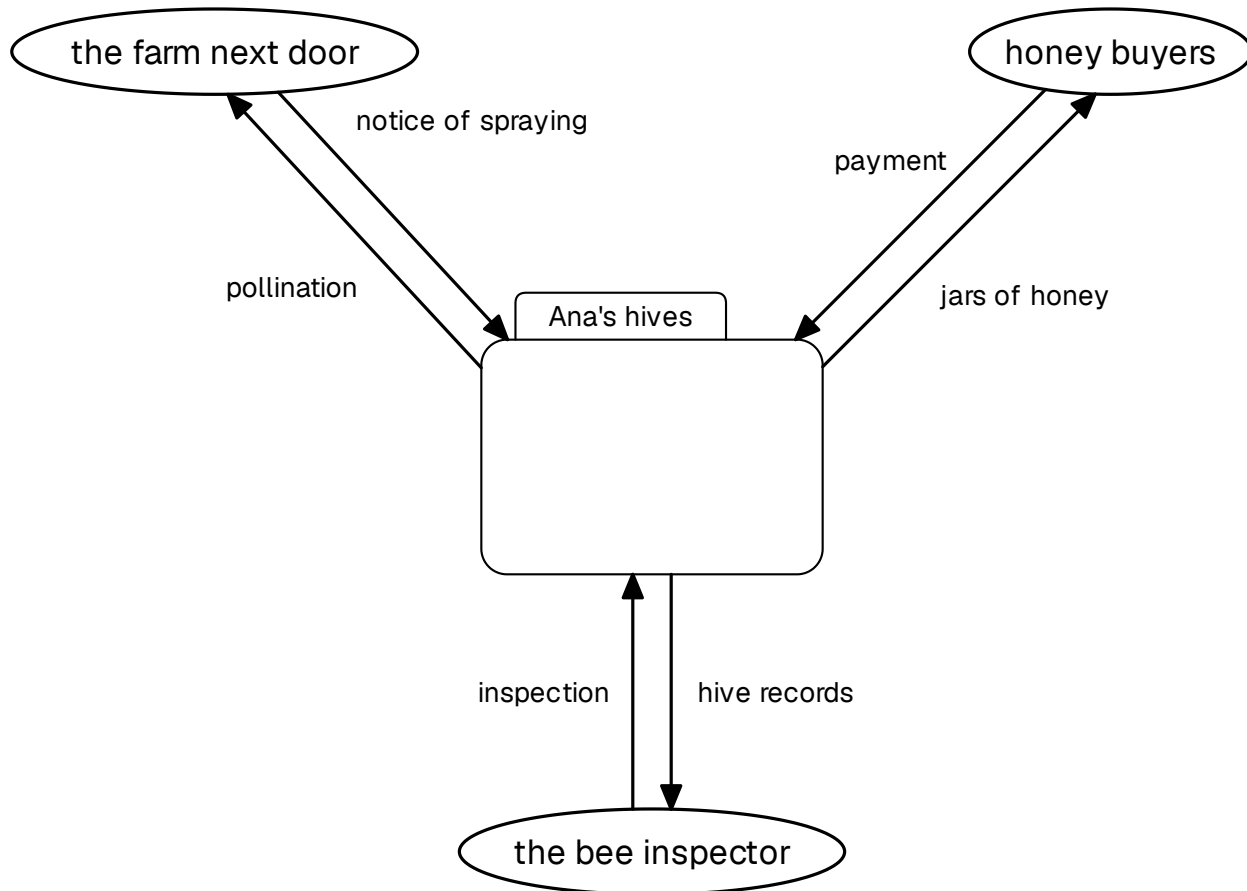
Ana keeps two colonies of honey bees in her garden. She sells honey, the farm next door sprays its crops, and a bee inspector calls. Her questions:

1. Whom do I deal with, and what passes each way?
2. What bears on the honey I harvest?
3. Why does a growing colony swarm?
4. How much honey can I take and still leave enough?
5. How do I keep each hive heavy enough for winter?
6. Have I seen this story before?

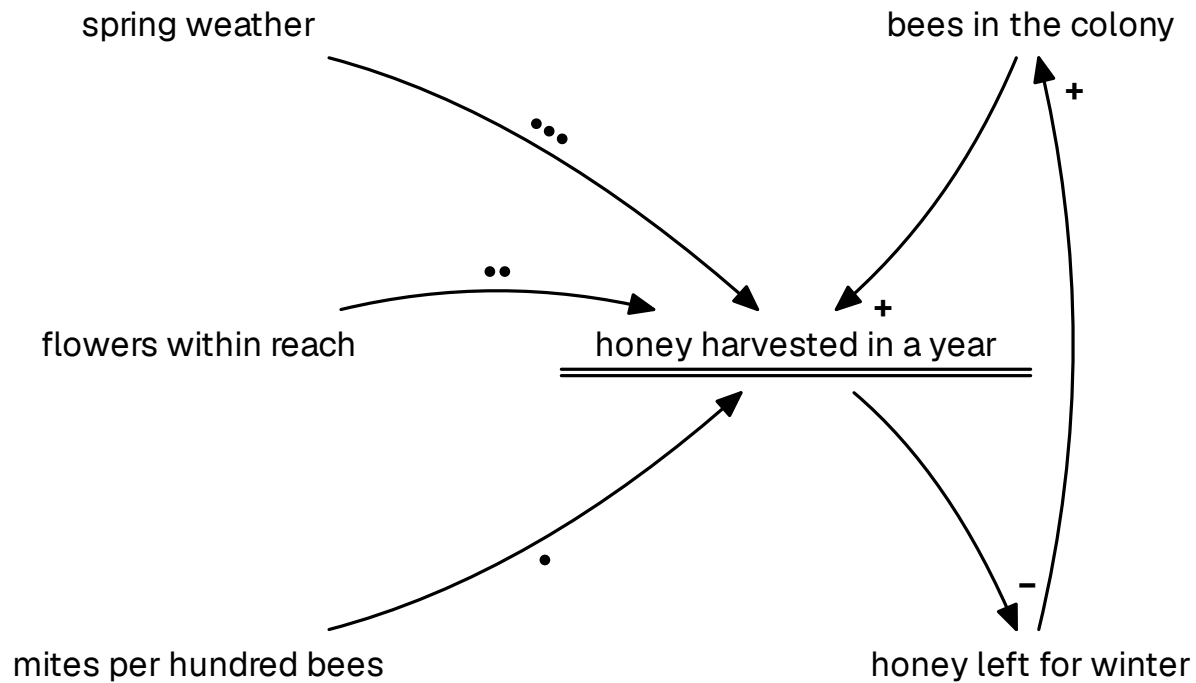
In Britain a colony needs 15 to 20 kg of stored honey to survive the winter. Beekeepers judge what a hive holds by hefting it, lifting one side a few inches, and feed a light one sugar syrup in autumn (Gill, 2021). A crowded colony swarms: half or more of its workers leave with the old queen, and the colony splits in two (Ellis, DeBerry and Crowley).

What each type answers

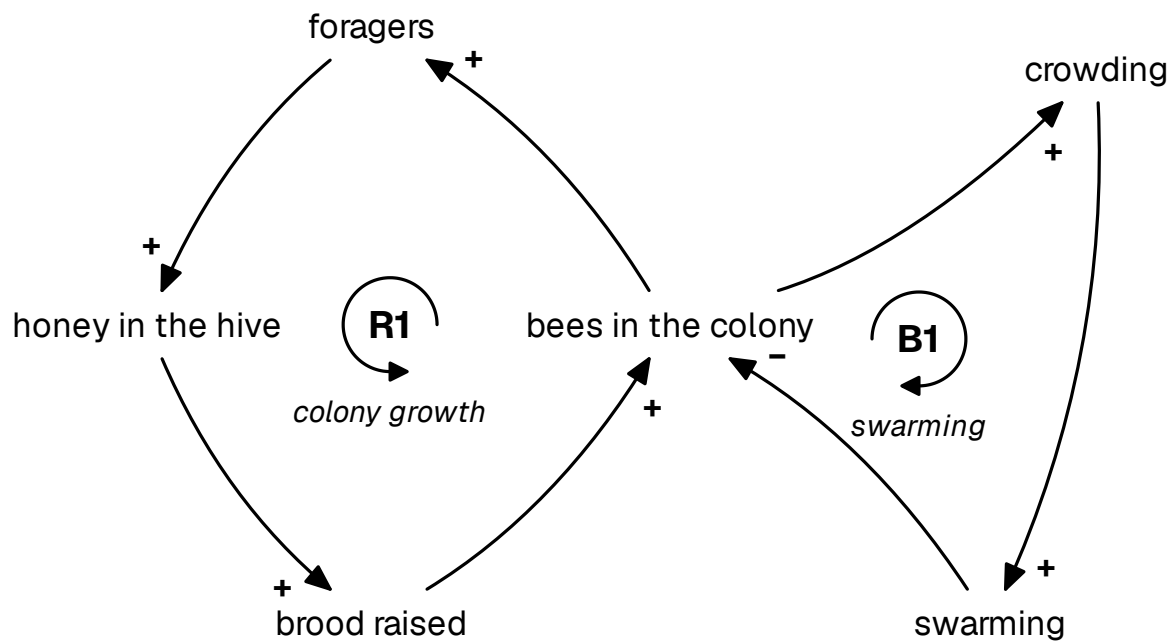
System context map



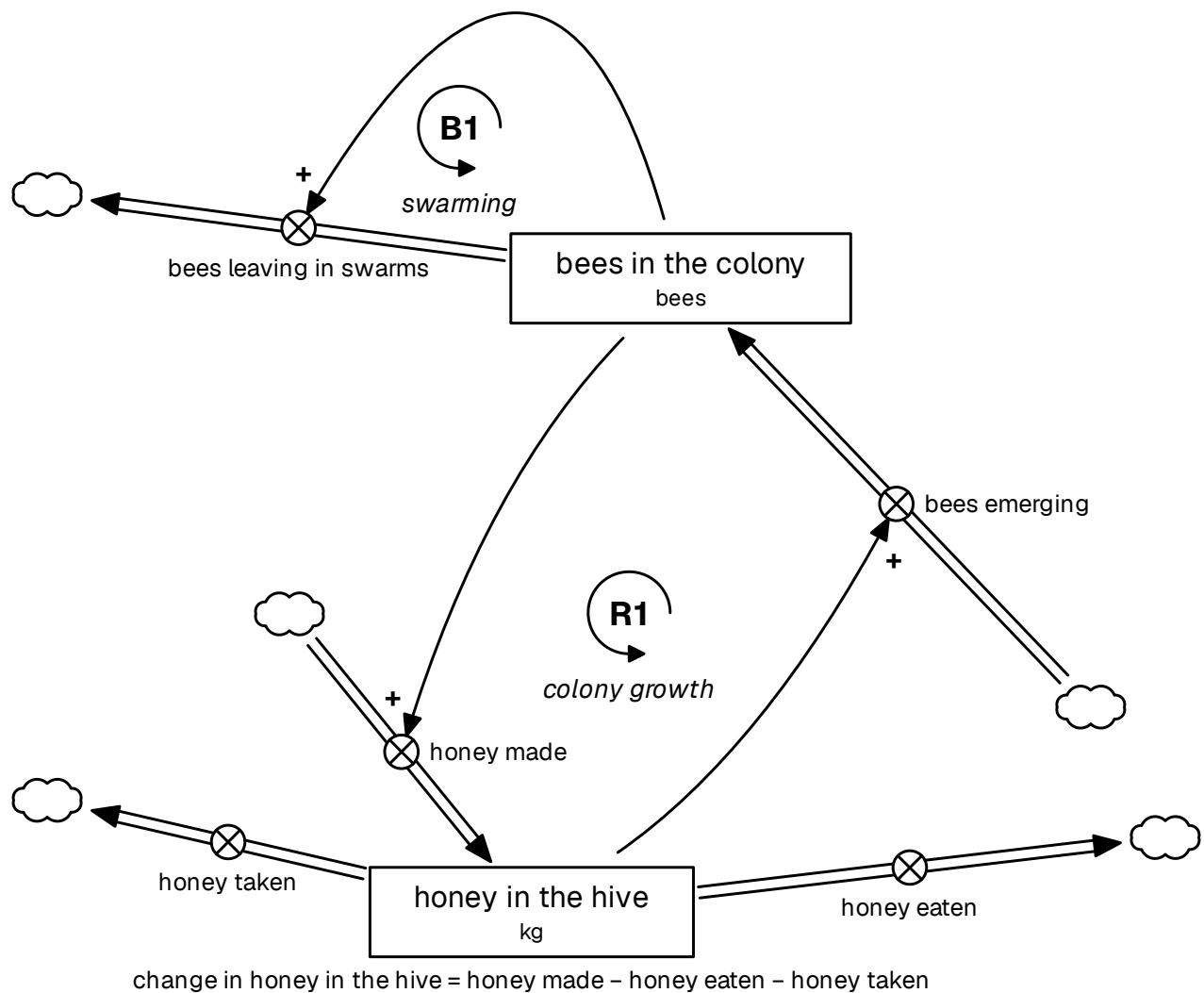
For question 1, the boundary is *Ana's hives*, with three parties outside it and one exchange each way with each. Nothing inside the hives is drawn, and no amount or date. The marks are chapter 2's thinking-in-diagrams.aryehnielsen.com/framing/drawing-the-boundary/#what-the-notation-expresses.

Influence map

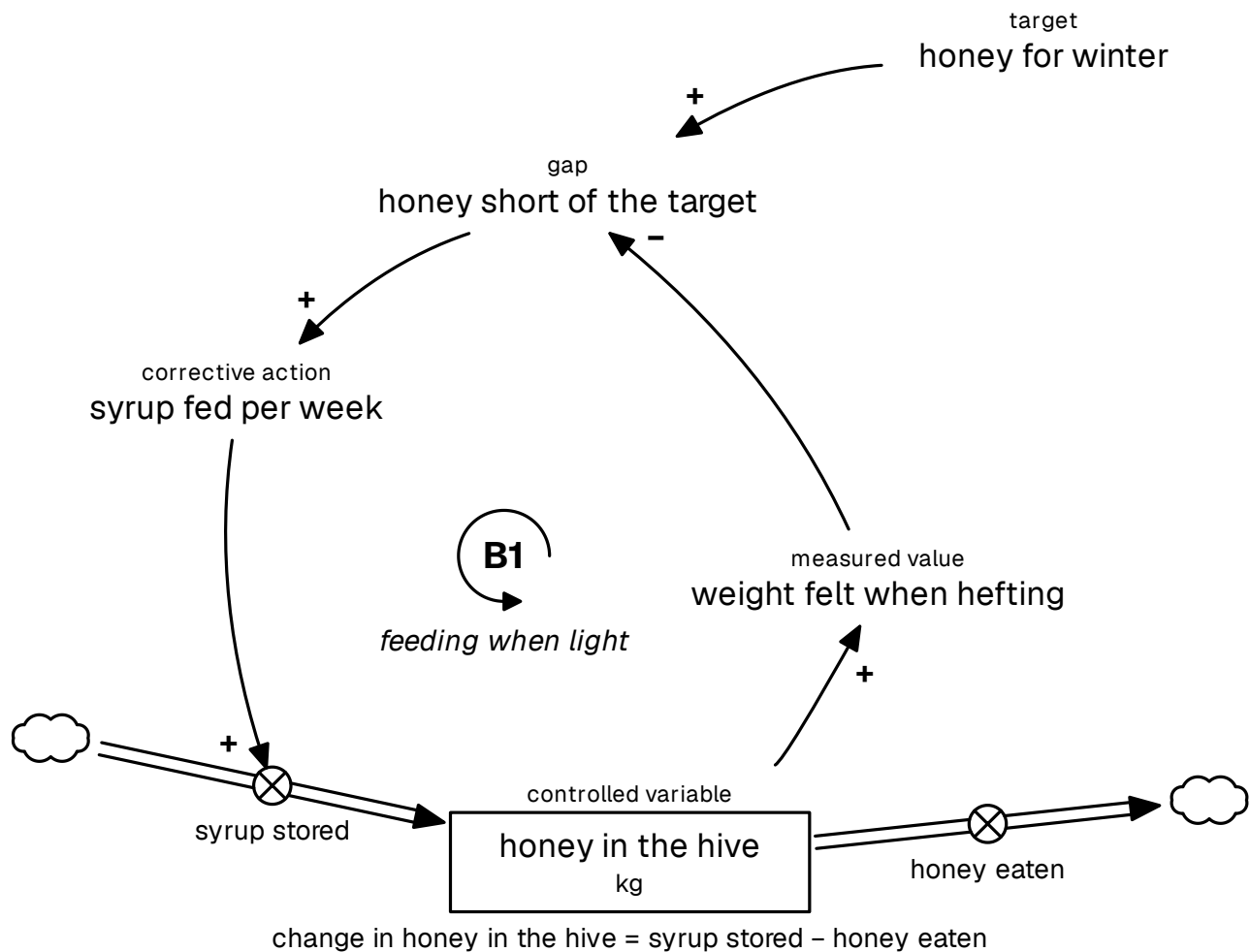
For question 2, spring weather, flowers within reach and mites per hundred bees bear on *honey harvested in a year*, weighted by Ana, with no direction: she has no record of which way each acts. Its causal claims are the three effects Ana measured from past years' records. No amount is drawn. The marks are chapter 3's thinking-in-diagrams.aryehnielsen.com/framing/surfacing-influences/#what-the-notation-expresses.

Causal loop diagram

For question 3, R1, *colony growth*, runs through foragers, honey and brood, and B1, *swarming*, through crowding. The loops share only *bees in the colony*: the more bees, the more crowding, and a crowded colony swarms through B1. Nothing shows what accumulates, nor how many bees crowd a hive. The marks are chapter 4's thinking-in-diagrams.aryehnielsen.com/feedback/loops-that-amplify-loops-that-correct/#what-the-notation-expresses, with chapter 5's.

Stock & flow diagram

For question 4, *bees in the colony* and *honey in the hive* accumulate, in bees and kilograms, filled and drained by flows per week. Honey taken drains the stock that honey eaten drains all winter: the stock equation, *change in honey in the hive = honey made - honey eaten - honey taken*, shows that what Ana takes in late summer has to leave 15 to 20 kg behind. Why the flows change is drawn only as far as three signals. The marks are chapter 6's thinking-in-diagrams.aryehnielsen.com/accumulation/what-accumulates/#what-the-notation-expresses, with chapter 7's.

Feedback control diagram

For question 5, this is the stock & flow diagram's honey with four variables and an inflow, *syrup stored*, added, and roles written above names, as chapter 8's thermostat

thinking-in-diagrams.aryehnielsen.com/control/sense-compare-correct/#control-with-accumulation is drawn over a stock:

honey for winter is the target, *weight felt when hefting* the measured value, *honey short of the target* the gap, *syrup fed per week* the corrective action, and *honey in the hive* the controlled variable. B1, *feeding when light*, is its control loop. Honey made and honey taken, off the loop, are left out. The marks are chapter 8's

thinking-in-diagrams.aryehnielsen.com/control/sense-compare-correct/#what-the-notation-expresses, with chapter 9's.

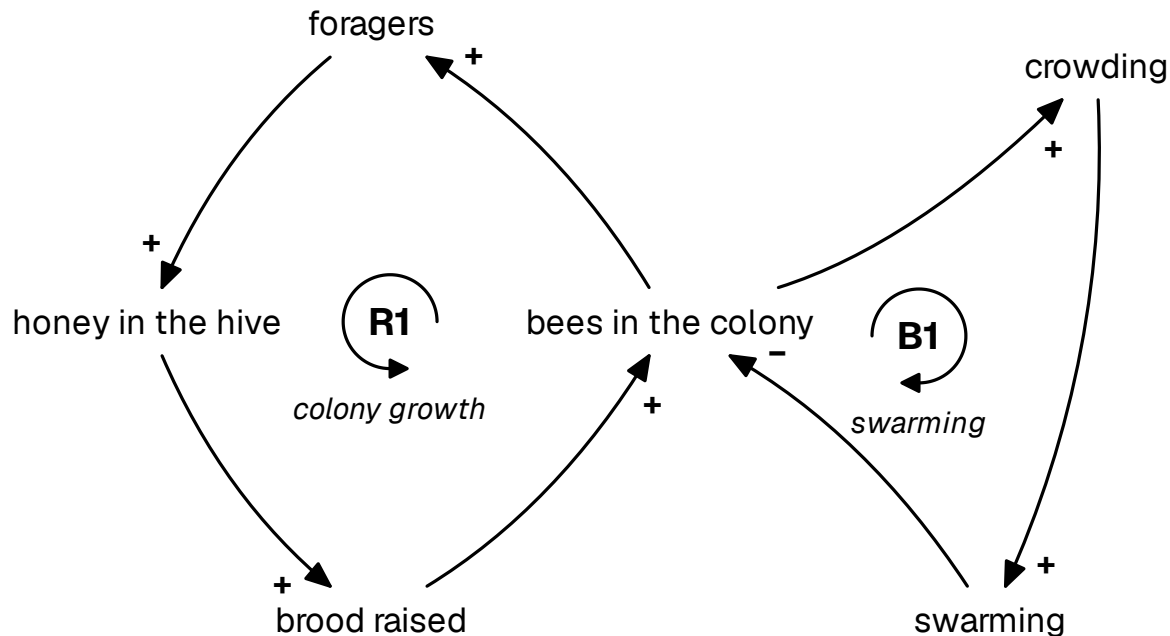
CHECK YOUR UNDERSTANDING

A family of five fills its laundry basket in a day or two. Each evening one parent looks in, and runs a wash if the clothes are above a line marked inside the basket; the machine washes at most one basketful a day. The parents' question: does one look each evening keep the basket from overflowing? Which diagram answers it?

- a A feedback control diagram
- b A stock & flow diagram
- c A causal loop diagram
- d A system context map

Feedback: Answers, chapter 12

System archetype



Archetype: limits to growth

For question 6, this is the causal loop diagram with one line written on it: *Archetype: limits to growth*. A reinforcing loop and a balancing loop sharing one variable, *bees in the colony*, match limits to growth

thinking-in-diagrams.aryehnielsen.com/pattern-and-judgment/structures-that-recur/#limits-to-growth: growth that meets a limit. No role is written, since limits to growth has none. The match is a hypothesis about the loops, not a verdict on the hives. The marks are chapter 10's

thinking-in-diagrams.aryehnielsen.com/pattern-and-judgment/structures-that-recur/#what-the-notation-expresses, with chapter 11's.

Converting between types

An influence map into a causal loop diagram, in the lab: chapter 3's conversion

thinking-in-diagrams.aryehnielsen.com/framing/surfacing-influences/#conversion-to-a-causal-loop-diagram carries over the variables and causal claims only. From Ana's map, three causal claims carry over, *bees in the colony* → *honey harvested in a year* → *honey left for winter* → *bees in the colony*, with one -: declared, their path is a balancing loop, *taking too much*. Ana decides which influence claim she upgrades next, and on what evidence.

A causal loop diagram into a system archetype, in the lab: a causal loop diagram's file opens in an archetype lab as its own, every variable, effect and loop carried over, with its matches

thinking-in-diagrams.aryehnielsen.com/pattern-and-judgment/structures-that-recur/#matching listed. Whoever draws it writes the roles and the declaration.

CHECK YOUR UNDERSTANDING

A causal loop diagram of a town's night buses shows R1, riders → fares collected → buses running → riders, all +, and B1, riders → standing passengers +, standing passengers → riders -. It is opened in an archetype lab and declared limits to growth. What changes in the drawing?

- a One line is added: Archetype: limits to growth
- b The variables are redrawn as stocks and flows
- c Roles are written above riders, fares collected and standing passengers
- d Nothing: the match is listed, so no declaration is written

Feedback: Answers, chapter 12

A causal loop diagram into a stock & flow diagram, by hand: Ana decides what accumulates. *Bees in the colony* and *honey in the hive* become stocks thinking-in-diagrams.aryehnielsen.com/accumulation/what-accumulates/#stocks ; *brood raised* and *swarming* become the flows *bees emerging* and *bees leaving in swarms*; *foragers* and *crowding* fold into the signals thinking-in-diagrams.aryehnielsen.com/accumulation/what-accumulates/#signals that set those flows. The lab has no such conversion: what accumulates is a judgment, and most causal loop diagrams have effects ending at variables that would become stocks, where a stock & flow diagram has no signal end.

A stock & flow diagram into a feedback control diagram, by hand: the stocks, flows, clouds and signals carry over, and Ana decides which variables are the target, the measured value, the gap, the corrective action and the controlled variable, adding those not yet drawn, as the thermostat is drawn over its stock in chapter 8

thinking-in-diagrams.aryehnielsen.com/control/sense-compare-correct/#control-with-accumulation. Auxiliaries become plain variables. Here Ana keeps the honey and *honey eaten*, and adds the target, the hefted weight, the gap, the syrup fed and *syrup stored*.

When not to draw

A sentence, a list or a table holds everything a diagram would when the answer is one quantity reached by arithmetic, when nothing comes back around, when no boundary is in dispute, or when the parties can be listed without what passes each way. Each type's own case is in its first chapter's *What stays informal*: chapter 2

thinking-in-diagrams.aryehnielsen.com/framing/drawing-the-boundary/#what-stays-informal, chapter 3

thinking-in-diagrams.aryehnielsen.com/framing/surfacing-influences/#what-stays-informal, chapter 4

thinking-in-diagrams.aryehnielsen.com/feedback/loops-that-amplify-loops-that-correct/#what-stays-informal, chapter 6

thinking-in-diagrams.aryehnielsen.com/accumulation/what-accumulates/#what-stays-informal, chapter 8

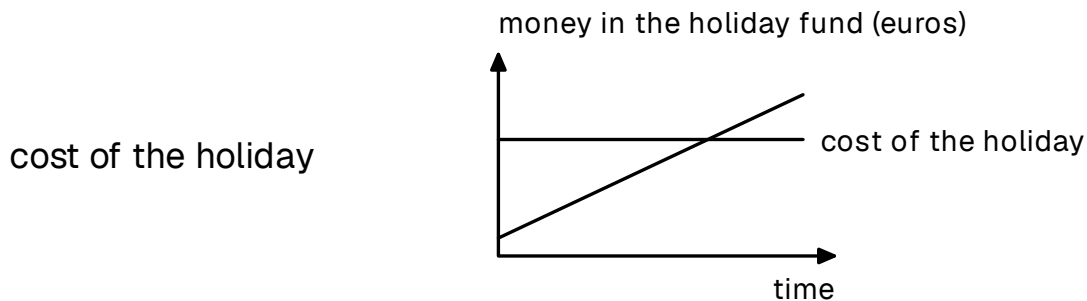
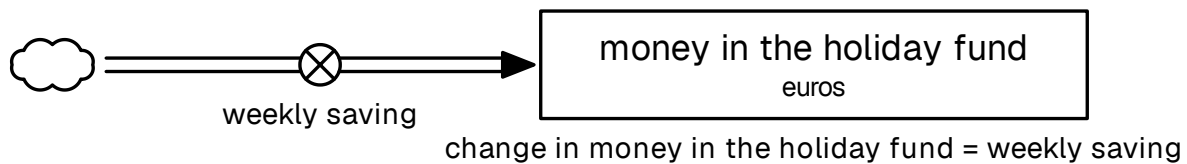
thinking-in-diagrams.aryehnielsen.com/control/sense-compare-correct/#what-stays-informal and chapter 10

thinking-in-diagrams.aryehnielsen.com/pattern-and-judgment/structures-that-recur/#what-stays-informal.

A diagram shows in one place what is used together, so less has to be searched for; drawn without that grouping, a diagram takes as much searching as the words (Larkin and Simon, 1987).

The bad diagram

What's wrong with this diagram of a holiday fund?



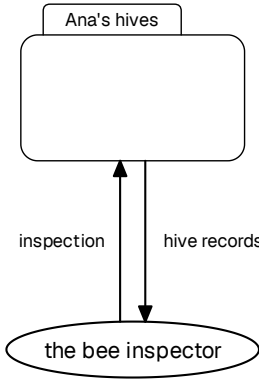
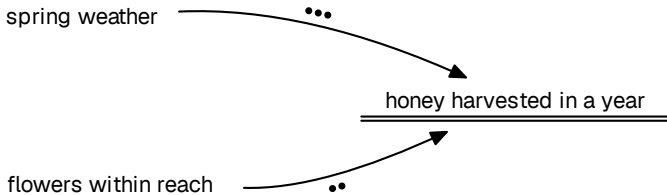
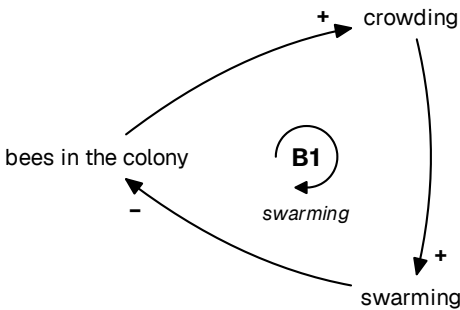
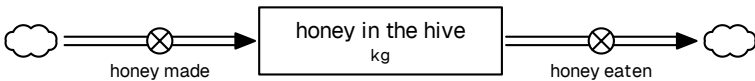
Nothing in its marks: each of the lab's checks on a stock & flow diagram passes or is pending.

The sentence

| At €50 a week from the €400 already saved, the fund reaches the holiday's €1,200 in 16 weeks.

The diagram holds one stock, one steady inflow, no outflow and no loop, and the sentence holds all of it, with the numbers missing from the diagram.

Notation moves

Notation move	When	What it shows	Example
Draw a system context map	The question is whom a system deals with	The boundary, the parties outside, what passes each way	<i>Ana's hives</i> and the bee inspector
			
Draw an influence map	Many things bear on one outcome, most in unmeasured directions	What bears on the outcome, ranked	<i>honey harvested in a year</i>
			
Draw a causal loop diagram	A change comes back around	Loops and their kinds	B1 <i>swarming</i>
			
Draw a stock & flow diagram	Something accumulates	Stocks, the flows that fill and drain them, units	<i>honey in the hive, in kg</i>
			

Notation move	When	What it shows	Example
Draw a feedback control diagram	Someone holds a quantity near a value they chose	The control loop, its roles written	<i>honey for winter, the target</i>
Draw a system archetype	The loops have a structure that recurs across situations	A hypothesis about the loops	<i>Archetype: limits to growth</i>
Archetype: limits to growth			
Convert an influence map into a causal loop diagram	Causal claims close a path	The loop, to declare	<i>B1 taking too much</i>
Open a causal loop diagram in an archetype lab	The question turns to which archetype the loops match	The loops, their matches listed	the hives' R1 and B1

Notation move	When	What it shows	Example
Write a sentence	The answer is one quantity reached by arithmetic	Everything the diagram would	the holiday fund

Common misreading

A type is read as a property of the situation: the hives as a *stock & flow situation*, the holiday fund as a *stock & flow problem*. The type belongs to the question. Ana's hives are drawn as all six types, one per question, and the holiday fund's one question as none.

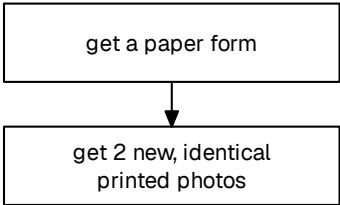
The strongest objection

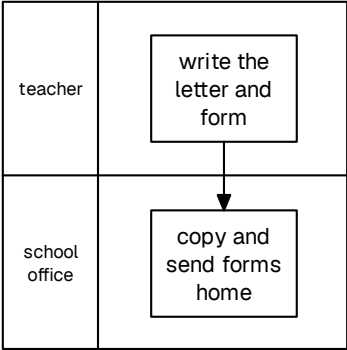
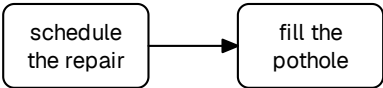
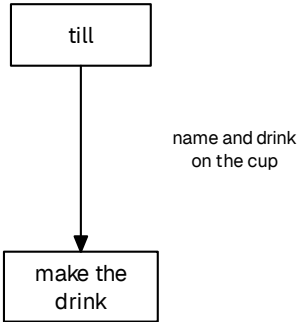
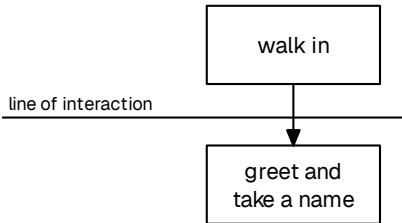
The question rarely comes first: people draw to find out what it is. In soft systems methodology the problem in many situations is “what is the problem?”, and a rich picture of the situation is drawn before any problem is defined (Institute for Manufacturing).

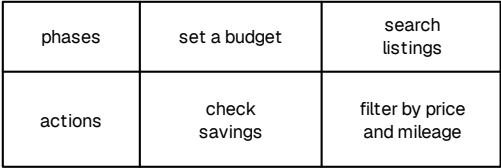
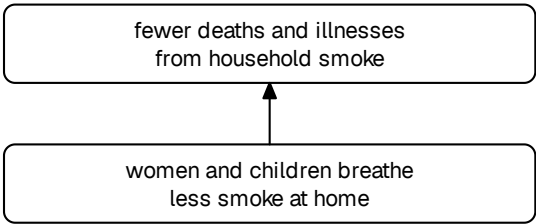
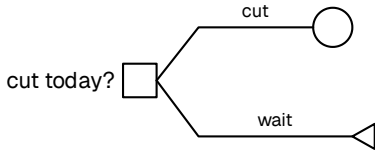
Two of the six types are drawn before the question is settled. A system context map holds only a boundary, the parties outside it and what passes each way, and an influence map only an outcome and what bears on it, no direction known. When the question changes, the drawing is converted, as Ana's influence map was into a causal loop diagram, or redrawn in the type of the new question.

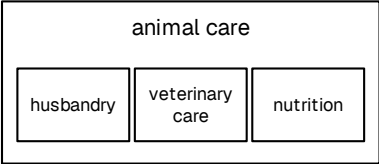
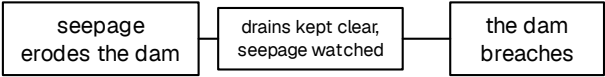
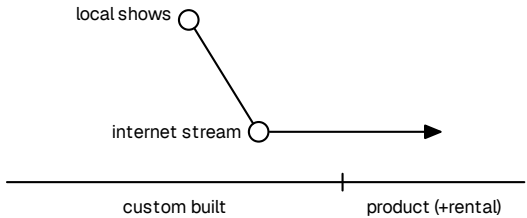
Other families

A line with an arrowhead means *changes* in four of the six types, *passes* in a system context map and *bears on* in an influence map, but *then* in a process map, where a closed path is rework, not a loop, so a process map can't share their editor or checker.

Type	Family	Question it answers	A line with an arrowhead means
process map thinking-in- diagrams.aryehnielsen.com/field- guide/process-map/	processes & experience	What steps does the work go through, with its decisions, exceptions and rework?	<i>then</i> : the next step
 <pre> graph TD A[get a paper form] --> B[get 2 new, identical printed photos] </pre>			

Type	Family	Question it answers	A line with an arrowhead means
swimlane diagram thinking-in-diagrams.aryehnielsen.com/field-guide/swimlane-diagram/	processes & experience	Who does each step, and where does work change hands?	<i>then</i> , across lanes at a change of hands
			
BPMN thinking-in-diagrams.aryehnielsen.com/field-guide/bpmn/	processes & experience	What happens, precisely enough that it could be run?	<i>then</i> ; between participants, what is sent
			
value stream map thinking-in-diagrams.aryehnielsen.com/field-guide/value-stream-map/	processes & experience	Where does material wait from order to delivery, and what starts each step?	<i>then</i> ; separate lines carry information
			
service blueprint thinking-in-diagrams.aryehnielsen.com/field-guide/service-blueprint/	processes & experience	How does what the customer sees connect to the work behind it?	<i>depends on</i> , across the rows; time is position
			

Type	Family	Question it answers	A line with an arrowhead means
customer journey map thinking-in-diagrams.aryehnielsen.com/field-guide/customer-journey-map/	processes & experience	How does the customer's experience change, stage by stage?	No arrowheads: stages are columns
			
theory of change thinking-in-diagrams.aryehnielsen.com/field-guide/theory-of-change/	strategy & decisions	What must change, and in what order, to reach a long-term outcome?	<i>must come before</i> : a precondition
			
decision tree thinking-in-diagrams.aryehnielsen.com/field-guide/decision-tree/	strategy & decisions	Which choice, given the chances of what follows each?	No arrowheads: a branch per choice or outcome
			
stakeholder map thinking-in-diagrams.aryehnielsen.com/field-guide/stakeholder-map/	strategy & decisions	Who can affect or is affected by a decision, with what power and interest?	Nothing: each party has a place on two axes
			

Type	Family	Question it answers	A line with an arrowhead means
capability map thinking-in-diagrams.aryehnielsen.com/field-guide/capability-map/	strategy & decisions	What must an organization be able to do, whatever its structure?	Nothing: a box inside another is part of it
			
risk bow-tie thinking-in-diagrams.aryehnielsen.com/field-guide/risk-bow-tie/	strategy & decisions	What could release one hazard, what follows, and what barriers stand between?	No arrowheads: <i>can lead to</i> , threat to top event to consequence
			
Wardley map thinking-in-diagrams.aryehnielsen.com/field-guide/wardley-map/	strategy & decisions	What does someone need, what chain of components meets it, and how evolved is each?	<i>moves to</i> : expected evolution; plain lines, <i>needs</i>
			

Check your understanding

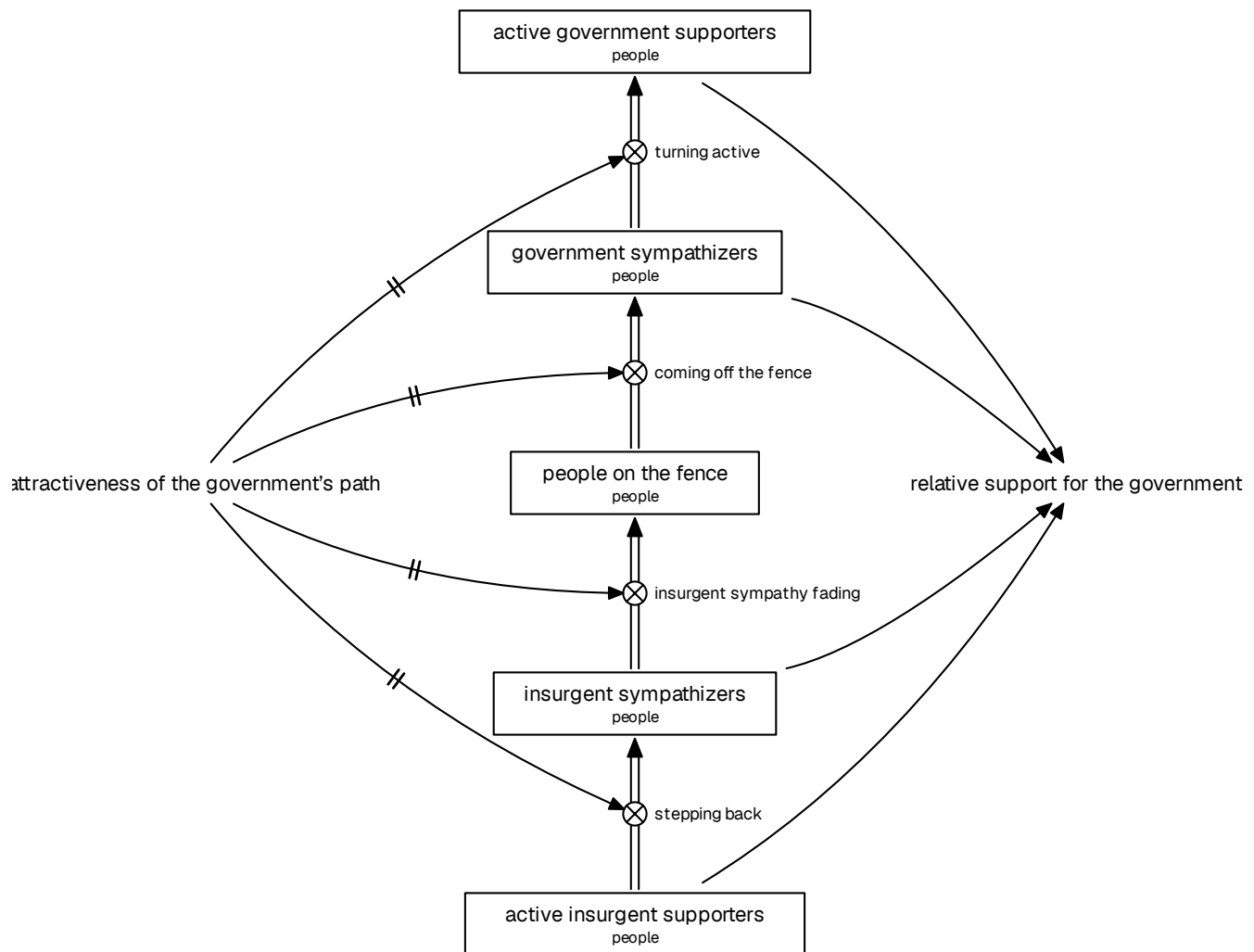
CHECK YOUR UNDERSTANDING

A chess club's treasurer is asked three things. Which one can the treasurer answer without a diagram?

- a How many weeks until the club's fund, €200 now and €40 added a week, reaches the €680 that new clocks cost
- b Why more members bring more volunteers to teach beginners, and more teaching brings more members
- c Whom the club deals with, from the hall it rents to the league it plays in, and what passes each way

Feedback: Answers, chapter 12

Popular support in Afghanistan, redrawn



Redrawn from PA Consulting Group, "Afghanistan Stability / COIN Dynamics", in Dynamic Planning for COIN in Afghanistan, working draft (2009), as published by NBC News

web.archive.org/web/20091228212221/http://msnbcmedia.msn.com:80/i/MSNBC/Components/Photo/_new/Afghanistan_Dynamic_Planning.pdf, page 22, its popular support cluster. © PA Knowledge Limited 2009; its structure and short labels only.

Seven of its 110 or so variables, its popular support cluster, with the lines into it from other clusters left out; its five stocks of people renamed shorter, the first losing & SF, and given units, people, and the month declared as the time unit the slide leaves out; each flow, drawn there running both ways, drawn one way, toward the government's side, as the net movement, and named; its other two names shortened; its lines left without + or -, as drawn; its double strokes for a significant delay drawn as delays; its color left out

QUESTION 1 OF 3

Which question does this part of the slide, drawn as a stock & flow diagram, answer?

- a Why people move toward the government or toward the insurgents.
- b How many people hold each of five stances, and how fast they move between neighboring stances.
- c Whether the coalition's actions shift popular support.

QUESTION 2 OF 3

The slide comes from a brief for planning a counterinsurgency: which actions shift popular support toward the government, and how fast. Which drawing would answer that?

- a** The whole slide, since every variable is on it.
- b** An influence map, with popular support as its central outcome.
- c** A stock & flow diagram of the five stocks with the few loops through their flows that the plan acts on.

QUESTION 3 OF 3

Would a sentence do in place of this part?

- a** No: five stocks are too many for a sentence.
- b** No: a sentence can't carry the delays.
- c** Yes: no loop closes in it, and one sentence holds what it shows.

Feedback: Answers, chapter 12

Exercises

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

CD 01 A mountain rescue team

Ines is the new leader of a volunteer mountain rescue team in a valley of hill farms. The police take each emergency call from the hills and pass the team a callout, and after each rescue the team sends the police a rescue report. The team carries casualties down to the hospital in the valley town, and the hospital returns the team's stretchers. For a serious injury or a long carry, the team requests a helicopter from the helicopter service, which airlifts the casualty. Donors give the team money, and the team sends them a yearly account of what it spent. Walkers and farmers phone in reports of washed-out paths and fallen bridges, and the team posts route warnings at the valley's car parks. Ines's question: whom does the team deal with, and what passes each way?

WHICH DIAGRAM?

What does Ines draw, or write, to answer her question?

- a** A system context map
- b** No diagram: a list
- c** A causal loop diagram
- d** An influence map
- e** A stock & flow diagram

Feedback: Answers, chapter 12

CD 01 A mountain rescue team

The parties outside one boundary, and what passes each way

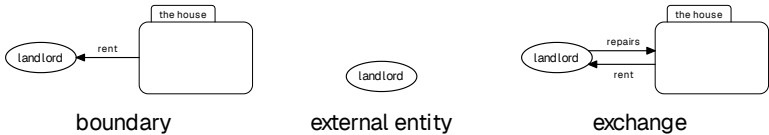
Reasoning ●●○○○ 2 of 5 Polish ●●○○○ 2 of 5

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The brief

- ☐ Draw one boundary around the team.
- ☐ Place at least four external entities outside it.
- ☐ Draw at least six exchanges, each naming one thing.
- ☐ Show at least three external entities that both give to the team and receive from it.
- ☐ The helicopter service is a party outside the team, not part of it.

Your palette



Draw here

A large grid of dots for drawing.

CD 02 Moving to another city for a job

Mateus has been offered a job in a city four hours away by train, at a salary a third above what he earns now, leading a team of eight people; he has never led a team. His partner, Ilse, teaches piano to thirty pupils near their flat, and her chances of work in the city depend on its music schools, one of which is hiring. His parents live ten minutes away, and he spends about five hours a week helping them, how many depending on his father's health. Only the salary's pull is plain to him: the higher the salary on offer, the stronger his wish to move. Of the rest, he can't yet say which way each pushes: he would miss the Saturdays with his parents and would also have them to himself; leading eight people might draw him to the job or put him off it; and Ilse hasn't said whether starting again in the city would suit her. Mateus's question: what bears on his wish to move?

WHICH DIAGRAM?

What does Mateus draw, or write, to answer his question?

- a** A causal loop diagram
- b** No diagram: a list
- c** An influence map
- d** A system context map
- e** A stock & flow diagram

Feedback: Answers, chapter 12

CD 02 Moving to another city for a job

What bears on one outcome, most of it in no known direction

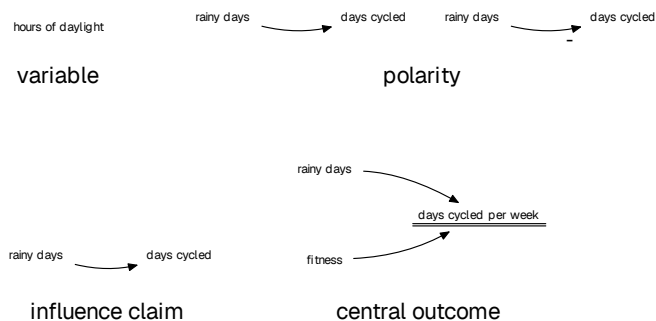
Reasoning ●●○○○ 2 of 5 Polish ●●●○○ 3 of 5

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The brief

- ☐ Draw at least four direct influences on Mateus's wish to move.
- ☐ Draw at least one indirect influence.
- ☐ Leave at least three claims without a + or –.
- ☐ Upgrade exactly one claim: the one whose direction Mateus can say.
- ☐ Each variable is a quantity that could be more or less, such as hours a week helping his parents, not a topic such as family.

Your palette



Draw here

CD 03 Carbon dioxide in the atmosphere

Halima reads that the world's yearly emissions of carbon dioxide may soon stop growing. Burning fossil fuels and clearing land put about 11 billion tonnes of carbon a year into the air, as carbon dioxide. The oceans absorb about 3 billion tonnes of it a year, and forests and other vegetation on land about 2; the rest stays in the air. Suppose emissions hold steady at 11 billion tonnes a year from now on, and the oceans and the vegetation go on absorbing about as much as now. Count the carbon dioxide by the carbon it holds, in billion tonnes, and time in years.

Halima's question: if emissions stop growing and hold steady, does the carbon dioxide in the air stop rising?

WHICH DIAGRAM?

What does Halima draw, or write, to answer her question?

- a** A causal loop diagram
- b** A stock & flow diagram
- c** No diagram: a sentence
- d** An influence map
- e** A feedback control diagram

Feedback: Answers, chapter 12

CD 03 Carbon dioxide in the atmosphere

An amount filled faster than it drains

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

Halima reads that the world's yearly emissions of carbon dioxide may soon stop growing. Burning fossil fuels and clearing land put about 11 billion tonnes of carbon a year into the air, as carbon dioxide. The oceans absorb about 3 billion tonnes of it a year, and forests and other vegetation on land about 2; the rest stays in the air. Suppose emissions hold steady at 11 billion tonnes a year from now on, and the oceans and the vegetation go on absorbing about as much as now. Count the carbon dioxide by the carbon it holds, in billion tonnes, and time in years. Halima's question: if emissions stop growing and hold steady, does the carbon dioxide in the air stop rising?

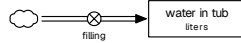
The brief

- ☐ Draw the carbon dioxide in the air as one stock, counted in billion tonnes of carbon.
- ☐ Draw the emissions as an inflow.
- ☐ Draw at least one outflow: what the oceans and vegetation on land absorb.
- ☐ Add a behavior-over-time graph of the stock while emissions hold steady: its direction is Halima's answer.
- ☐ Emissions held steady still exceed what the oceans and vegetation on land absorb.

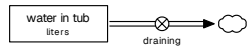
Your palette



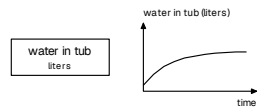
stock



flow



cloud



behavior-over-time graph

Draw here

CD 04 Two siblings and one games console

Noor, eleven, and Felix, nine, share one games console. Each Sunday their father splits the coming week's turns on it between them by their best scores that week in the racing game they both play: the higher Noor's best score, the larger her share of the turns, and the higher Felix's, the smaller her share. The more turns a child gets, the more hours that child plays, and the more hours played, the higher that child's best score. In the first week, Noor scored a few points higher than Felix. Their father's question: is this a story others have seen, and how does it usually run?

WHICH DIAGRAM?

What does their father draw, or write, to answer his question?

- a** A causal loop diagram
- b** An influence map
- c** A system archetype
- d** A stock & flow diagram
- e** No diagram: a sentence

Feedback: Answers, chapter 12

CD 04 Two siblings and one games console

Two loops through one split, and the name of their story

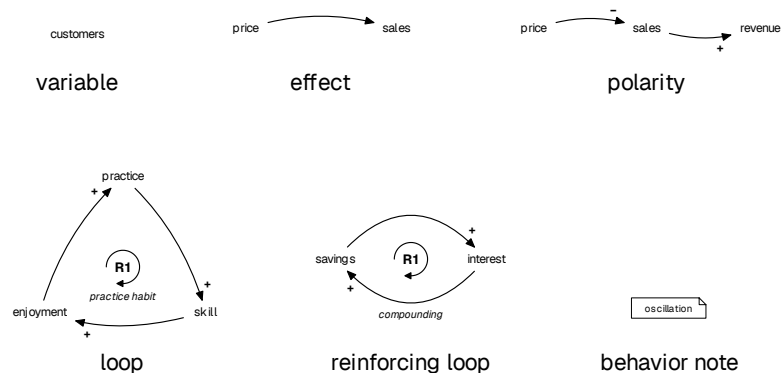
Reasoning ●●●○○ 3 of 5 Polish ●●●○○ 3 of 5

Noor, eleven, and Felix, nine, share one games console. Each Sunday their father splits the coming week's turns on it between them by their best scores that week in the racing game they both play: the higher Noor's best score, the larger her share of the turns, and the higher Felix's, the smaller her share. The more turns a child gets, the more hours that child plays, and the more hours played, the higher that child's best score. In the first week, Noor scored a few points higher than Felix. Their father's question: is this a story others have seen, and how does it usually run?

The brief

- ☐ Draw two reinforcing loops, one through each child's hours on the console.
- ☐ Match the two loops to one of chapter 10's archetypes.
- ☐ Declare that archetype in one line.
- ☐ Add a behavior note on how the split runs, week by week.
- ☐ The father's rule is one variable, Noor's share of the turns, on both loops.
- ☐ In the note: Noor's lead of a few points in the first week, and her share larger every week after.

Your palette



Archetype: fixes that fail

archetype

Draw here

CD 05 A canal through a dry summer

Through a dry summer, Ruth keeps the long top stretch of a canal deep enough for boats. Every boat through a lock at either end of the stretch draws thousands of litres of water out of it, and on a busy day dozens of boats pass. Water comes into the stretch from a lake dammed in the hills, along a feeder, and Ruth sets how much she lets in each day; the feeder carries only so much a day. She reads the depth on a gauge board once each morning, and the further it reads below the depth boats need, the more water she lets in that day. Count the water in the stretch as its depth, in centimetres, and time in days. Ruth's question: how do her morning reading and the water she lets in hold the stretch at the depth boats need, and where can that fall short?

WHICH DIAGRAM?

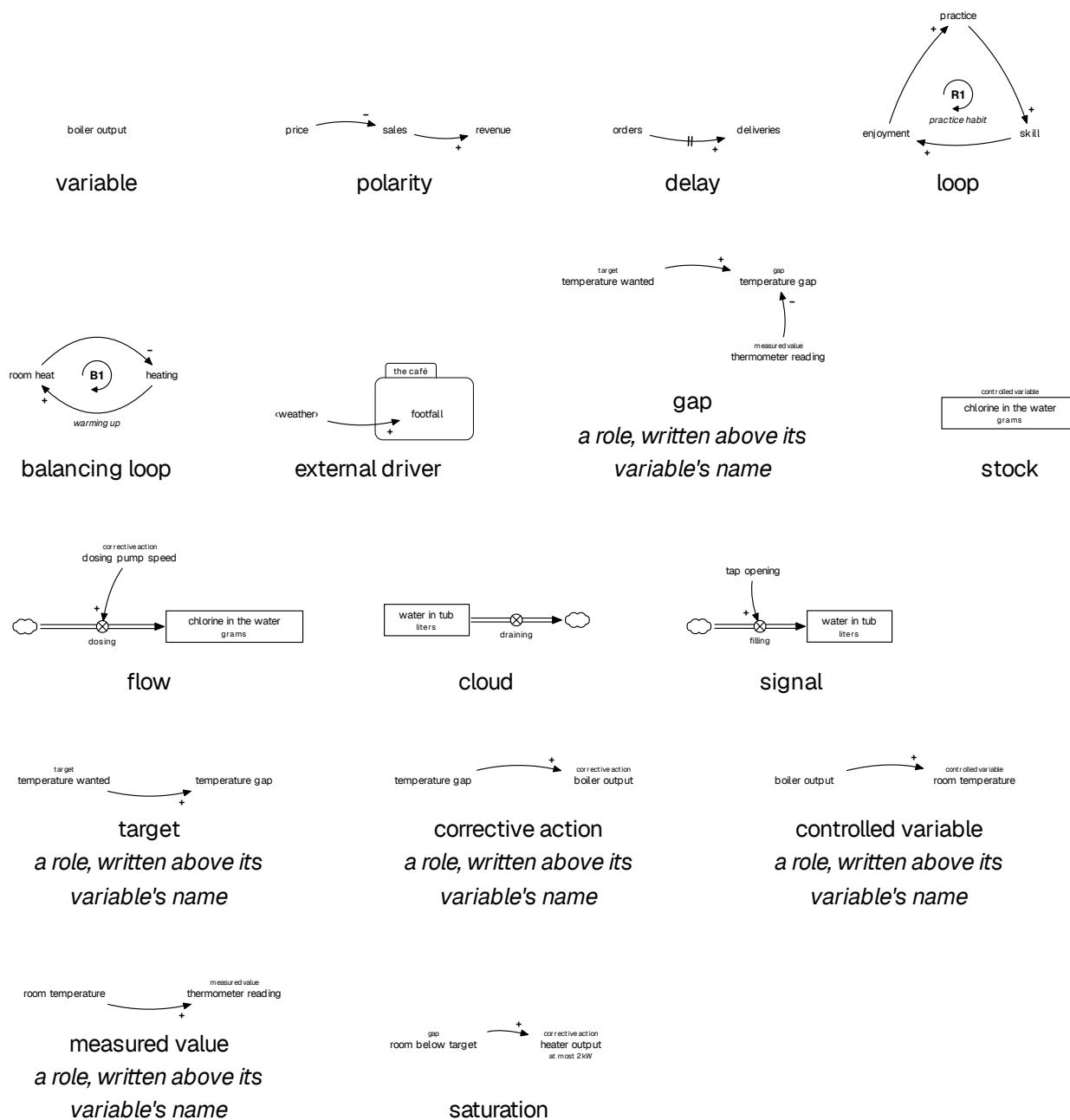
What does Ruth draw, or write, to answer her question?

- a** A stock & flow diagram
- b** A causal loop diagram
- c** A system context map
- d** A feedback control diagram
- e** No diagram: a sentence

Feedback: Answers, chapter 12

CD 05 A canal through a dry summer

Your palette



CD 05 A canal through a dry summer

A depth held by a reading once a day and an inflow with a limit

Reasoning ●●●●○ 4 of 5 Polish ●●●●○ 4 of 5

Through a dry summer, Ruth keeps the long top stretch of a canal deep enough for boats. Every boat through a lock at either end of the stretch draws thousands of litres of water out of it, and on a busy day dozens of boats pass. Water comes into the stretch from a lake dammed in the hills, along a feeder, and Ruth sets how much she lets in each day; the feeder carries only so much a day. She reads the depth on a gauge board once each morning, and the further it reads below the depth boats need, the more water she lets in that day. Count the water in the stretch as its depth, in centimetres, and time in days. Ruth's question: how do her morning reading and the water she lets in hold the stretch at the depth boats need, and where can that fall short?

The brief

- ☐ Draw the water in the stretch as one stock, counted in centimetres of depth.
- ☐ Close one control loop through the water from the hill lake.
- ☐ Write one target: the depth boats need.
- ☐ Draw the boats through the locks as an external driver acting on the water in the stretch.
- ☐ Mark the once-a-morning reading as a delay on the return path.
- ☐ Write what the feeder carries in a day as the limit on the water Ruth lets in.
- ☐ The target depth is Ruth's choice: no signal ends at it.

Your palette

On the page before this sheet.

Draw here

Grid area for drawing.

CS 12 Kelsham Primary School: the council's question

In October 2026 Kelsham Primary School has 88 pupils, and the county council asks whether to close it. David Brennan, its officer for school places, has the births in the villages to 2025: 12 in 2023, 12 in 2024 and 11 in 2025. Each year's children start school in the September four years later, fewer of them at Kelsham than were born, since some families choose Brayford Primary School: in the year to October 2026, 9 children started and 16 pupils left. Larkfield Homes will finish the 60 homes at Mill Lane from 2027 to 2029, and the county council counts 0.25 children of primary school age for each new home: 15 children in all, joining as the homes are first lived in, and none once the last one is. Tom Hale tells the council the homes will turn the roll around. Count the pupils in pupils, and time in years. David Brennan's question: once the last Mill Lane home is lived in, does the roll go on falling?

WHICH DIAGRAM?**What does David Brennan draw, or write, to answer his question?**

- a** A causal loop diagram
- b** A stock & flow diagram
- c** An influence map
- d** A feedback control diagram
- e** No diagram: a sentence

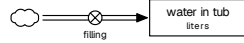
Feedback: Answers, chapter 12

CS 12 Kelsham Primary School: the council's question

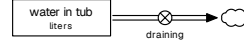
Your palette



stock



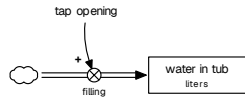
flow



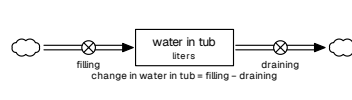
cloud

tap opening

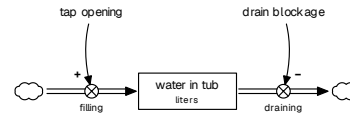
auxiliary



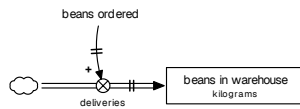
signal



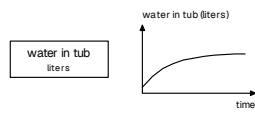
stock equation



polarity



delay

behavior-over-time
graph

CS 12 Kelsham Primary School: the council's question

Choosing the drawing for whether the roll recovers

Reasoning ●●●●○ 4 of 5 Polish ●●●●○ 4 of 5

In October 2026 Kelsham Primary School has 88 pupils, and the county council asks whether to close it. David Brennan, its officer for school places, has the births in the villages to 2025: 12 in 2023, 12 in 2024 and 11 in 2025. Each year's children start school in the September four years later, fewer of them at Kelsham than were born, since some families choose Brayford Primary School: in the year to October 2026, 9 children started and 16 pupils left. Larkfield Homes will finish the 60 homes at Mill Lane from 2027 to 2029, and the county council counts 0.25 children of primary school age for each new home: 15 children in all, joining as the homes are first lived in, and none once the last one is. Tom Hale tells the council the homes will turn the roll around. Count the pupils in pupils, and time in years. David Brennan's question: once the last Mill Lane home is lived in, does the roll go on falling?

The brief

- ☐ Draw the pupils on roll as one stock, counted in pupils.
- ☐ Draw two inflows: the children starting each September, and the children moving into the Mill Lane homes.
- ☐ Draw the pupils leaving as one outflow.
- ☐ Show the stock equation.
- ☐ Draw the births in the villages with a signal to the children starting, delayed by the four years before a child starts.
- ☐ Add a behavior-over-time graph of the roll once the last Mill Lane home is lived in: its direction is David Brennan's answer.
- ☐ The inflow from Mill Lane ends with the last home lived in; the children starting go on each September.

Your palette

On the page before this sheet.

Draw here

Diagram drawing area with a grid of dots.

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Answers

Chapter 12 · Choosing the Diagram

A family of five fills its laundry basket in a day or two. Each evening one parent looks in, and runs a wash if the clothes are above a line marked inside the basket; the machine washes at most one basketful a day. The parents' question: does one look each evening keep the basket from overflowing? Which diagram answers it?

- a A feedback control diagram

Yes. The marked line is a target the parents chose, the evening look a measured value, the clothes above the line a gap, the washes run a corrective action, and the clothes in the basket the controlled variable: a stock with roles written above its names. Whether the washing keeps up turns on the reading once a day and the one basketful a day at most.

- b A stock & flow diagram

Not quite. The clothes in the basket are a stock, filled as clothes are worn and drained by washes, so this diagram holds half the answer. The marked line and the evening look are a target and a measured value; written above its names as roles, they make it a feedback control diagram.

- c A causal loop diagram

Not quite. It would show the loop, more clothes in the basket, more washes, fewer clothes, but not that the clothes accumulate, nor the line the parents chose to keep them under.

- d A system context map

Not quite. It would show the household's boundary and what passes across it, such as clothes bought and given away, and nothing inside it, where the basket is.

A causal loop diagram of a town's night buses shows R1, riders → fares collected → buses running → riders, all +, and B1, riders → standing passengers +, standing passengers → riders -. It is opened in an archetype lab and declared limits to growth. What changes in the drawing?

- a One line is added: Archetype: limits to growth

Yes. The diagram opens with every variable, effect and loop as drawn. A reinforcing loop and a balancing loop sharing riders match limits to growth, and the declaration is the one line added. Limits to growth has no symptomatic solution, fundamental solution or side effect, so no role is written.

- b The variables are redrawn as stocks and flows

Not quite. That conversion is into a stock & flow diagram, by hand, and no archetype is declared on one. In an archetype lab the causal loop diagram's marks stay as they are.

- c Roles are written above riders, fares collected and standing passengers

Not quite. Roles are written only where an archetype has them: symptomatic solution, fundamental solution and side effect. Limits to growth has none, so the declaration is the only line added.

- d Nothing: the match is listed, so no declaration is written

Not quite. The matches are listed after every change, but a declaration is written by whoever draws the diagram: a hypothesis about its loops, checked against the matches.

A chess club's treasurer is asked three things. Which one can the treasurer answer without a diagram?

- a How many weeks until the club's fund, €200 now and €40 added a week, reaches the €680 that new clocks cost
Yes. The answer is one quantity reached by arithmetic, $(680 - 200) \div 40 = 12$ weeks, and a sentence carries it. Nothing comes back around, and no boundary is in question.
- b Why more members bring more volunteers to teach beginners, and more teaching brings more members
Not quite. That change comes back around, from members to volunteers to members: a loop, which a causal loop diagram shows with its kind.
- c Whom the club deals with, from the hall it rents to the league it plays in, and what passes each way
Not quite. Several parties, each with something passing each way, are what a system context map shows. A list would name the parties and leave out what passes.

QUESTION 1 OF 3

Which question does this part of the slide, drawn as a stock & flow diagram, answer?

- a Why people move toward the government or toward the insurgents.
Not quite. One auxiliary sets every flow, attractiveness of the government's path, after a delay. What makes that path attractive is drawn in the slide's other clusters, about a hundred variables left out here.
- b How many people hold each of five stances, and how fast they move between neighboring stances.
Yes. Five stocks of people, filled and drained by four flows, each from one stance to the next: what accumulates, and how fast it changes. No one moves from active insurgent supporter to government sympathizer without passing through the fence.
- c Whether the coalition's actions shift popular support.
Not quite. No loop closes in the part: no stock reaches attractiveness of the government's path, so no change in support comes back around to the flows. Any action reaches the flows through the slide's other clusters, not drawn here.

QUESTION 2 OF 3

The slide comes from a brief for planning a counterinsurgency: which actions shift popular support toward the government, and how fast. Which drawing would answer that?

- a The whole slide, since every variable is on it.
Not quite. About 110 variables and the lines among them are on it, and no path through them can be followed by eye, so it answers no question by itself. The brief's own pages take it a cluster at a time, then one loop at a time.
- b An influence map, with popular support as its central outcome.
Not quite. An influence map answers what bears on one outcome before anyone knows which way each acts, and the slide's lines carry no + or -, as a map's influence claims don't. But an influence map has no stock or flow, so it can't show how many people move, or how fast.
- c A stock & flow diagram of the five stocks with the few loops through their flows that the plan acts on.
Yes. Support accumulates in stocks of people, and an action shifts it by changing how fast people move, through loops that close back on the flows: chapter 7's stocks inside feedback. Drawn a few loops at a time, each can be followed.

QUESTION 3 OF 3

Would a sentence do in place of this part?

- a** No: five stocks are too many for a sentence.

Not quite. A sentence holds the five in order. What a sentence can't hold is a change coming back around through several variables, and in this part none does.

- b** No: a sentence can't carry the delays.

Not quite. A sentence carries a delay in words, after a delay, as a behavior note does; the mark adds nothing a reader of the sentence lacks.

- c** Yes: no loop closes in it, and one sentence holds what it shows.

Yes. People move one stance at a time between active government supporter and active insurgent supporter, toward the government's side as its path grows more attractive, after a delay, and relative support is read from the four stocks off the fence. Nothing comes back around. Joined to the slide's loops, the part would have to be drawn again.

CD 01 Which diagram?**What does Ines draw, or write, to answer her question?**

- a** A system context map

Yes. Whom the team deals with is the parties outside one boundary, the team's, and what passes each way is the exchanges, each a named one-way line between a party and the boundary. Callouts from the police and rescue reports to them are two exchanges, one each way.

- b** No diagram: a list

Not quite. A list names the five parties but not what passes each way: the police, on a list, carry neither the callouts they send nor the rescue reports they receive.

- c** A causal loop diagram

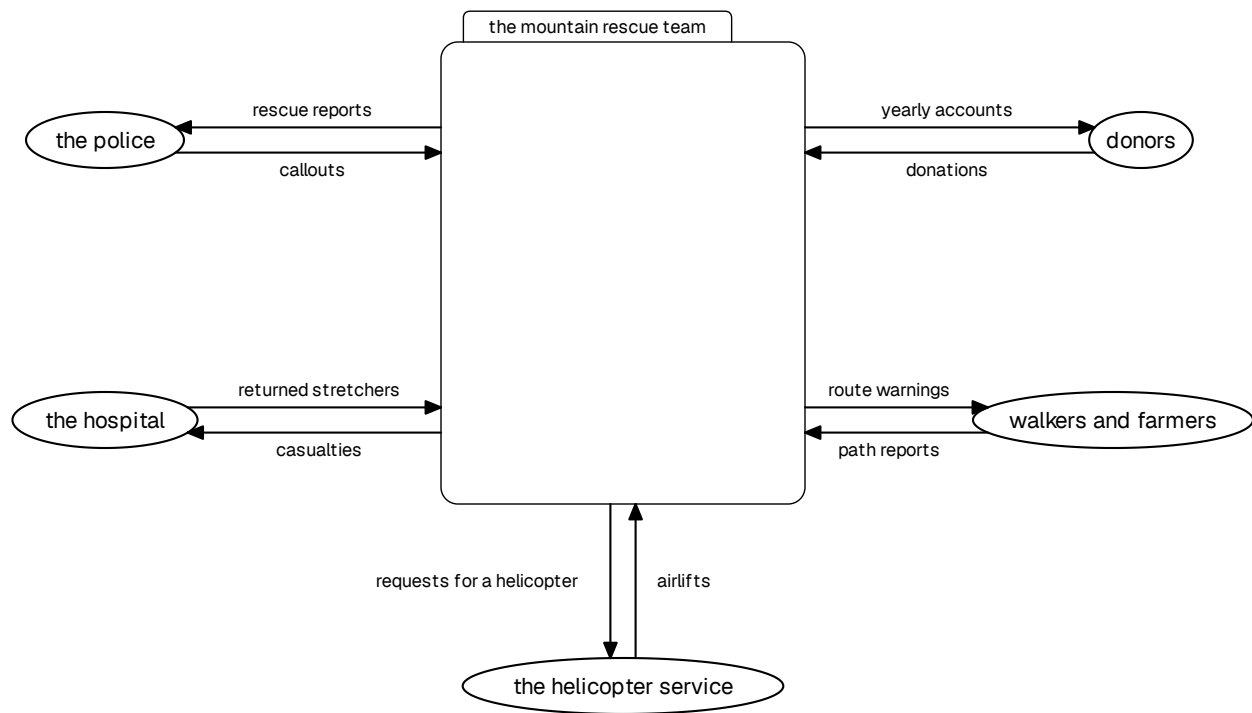
Not quite. A causal loop diagram shows how a change in one variable produces a change in another, and where those changes come back around in loops. Ines is after who sends what to whom, not what changes what.

- d** An influence map

Not quite. An influence map shows what bears on one outcome, ranked. Ines names no outcome: she is after the parties and what passes between them and the team.

- e** A stock & flow diagram

Not quite. A stock & flow diagram shows what accumulates and what fills and drains it: money in the team's account, filled by donations. The police, the hospital and the walkers have no place in it.

CD 01 A mountain rescue team

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.

One boundary, the mountain rescue team, with five parties outside it: the police, the hospital, the helicopter service, donors, and walkers and farmers. Ten named exchanges cross it, one each way with every party: callouts in and rescue reports out; casualties out and returned stretchers in; requests for a helicopter out and airlifts in; donations in and yearly accounts out; path reports in and route warnings out.

Why it works

- One boundary, named for the team, so the volunteers are the system and none of them is drawn as a party
- The helicopter service outside the boundary: the team requests its helicopter and doesn't run it
- Walkers and farmers drawn as one party, since they send the same reports and read the same warnings
- Each exchange names one thing, so callouts and rescue reports are two lines, not one with two arrowheads
- Every party both gives and receives, which a list of the five leaves out

Step by step

1. The mountain rescue team as the boundary, drawn alone: every exchange Ines asks about crosses it.
2. The police, with callouts in and rescue reports out: every rescue starts with their callout.
3. The hospital, with casualties out and returned stretchers in: where each carry down the hill ends.
4. The helicopter service, with requests for a helicopter out and airlifts in: called only for a serious injury or a long carry.
5. Donors, with donations in and yearly accounts out: the money behind the rescues, which reaches the team apart from any callout.
6. Walkers and farmers, with path reports in and route warnings out: exchanges that run between rescues, before any call.

What another defensible answer might vary

Another defensible answer might draw walkers and farmers as two parties, or leave out the returned stretchers. The casualties the helicopter service flies to the hospital pass between two parties outside the team, so no exchange of the team's carries them. What stays the same is one named boundary, the parties outside it, and one thing per exchange.

CD 02 Which diagram?**What does Mateus draw, or write, to answer his question?**

- a** A causal loop diagram

Not quite. A causal loop diagram gives every effect a + or – and shows the loops they close. Mateus can give a + or – only to the salary's effect: drawn there, the other effects would carry guesses as findings, and no loop runs through his wish to move.

- b** No diagram: a list

Not quite. A list names the salary, Ilse's chances, the hours with his parents and the team he would lead, but not that the music schools reach his wish to move only through Ilse's chances, or his father's health only through the hours he helps.

- c** An influence map

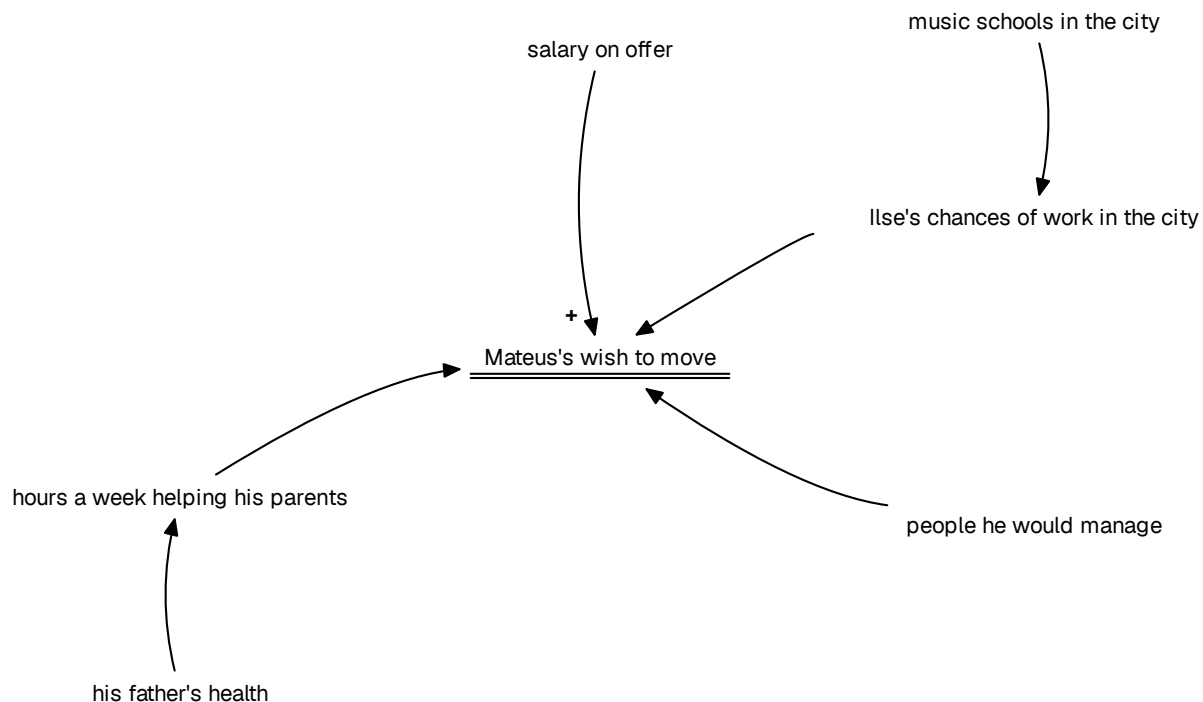
Yes. What bears on his wish to move is one central outcome and the variables that act on it. That he can't yet say which way most of them push makes each an influence claim, with no + or –; the salary's claim alone is upgraded, with a +.

- d** A system context map

Not quite. A system context map shows the parties outside a boundary and what passes each way: Mateus's household, his parents, the new employer. Who sends what to whom leaves out what draws him to the city and what holds him at home.

- e** A stock & flow diagram

Not quite. A stock & flow diagram shows what accumulates and what fills and drains it: Mateus's savings, filled faster by the higher salary. His question is what bears on one wish, and a wish fills from no flow.

CD 02 Moving to another city for a job

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.

Mateus's wish to move as the central outcome, with four direct influences: the salary on offer, Ilse's chances of work in the city, the hours a week he spends helping his parents, and the people he would manage. The salary's claim is a causal claim with a +; the other three are influence claims, since he can't yet say which way they push. Music schools in the city reach his wish through Ilse's chances, and his father's health through the hours he helps, each an influence claim too.

Why it works

- One central outcome, a quantity: how strong his wish to move is
- One causal claim, the salary's, the only direction Mateus can say
- The hours with his parents and the team he would lead left as influence claims: each could push either way
- Music schools and his father's health drawn to the variables they act on, not to his wish

Step by step

1. Mateus's wish to move, the central outcome, drawn alone: his question names it, and every claim drawn after ends at it or reaches it.
2. Ilse's chances of work in the city, the hours a week helping his parents and the people he would manage, each with an influence claim on his wish: plain lines, since an influence claim is where every claim starts.
3. Music schools in the city and his father's health, each with an influence claim on the direct influence it acts through, drawn once those are there.
4. The salary on offer, its claim upgraded to a causal claim with a +, drawn last of the claims: a third above what he earns now, it is the pull Mateus is sure of.

What another defensible answer might vary

Another defensible answer might add rent in the city, or draw Ilse's wish to move as a variable of its own between her chances and his wish. What stays the same is one central outcome, Mateus's wish to move, one causal claim, the salary's, and every other claim an influence claim.

CD 03 Which diagram?**What does Halima draw, or write, to answer her question?**

- a** A causal loop diagram

Not quite. A causal loop diagram shows that more emissions bring more carbon dioxide in the air, a + effect, but not that the carbon dioxide accumulates. Read as an effect, steady emissions give steady carbon dioxide, which is wrong here.

- b** A stock & flow diagram

Yes. Whether the carbon dioxide in the air stops rising is a question about how an amount changes over time: it is a stock, filled by emissions and drained by what the oceans and vegetation on land absorb. Holding emissions steady fixes the inflow, not the stock: with about 11 in and about 5 out each year, the stock goes on rising.

- c** No diagram: a sentence

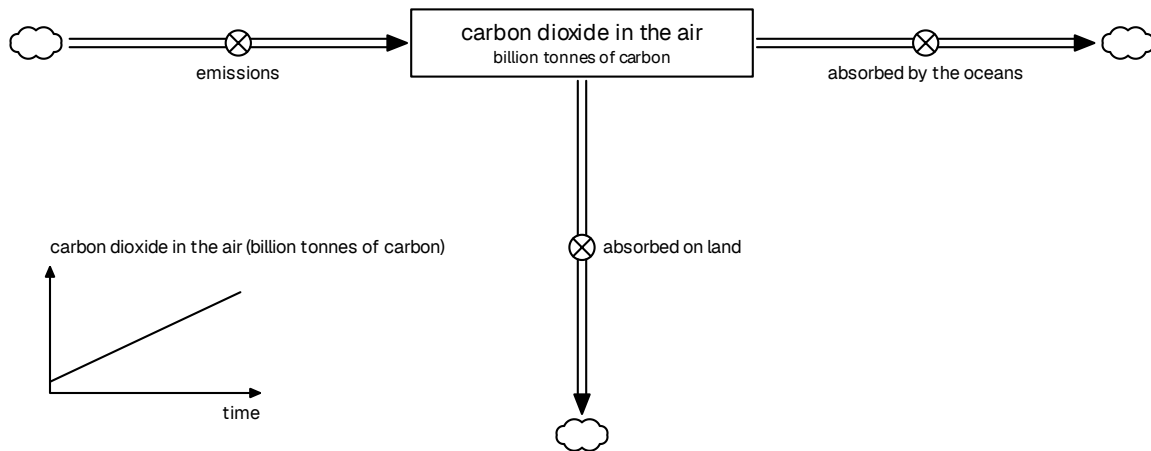
Not quite. The sentence is what Halima writes once the stock is drawn: while emissions exceed what the oceans and vegetation on land absorb, the carbon dioxide in the air rises. Without the stock, most adults Sterman and Booth Sweeney tested expected it to hold steady once emissions did.

- d** An influence map

Not quite. An influence map shows what bears on one outcome, ranked. What bears on the carbon dioxide in the air is known here: emissions and what is absorbed. Halima's question is how much of it there is as the years pass.

- e** A feedback control diagram

Not quite. A feedback control diagram shows a target, a measured value and a correction that closes the gap between them. Nothing here holds the carbon dioxide in the air to a target; Halima's question is what steady emissions do to it.

CD 03 Carbon dioxide in the atmosphere

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.

One stock, carbon dioxide in the air, counted in billion tonnes of carbon, filled from a cloud by emissions and drained to two clouds by what the oceans and vegetation on land absorb. The time unit is a year, so each flow is counted in billion tonnes of carbon a year. Held steady, emissions of about 11 still exceed the about 5 absorbed, so the stock gains about 6 a year: it goes on rising, and stops rising only when emissions fall to what is absorbed.

Why it works

- The carbon dioxide in the air is the stock: an amount there at any moment, changed only by its flows
- Emissions held steady fix the inflow, not the stock, which rises while the inflow exceeds the outflows
- One outflow for the oceans and one for vegetation on land, each to a cloud outside what the model holds
- The graph rises: Halima's answer is no

Step by step

1. Carbon dioxide in the air, the stock, counted in billion tonnes of carbon, drawn first: Halima asks how much of it there will be as the years pass.
2. Emissions, the inflow, from a cloud: about 11 billion tonnes of carbon a year, which Halima supposes will hold steady.
3. Absorbed by the oceans and absorbed on land, two outflows to clouds, about 3 and 2 billion tonnes a year: drawn after the inflow, to be set against it.
4. The behavior-over-time graph of the stock, drawn last, since its shape follows from the flows: a straight line rising while they hold as they are.

What another defensible answer might vary

Another defensible answer might draw one outflow for what the oceans and vegetation on land absorb together, or a graph that rises and flattens, taking the oceans and vegetation to absorb more as the carbon dioxide in the air rises. What stays the same is one stock, emissions flowing in, at least one outflow, the time unit a year, and a graph that rises.

CD 04 Which diagram?

What does their father draw, or write, to answer his question?

- a** A causal loop diagram

Not quite. A causal loop diagram shows the two reinforcing loops through Noor's share of the turns, and no archetype. The same loops drawn there and opened in an archetype lab, with the archetype they match declared, are the diagram that answers whether others have seen this story.

- b** An influence map

Not quite. An influence map shows what bears on one outcome, its directions left open until measured. The father's rule fixes every direction here, and the effects close two loops, which no one declares on an influence map.

- c** A system archetype

Yes. The father asks after a recurring loop structure with a name: a story others have seen, and how it usually runs. The two reinforcing loops, one through each child's hours, share Noor's share of the turns, and that structure matches an archetype, declared in one line; how the split usually runs is that archetype's known course.

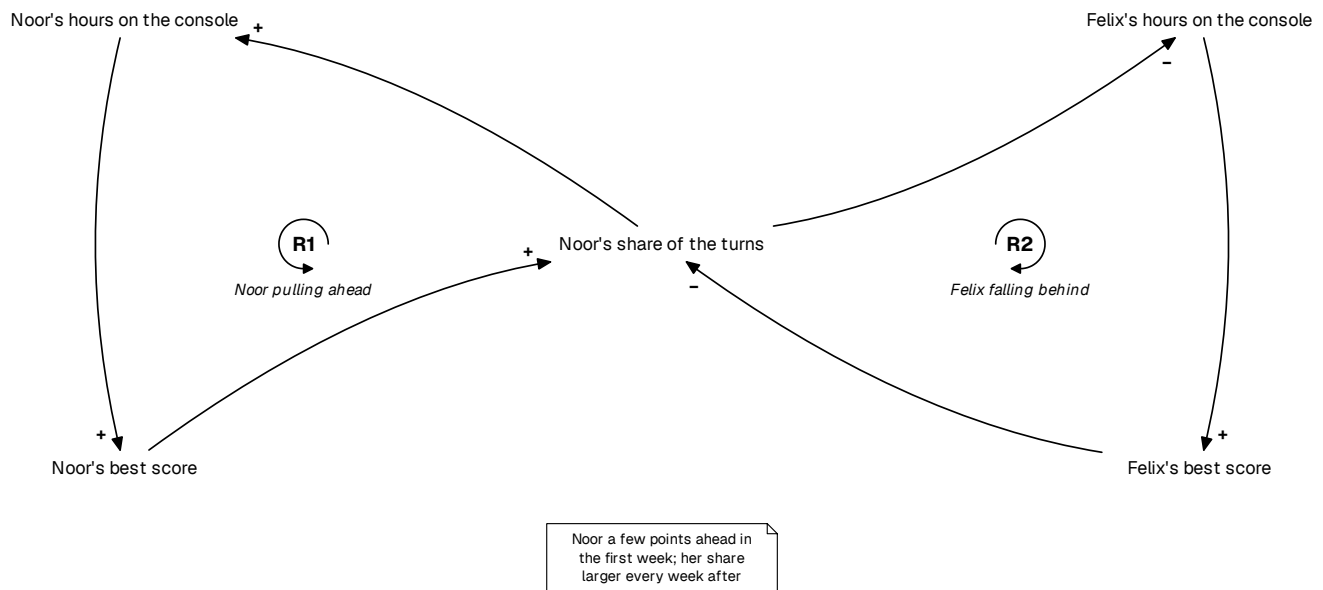
- d** A stock & flow diagram

Not quite. A stock & flow diagram shows what accumulates and what fills it, such as each child's hours played. The father's question is whether the two loops through the split are a story with a name, which no stock or flow carries.

- e** No diagram: a sentence

Not quite. A sentence states the father's rule and Noor's lead in the first week. Whether the story recurs elsewhere is read from its loops: two reinforcing loops through one split, matched to an archetype.

CD 04 Two siblings and one games console



Archetype: success to the successful

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.

Noor's share of the turns sits on both loops. In R1, a larger share gives Noor more hours on the console (+), more hours a higher best score (+), and a higher score a larger share (+). In R2, a larger share for Noor gives Felix fewer hours (-), fewer hours a lower best score (+), and a higher score for Felix a smaller share for Noor (-): two - effects, so R2 is reinforcing too. The father declares success to the successful, which the structure matches with the share as the allocation: which child ends ahead depends on who started ahead as much as on what each could do with an equal share, so Noor's lead of a few points grows every week.

Why it works

- The father's rule is one variable, Noor's share of the turns, so both loops pass through it
- Each child's hours on the console sit between the share and that child's score, a chain the archetype's match allows
- R2 has two - effects, an even number, so it is reinforcing
- The declaration names the archetype in one line, which a causal loop diagram of the same loops lacks
- The note names Noor's first-week lead and its growth

Step by step

1. Noor's share of the turns, drawn first: it is the father's rule, set each Sunday, that both children's play depends on.
2. Noor's hours on the console and her best score, with three + effects from the share through both and back to it, closing R1, Noor pulling ahead: the child the rule favors from the first week.
3. Felix's hours and best score, with a - effect from the share, a + effect to his score and a - effect back, closing R2, Felix falling behind: the father's rule seen from Felix's side.
4. The behavior note under the share, written once both loops are drawn: the week-by-week course the father asks about.

5. Success to the successful, declared last in one line: the name of the story the father asks after, given once the loops it names are drawn.

What another defensible answer might vary

Another defensible answer might draw Felix's share of the turns instead, which changes the polarity of every effect into and out of it and leaves both loops reinforcing, or draw each score straight to and from the share, leaving out the hours. What stays the same is one variable for the split, two reinforcing loops through it, and success to the successful declared.

CD 05 Which diagram?

What does Ruth draw, or write, to answer her question?

a A stock & flow diagram

Not quite. A stock & flow diagram shows the water in the stretch, the water from the hill lake and the water drawn by the locks: the same stock and flows a feedback control diagram of the stretch holds, without its roles. With no target, gap or corrective action written, it shows neither the depth Ruth holds the stretch to nor that her morning reading arrives late.

b A causal loop diagram

Not quite. A causal loop diagram shows the balancing loop through the depth and the water let in, but not what accumulates, nor which variable is the target and which the reading. Ruth's question turns on both.

c A system context map

Not quite. A system context map shows the parties outside the canal, such as boaters and the lake's owners, and what passes each way. It leaves out how the depth is held, and where that falls short.

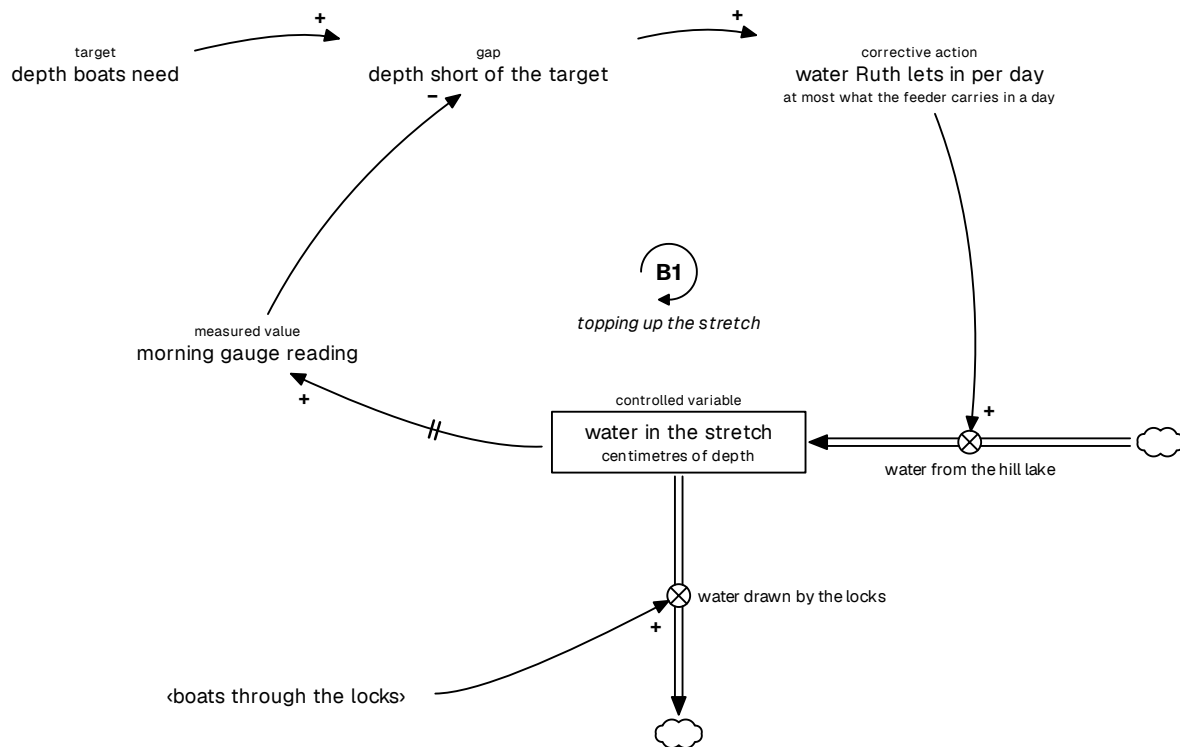
d A feedback control diagram

Yes. Ruth holds the stretch at the depth boats need: that depth is a target, and her morning reading a measured value, up to a day behind the water in the stretch. The gap between them sets the water she lets in, which the feeder limits: one control loop, its roles written over the stretch's stock and flows.

e No diagram: a sentence

Not quite. A sentence states Ruth's rule: the further the depth reads below what boats need, the more water she lets in. Where that falls short, between one morning's reading and the next and at the feeder's limit, shows on the loop drawn with its delay and its limit.

CD 05 A canal through a dry summer



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.

One stock, water in the stretch, counted in centimetres of depth: the controlled variable. Water from the hill lake fills it from a cloud and water drawn by the locks drains it to a cloud, both in centimetres a day. Depth short of the target is the gap, read from the depth boats need (+) and the morning gauge reading (-); it sets the water Ruth lets in per day (+), at most what the feeder carries in a day, whose signal reaches the valve of water from the hill lake (+). The reading follows the water in the stretch with a delay, one reading a morning. B1 has one – step, so it is balancing. Boats through the locks act at the valve of water drawn by the locks. A busy day of boats lowers the stretch between readings, and when the locks draw more in a day than the feeder carries, the stretch falls however large the gap.

Why it works

- The target, the depth boats need, has no signal into it: Ruth sets it
- The once-a-morning reading is a delay between the water in the stretch and the reading: the return path
- What the feeder carries in a day is written as the limit beneath the water Ruth lets in
- The boats act on the controlled variable at the valve of water drawn by the locks, never on the gap
- The one – step, from the reading to the gap, makes the loop balancing

Step by step

1. Water in the stretch, the controlled variable, a stock counted in centimetres of depth: the amount Ruth keeps deep enough for boats, drawn first.
2. Morning gauge reading, the measured value, with a + signal from the water in the stretch, delayed: water drawn at noon shows on the board only the next morning.

3. Depth boats need, the target, and depth short of the target, the gap, with a + signal from the target and a – signal from the reading: what Ruth works out each morning.
4. Water Ruth lets in per day, the corrective action, limited by what the feeder carries in a day, with a + signal from the gap and a + signal to the valve of water from the hill lake, the inflow, closing B1, topping up the stretch.
5. Boats through the locks, an external driver, with a + signal to the valve of water drawn by the locks, the outflow: drawn last, as what Ruth's loop has to keep up with, dozens of boats on a busy day.

What another defensible answer might vary

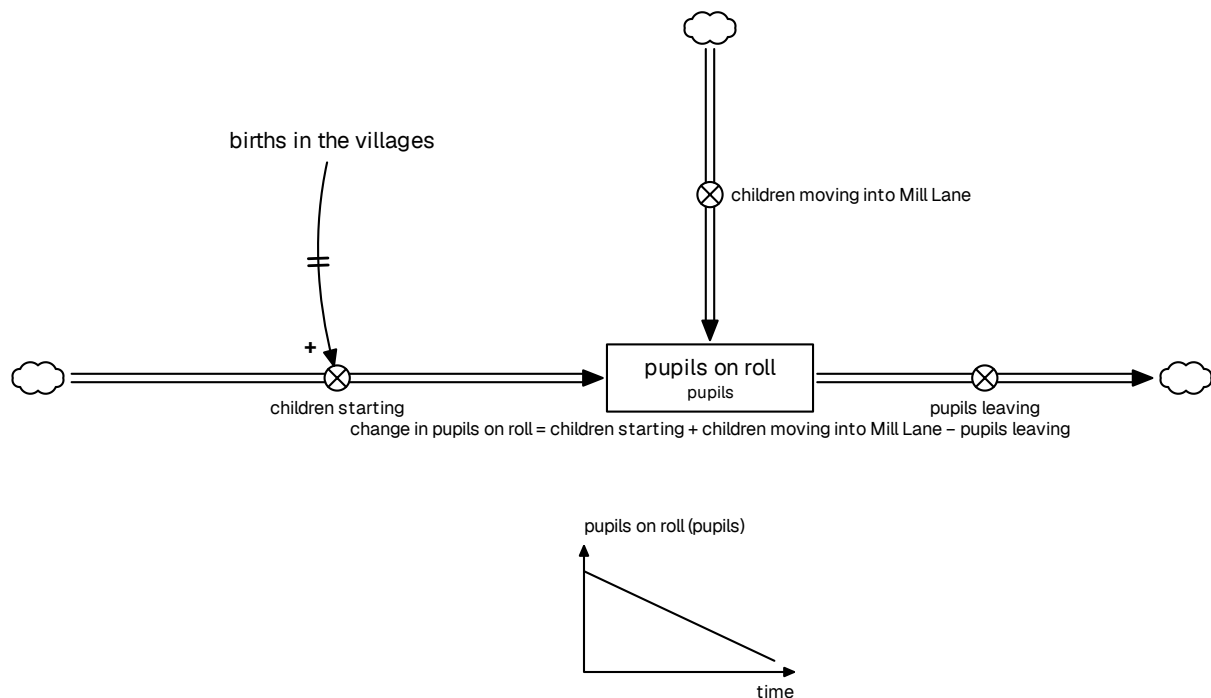
Another defensible answer might count the water in cubic metres, with the target and the reading in cubic metres too, or add evaporation as a second outflow in a dry summer. What stays the same is one stock with water from the hill lake flowing in and water drawn by the locks flowing out, one balancing control loop with the target off it, a delay on the morning reading, and the feeder's limit on the water Ruth lets in.

CS 12 Which diagram?

What does David Brennan draw, or write, to answer his question?

- a A causal loop diagram
Not quite. In a causal loop diagram, homes lived in at Mill Lane → pupils on roll is a + effect, which reads as more homes, more pupils for good. The homes bring their 15 children once, as they are first lived in; whether the roll goes on falling afterwards turns on what fills it and what drains it each year.
- b A stock & flow diagram
Yes. Whether the roll goes on falling is a question about how an amount changes over the years: the pupils on roll are a stock, filled by the children starting and the children moving into Mill Lane, and drained by the pupils leaving. The inflow from Mill Lane stops once the last home is lived in, and the children starting, fewer than the births four years before, are fewer each year than the pupils leaving.
- c An influence map
Not quite. An influence map shows what bears on one outcome, ranked, its directions left open. Here every direction is known: the births, the homes and the pupils leaving each fill or drain the roll. David Brennan's question is how many pupils are left as the years pass.
- d A feedback control diagram
Not quite. A feedback control diagram shows a target, a measured value and a correction that closes the gap between them. Nothing here holds the roll to a target; the question is where the roll goes once the homes are lived in.
- e No diagram: a sentence
Not quite. The sentence is what David Brennan writes once the roll is drawn as a stock: after 2029 only the children starting fill it, and fewer start than leave each year, so it goes on falling. Without the stock, Tom Hale's reading, that the homes turn the roll around, goes unchecked.

CS 12 Kelsham Primary School: the council's question



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.

One stock, pupils on roll, counted in pupils, a year at a time. It is filled from clouds by the children starting each September, set by the births in the villages four years before through a delayed signal, and by the children moving into Mill Lane, 15 in all from 2027 to 2029; it is drained to a cloud by the pupils leaving. Once the last home is lived in, the inflow from Mill Lane stops, and the children starting, fewer than the 11 or 12 born each year since 2023, are fewer than the pupils leaving, 16 in the year to October 2026: the stock goes on falling. David Brennan's answer is yes: the homes slow the fall while they fill, and don't turn the roll around.

Why it works

- The pupils on roll are the stock: an amount there each October, changed only by its flows
- The Mill Lane homes fill the roll only while they are first lived in, 15 children in all, and not after
- The births set the children starting four years later through a delayed signal, so the starters to 2029 are known now
- The graph falls: once the homes are lived in, fewer children start than pupils leave

Step by step

1. Pupils on roll, the stock, counted in pupils with its stock equation, drawn first: David Brennan asks how many there will be as the years pass.
2. Children starting, an inflow from a cloud: each September's starters, 9 in the year to October 2026.
3. Births in the villages, with a + signal to the children starting, delayed by the four years before a child starts: the births to 2025 set the starters to 2029.

4. Children moving into Mill Lane, a second inflow from a cloud: 15 in all, as the 60 homes are first lived in from 2027 to 2029.
5. Pupils leaving, the outflow to a cloud, drawn after both inflows to be set against them: 16 in the year to October 2026.
6. The behavior-over-time graph of the stock, drawn last, since its direction follows from the flows: falling once the last home is lived in.

What another defensible answer might vary

Another defensible answer might draw the homes lived in at Mill Lane as an auxiliary with a signal to the children moving into Mill Lane, or the pupils leaving as two outflows, for secondary school and for Brayford Primary School. Or its graph might fall and flatten, as smaller years reach Year 6 and fewer pupils leave. What stays the same is one stock, two inflows, one outflow, the births' delay, and a graph that falls once the homes are lived in.