

What the change leaves behind

How many scraps a sharp change leaves,
and which of them last

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A sharp change rarely finishes the job. Ice that forms quickly traps bubbles. A crowd that leaves a stadium leaves coats on the seats.

This paper is about what a sharp change leaves behind in a toy model of dots and links. The first paper in this series [1] found that a particular curled arrangement of the toy waits, then changes all at once and gives off energy. That paper named the release **the burp**. The change makes two things: the burp, and what is left behind. The first paper found that the change usually stops one small piece short of finishing, and that the leftover piece is not always the same kind of thing. We call a leftover piece a **scrap**. Here we ask what kinds of scrap there are, what they have in common and what sets them apart, how they come to be, how many are left, and whether they last.

THE AUTHOR'S CLAIM The reason for asking is the author's hypothesis that space emerged from something else by a sharp change, and that such a change leaves a remainder. She wants to test whether a remainder can last. Everything below is a test of that one question inside one toy. None of it is a measurement of the real universe.

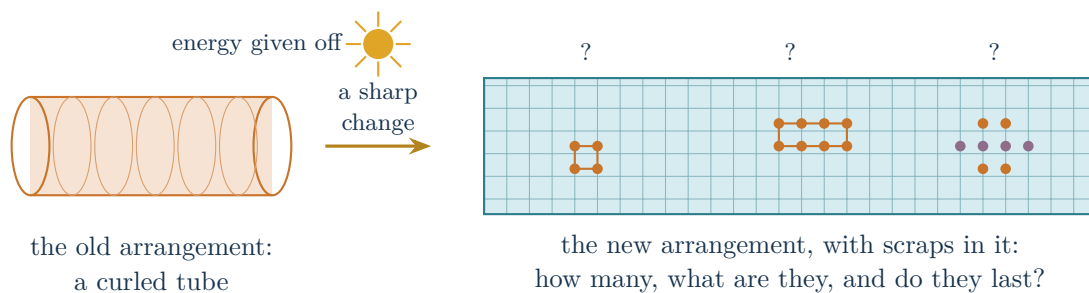


Figure 1. The question in one picture. **SKETCH, NOT DATA** A curled arrangement changes sharply into a new one and gives off energy. Small pieces are left over. This paper counts them, reads what they are, and follows them while their surroundings stay warm or cool down.

Who is saying what

The project keeps four kinds of statement apart, and this edition tags them where it matters.

- **EXACT** Arithmetic, or a reading of a saved network link by link. True of the toy whatever a run does.
- **MEASURED** A simulation whose rules and predictions were written down before it ran, with its

verdict. **MEASURED, EXPLORATORY** means a closer look at runs already read, with no prediction written first.

- **PUBLISHED** Other researchers' published results.
- **OUR READING, UNVERIFIED** A reading of a result, offered by the author and her AI assistants and checked by no physicist. **THE AUTHOR'S CLAIM** The author's hypothesis about reality, stated as hers.

Numbers in square brackets point to the sources listed at the end.

1 THE STORY SO FAR

A tube of dots that burps

This chapter repeats, briefly, what the first paper established [1]. A reader who has that paper fresh can skip to Chapter 2.

The toy

PUBLISHED The toy is a network: dots joined by links, every dot holding exactly four links. It comes from a published model in which space is not a stage but an arrangement of such a network [2, 3, 4]. Four dots joined in a loop make a **square**. The toy gives every network an energy by counting squares, and the whole rule is a price list of two lines: a missing square costs 16 units, and a link that carries more than two squares pays extra for each surplus one.

The extra price is set by a number we call **the knob**. With the knob at 1 the toy is the published model. Every result in this paper has the knob at 1.25, where a surplus square costs 5 units. That setting is our addition, so this toy is a close cousin of the published model and not the model itself.

The toy changes by one kind of move, a **swap**: two links trade partners. A run is a long chain of swaps, each proposed at random and then accepted or refused.

The tube, and its burp

EXACT Wrap a square grid of dots into a tube only four dots around and join its ends. Every ring of four dots around the tube is itself a square, so every link around the tube carries a surplus square and pays for it. Call this **the curled tube**. It costs exactly 1 unit per dot more than an arrangement in which every link carries two squares, which costs nothing at all.

So a lower arrangement exists. But no single swap leads toward it: a swap either leaves the tube's energy where it was or costs at least 12 units. The tube is stable for now. **MEASURED, EXPLORATORY** Given 12 units, every tube tested left, and with less none did. The change then spreads along the tube until every dot has been through it, giving off 1 unit for each dot. That release, and the event that gives it off, is the burp.

What the tube turns into

EXACT Here is the first paper's least expected result. Read link by link, 98 of every 100 runs that finished with nothing left over had turned the curled tube into another tube. Its seam has slipped by

two dots, so that going around it now takes six steps where it took four. Six around is the least a tube can be without paying for surplus squares, so the new tube costs nothing. Around every dot the squares fit together as they do on a flat sheet of graph paper, and we call an arrangement like that **flat**. Flat describes what a dot sees close by. It says nothing about how wide the tube is.

The seam could slip further, by four dots or six, and the tube would be eight or ten around, also at no cost. Runs that finished clean almost never did that; runs that kept a scrap sometimes did, in part of the tube. Like the first paper, this one mostly follows the tube six around. Chapter 8 comes back to the other widths.

A tube of 96 dots	what it costs	what it has given off
curled, four around	96 units	nothing yet
after the burp, six around, no scrap	0 units	96 units
after the burp, six around, one common scrap	14 units	82 units

The last line of that table is this paper’s subject. **MEASURED** In the first paper’s runs the change usually stopped one small piece short of finishing, leaving a scrap.

The point to keep: A curled tube of dots is stable for now. Given a small push it changes all at once into a wider tube, six around, and gives off 1 unit of energy per dot: the burp. The change usually leaves a scrap.

2 THE SCRAP

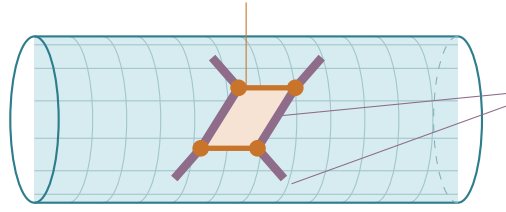
What a single change leaves behind

Read the wiring, not the count

A run reports numbers: how many squares, how many dots that look flat. It is tempting to name a shape from those numbers. This project has done that five times and been wrong five times. So every statement below about what a scrap *is* comes from reading a saved network link by link.

EXACT The common scrap is a closed loop of four dots that still closes a square, as each ring of the old tube did. It is still curled, in that sense, but it does not go around the new tube: it lies in the tube’s wall. Six of the links at its dots carry a third square. At our knob setting it holds 14 units, which is the burp of fourteen dots, held back. We call it a **curled loop**.

four dots joined in a loop that still closes a square



a short stretch of the new tube, six around

thick: a link that carries a third square,
like each link around the old tube;
six of them, two on the loop
and one leaving each dot

six surplus squares, at 5 each	+30
one extra square, saved	-16
the curled loop holds	14

Figure 2. The common scrap, link by link. **EXACT** The wiring and the bill. Read from the saved networks of the first paper's maps and this paper's large test, 1,094 of 2,045 four-dot scraps are wired this way. Most of the rest are a lighter kind, 4 units, in which all four sides of the loop carry a third square and no link leaving it does; a few have five surplus squares and hold 9. None of the 2,045 goes around the new tube. **SKETCH, NOT DATA** Where the loop sits on the tube is drawn to show its size. The network has no positions, and the tube is too narrow for a picture of the fabric around the scrap to be read off the wiring.

One push, about one scrap

To follow the energy to the last unit, the first paper sealed the toy in a box. **EXACT** A **sealed** run has no outside. Beside the network sit **stores**, each holding some units. A swap that costs energy is paid from a store, and a swap that gives energy off pays into one. Network plus stores never changes, and that was checked in every run. With two stores for every dot, the burp spreads so thin that the box stays cold.

MEASURED Eighty tubes were sealed in cold boxes, twenty each at 64, 96, 192 and 288 dots, and each was given one 12-unit push, so that the change began in one place. We call a place where the change begins a **start**. The prediction written down beforehand was that a longer tube leaves more scraps. It does not. The count was 0.90, 0.85, 1.05 and 0.95 scraps per tube.

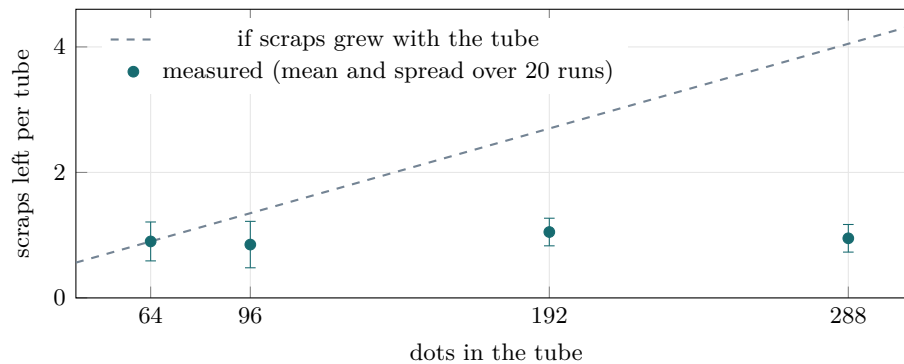


Figure 3. One start, about one scrap. **MEASURED** The dashed line is what a leftover growing in step with the tube would look like. The measured counts sit flat. The prediction that they would grow failed.

MEASURED A second test asked where the scrap sits. Two guesses were written down: at the place the change started, or at the far side, where the change spreading both ways around the tube would meet itself. It sits at neither. Its position is spread evenly along the tube. So this scrap is not a seam where the change met itself. We call a scrap that sits inside the new tube, away from any meeting place, a **free scrap**.

MEASURED, EXPLORATORY In 9 of the 80 boxes the leftover was not a curled loop. It was a different object holding 20 units, which the first paper called a twist. It comes back in Chapter 7.

The point to keep: A change that starts in one place leaves about one scrap, whatever the size of the tube, and the scrap can sit anywhere: it is a free scrap. The common one is a curled loop of four dots holding 14 units, and it is not the only kind.

3 MORE STARTS

Does every start leave a scrap?

A change in a large space need not start in one place. So the next question is what several starts leave.

Starts planted by hand

From each start the change spreads both ways along the tube. The moving edge between changed and unchanged tube is a **front**, and where two fronts meet, two changed stretches join.

MEASURED A tube of 384 dots was sealed in a cold box, and the change was started by hand at one, two, four or eight evenly spaced places, twenty runs each. The author's hypothesis fits one scrap per start. Another guess, which the last chapter invites, is one scrap per tube, however many starts. Neither held.

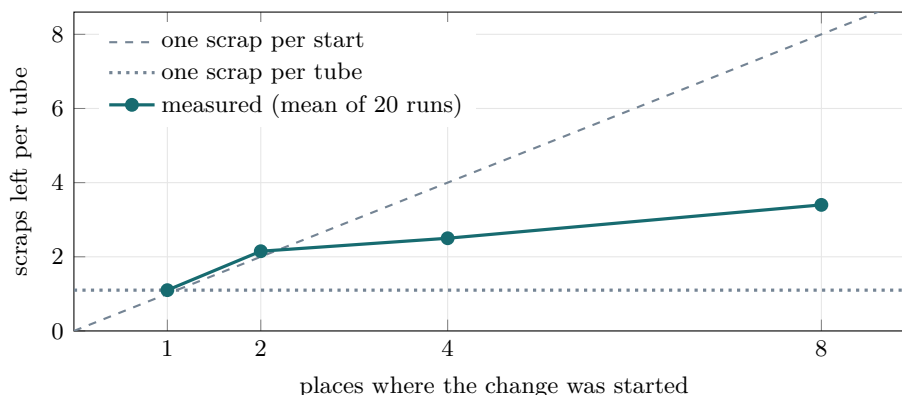


Figure 4. More starts, more scraps, but fewer than one each. **MEASURED** One start left 1.10 scraps on average, two left 2.15, four left 2.50 and eight left 3.40. Both guesses written down beforehand, one per start and one per tube, failed.

Tubes that start themselves

Nobody plants starts in a large space. To see what a tube does on its own, we need the other way of running the toy.

PUBLISHED Instead of a sealed box, picture the network sitting in a **bath** that lends it energy for a swap that costs and takes back what a swap gives off. The bath is endless. One number sets how freely it lends, and we call that number **the warmth**. In a warm bath costly swaps happen often. In a cold one they almost never do. Time in a run is counted in **sweeps**: one sweep is two proposed swaps for every dot.

In a bath the curled tube needs no push. Sooner or later the bath lends the 12 units somewhere, and the change starts there. In a long tube it starts in several places before any one change has crossed the tube.

MEASURED Tubes of 256 to 4,096 dots were left in baths at three warmths. Three predictions written down beforehand held: longer tubes start in more places, the changed share grows over time the way the textbook law for changes that start at random places and spread says it should [7], and longer tubes are left holding more energy.

MEASURED A later, larger test let tubes of 512, 1,024 and 2,048 dots start themselves at the coldest of those warmths and counted the curled loops left when the change was over.

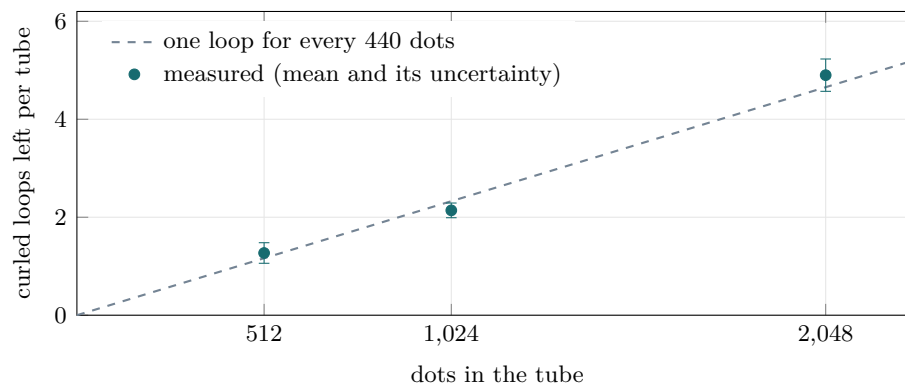


Figure 5. A tube that starts itself leaves scraps in step with its length. **MEASURED** 1.27, 2.14 and 4.90 curled loops per tube at 512, 1,024 and 2,048 dots: about one for every 400 to 480 dots. From 40, 80 and 40 tubes.

So the single scrap of Chapter 2 is what a single start leaves. A tube long enough to start in many places leaves scraps in proportion to its length.

A warning about warm baths

MEASURED The longest tubes in the two warmest baths did something else. More than half of their dots ended with too few squares around them, and the tubes had taken in about twice as much energy from the bath as a burp gives off. That is **melting**: the bath breaks squares faster than the toy re-forms them, and the network ends up linked any old way. **EXACT** A sealed tube cannot melt. Its own burp holds enough energy to break at most one square in sixteen. Melting needs energy from outside.

The point to keep: More starts leave more scraps, but fewer than one each. A tube long enough to start itself in many places leaves about one curled loop for every 400 to 480 dots.

4 WARMTH

Does a scrap last if its surroundings stay warm?

MEASURED New tubes of 96 dots were changed in cold sealed boxes, and those left holding exactly one curled loop were moved into a bath and held at one warmth for 100,000 sweeps. Three warmths were tried. Three outcomes were written down beforehand: the scrap wanders, or it heals in the warmer baths and stays in the colder, or it stays everywhere. To **heal** means that the scrap's dots rearrange into the flat pattern around them and its energy is given off.

It healed at every warmth.

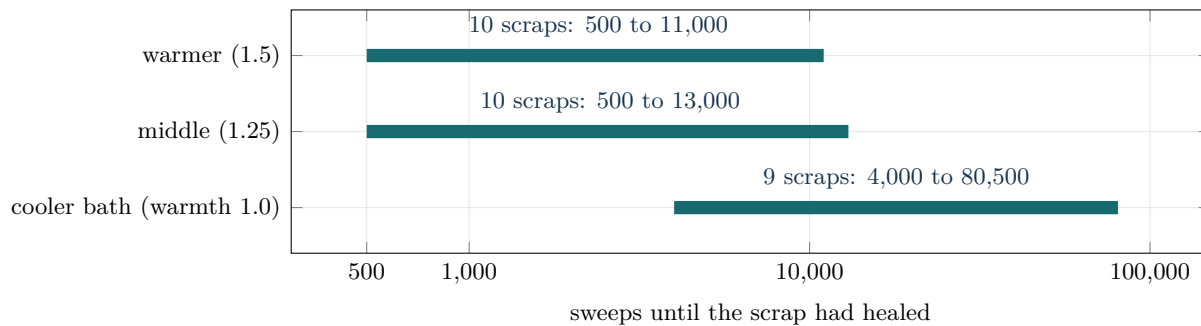


Figure 6. How long a lone curled loop lasted in a bath. **MEASURED** Each bar runs from the first scrap healed to the last. The scrap's position was read every 500 sweeps, so 500 is the shortest time the test could report. Even the coolest bath healed every one, in time.

MEASURED Two things about how it healed. Each tube held one scrap, so each scrap healed by itself, with nothing to meet. And 27 of the 29 were never seen to move first. A curled loop mostly sits where it is until it is gone.

In the cold sealed boxes of Chapter 2, by contrast, every scrap lasted the whole run.

The point to keep: A lone curled loop heals away in every bath we tried, in 500 to 80,500 sweeps. It lasts only where its surroundings are very cold.

5 THE RACE

What if the surroundings cool down?

Warm surroundings heal a scrap and cold ones keep it. Reality cooled as it expanded. So what matters for a remainder is a race: does the scrap heal before its surroundings get too cold to heal it?

MEASURED Tubes of 96 dots, each holding one curled loop, were put in a bath at warmth 1.25, where the last chapter saw every scrap heal within 13,000 sweeps. The bath was then cooled, in equal steps, to a warmth of 0.25, where no swap is ever accepted, and held there. The cooling was spread over anything from 300 to 100,000 sweeps. The verdict written down beforehand was *freezes in* if some cooling time keeps most scraps and the fastest cooling keeps the most.

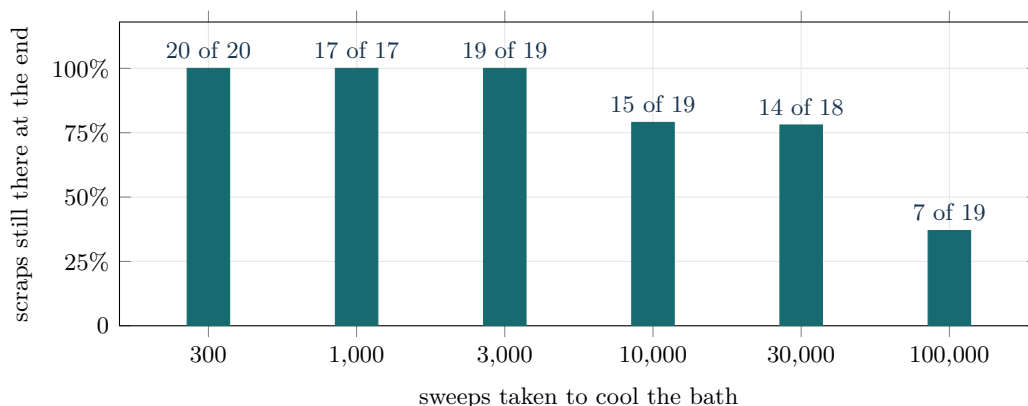


Figure 7. Cooling keeps a scrap that warmth would have healed. **MEASURED** Every scrap survived a fast cooling. About four in five survived a cooling of 10,000 or 30,000 sweeps. A third survived the slowest.

It freezes in. Even a cooling of 30,000 sweeps, more than twice the longest healing time at the starting warmth, kept most scraps, because the bath leaves the range where healing is quick early in the cooling. The scraps that healed did so in the first 15,000 sweeps.

The point to keep: A scrap that would heal in any warm bath survives if the bath cools, even slowly. Cooling freezes it in.

6 THE LARGE TEST

Many scraps, cooled slowly

The last three chapters used small tubes and one scrap at a time. This chapter puts the pieces together: tubes large enough to start themselves in many places, left with several scraps each, and then cooled.

A fair clock

One thing has to be fixed first. A swap needs two particular links to be picked together. In a network ten times larger, any particular pair is picked a tenth as often in a sweep. So anything local, like a scrap healing, takes more sweeps in a bigger network for no reason but bookkeeping. To compare sizes we count time in **fair sweeps**, the fair clock of the first paper's Chapter 5: sweeps scaled so that each small neighborhood gets as many chances as it would in a 96-dot network. At 1,024 dots one fair sweep is about eleven sweeps. The clock decides how a cooling time at one size compares with a cooling time at another. No energy, and no reading of a scrap's wiring, depends on it.

The test

MEASURED Eighty tubes of 1,024 dots were left in a bath at warmth 1.25 until the change was over. Each finished tube was then copied, and the copies were cooled at seven speeds, from an instant chill to a cooling spread over 300,000 fair sweeps. So every cooling speed began from the very same tubes. The slowest cooling used the first forty.

The question written down beforehand was the *shape* of the fall. Does each tenfold slowing of the cooling lose a steady fraction of the curled loops (a gentle fall), or does the count hold and then collapse (a cliff)? The author predicted a gentle fall.

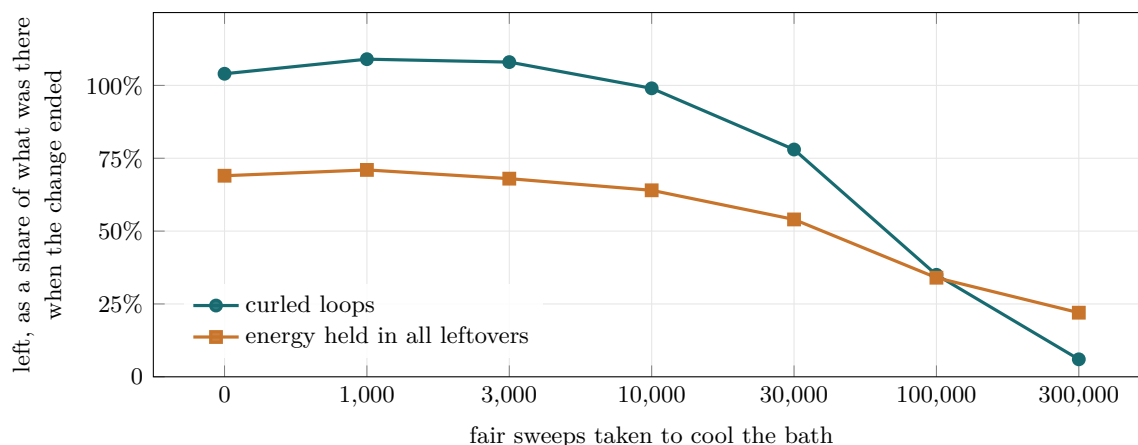


Figure 8. The curled loops fall off a cliff. The energy does not follow them. **MEASURED** Slowing the cooling from 10,000 to 100,000 fair sweeps lost two curled loops in three. Slowing it from 30,000 to 300,000 lost twelve in thirteen. The energy held in leftovers fell far less. About three units in ten of that energy go in any cooling, even an instant chill, as loose small pieces settle. The loop count can start above 100% because a few loops form after the first count.

A cliff. The prediction failed.

The energy that stays is not in the curled loops

MEASURED If curled loops were the only leftovers, the energy held in leftovers would have fallen with them. It did not. After the slowest cooling, 6 curled loops in 100 were left, and 22 units in 100 of the leftover energy. Something else was holding energy, and cooling slowly did nothing to it.

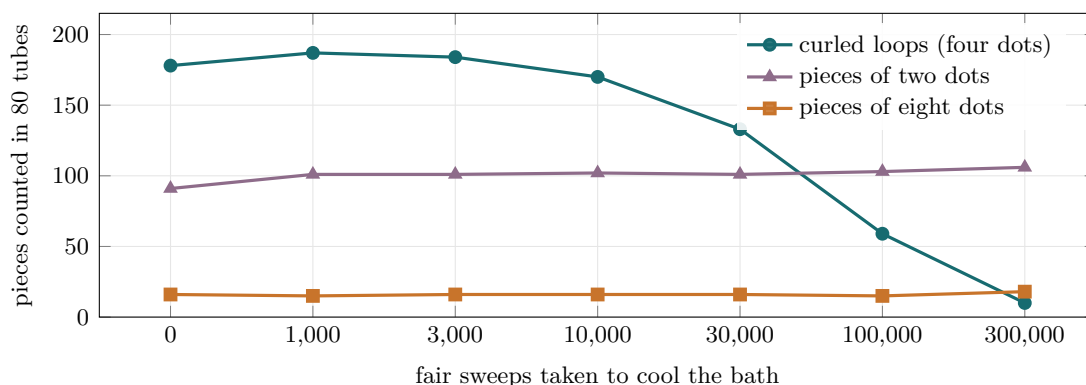


Figure 9. What slow cooling removes, and what it does not. **MEASURED** Leftover pieces sorted by how many dots they hold. The curled loops fall away. The pieces of two and of eight do not change at all across the whole range. The slowest cooling was run on forty tubes and its counts are doubled here.

Two checks on the test itself

MEASURED The fair clock made a prediction of its own: counted in fair sweeps, the 1,024-dot tubes should lose their curled loops at the same pace the 96-dot tubes of Chapter 5 did. At one of the two points checked they lost them sooner, by more than the margin allowed. So the fair clock is a better ruler than plain sweeps and still not an exact one. The second check held: at one cooling speed, tubes of 512, 1,024 and 2,048 dots kept the same number of curled loops for their length.

Why we went here. Chapters 4 and 5 said a scrap heals in warmth and freezes in when cooled. That left the question that matters for a remainder: across many scraps, how much is frozen in, and how does that depend on the speed of cooling? The answer was not the one predicted, and it pointed at leftovers nobody had looked at.

The point to keep: Cooled slowly enough, nearly all the curled loops heal. Most of the leftover energy stays anyway, held by smaller and larger pieces that no cooling we ran removed.

7 A CLOSER LOOK

What are the pieces that stay?

Three guesses, written down first

Before anyone read the pieces of two and of eight, three guesses about them were written down, with a test for each.

- **A scar:** damage that one swap would mend, if the bath ever offered that swap. The test: is there a single swap that removes the piece and lowers the energy?
- **A seam:** the stitching where two stretches of new tube, grown from different starts, met and did not match. The test: does the piece hold a link joining two places that are otherwise far apart?
- **Stuck on its own:** a small arrangement that sits in a dip of its own, so that every swap out of it costs energy. The registered name for this guess was KNOT.

The author predicted a seam.

EXACT All 600 saved tubes were read link by link. Not one piece of any size can be mended by a single swap. Of 2,121 pieces, 4 hold a far-reaching link. **MEASURED** The verdict was the third guess: stuck on its own. The author’s prediction failed.

Three kinds of scrap

EXACT Read from the wiring, the leftovers are three objects.

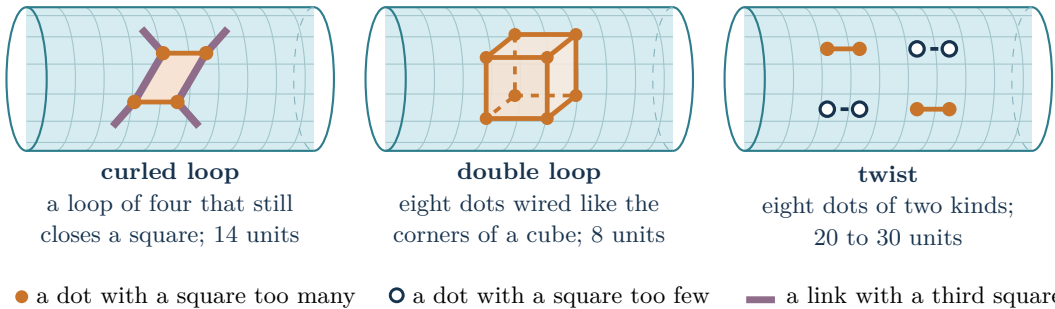


Figure 10. The three kinds of scrap. **EXACT** How many dots, how they are wired, and what they hold, read from the saved networks. The curled loop is the one of Figure 2. The double loop’s eight dots have twelve links among them, three each, wired like the corners and edges of a cube: two loops of four joined corner to corner, as two neighboring rings of the old tube were. In the twist, each orange dot has two links that carry a third square, and each hollow dot has two links that carry only one. **SKETCH, NOT DATA** Where each sits on the tube, and the pairs’ arrangement, are drawn to show the sizes.

	curled loop	double loop	twist
dots	4	8	8, of two kinds
holds	14 units	8 units	20 to 30 units
cheapest swap out	costs 12	costs 11	costs 11
when cooled slowly	heals	stays	stays

What the three share. **EXACT** Each is stuck on its own: every single swap out of it costs energy. Each holds a fixed amount, set by its wiring and not by the size of the tube. Each was made by the change, and almost none holds a link reaching far across the tube (4 pieces of 2,121). **What sets them apart** is their size, what they hold, whether their dots have a square too many or also a square too few, and their fate when cooled slowly. The count of leftover pieces in the last chapter split each twist into four pieces of two dots, which is why so many pieces of two appeared. **OUR READING, UNVERIFIED** The 20-unit twist that turned up in 9 of 80 boxes in Chapter 2 is the same kind of object. Whether it is wired exactly the same has not been settled.

The same first step, a different fate

EXACT The cheapest swap out of a curled loop costs 12 units. The cheapest swap out of a double loop or a twist costs 11 in nearly every one read. Those are nearly the same. Yet the curled loop heals when cooled slowly and the other two do not.

OUR READING, UNVERIFIED So the first step cannot be what decides. What decides must lie further along: after the first costly swap, a curled loop must have a way downhill to the flat pattern, and the other two must not have one within reach. Nobody has traced those paths. Until someone does, this paragraph is a guess.

Why we went here. A leftover named from a count has been wrong five times in this project. The pieces that survived cooling were going to carry the paper's main result, so they were read from the wiring before they were named, with the guesses and their tests written down first.

The point to keep: The change leaves three kinds of scrap: the curled loop, the double loop and the twist. All three are stuck on their own and hold a fixed amount, and none is a seam of the kind tested, a far-reaching link. Leaving any of them costs about the same first step, yet only the curled loop heals.

8 WHERE SCRAPS SIT

Free scraps, and scraps that are joints

Two tests so far said the scraps are not seams. The single scrap of Chapter 2 does not sit where the change met itself, and almost no leftover in Chapter 7 holds a link reaching far across the tube. A reading of the first paper's saved runs finds a seam of a different sort.

The new tube does not have to be six around

EXACT Chapter 1 said the curled tube turns into a tube six around, its seam slipped by two dots. The seam can slip further. Slip it by four and the tube is eight around. Slip it by six and it is ten around. Every one of those costs nothing, because the toy charges for loops of four dots and for nothing longer. So only the first slip, from four around to six, gives off energy, and nothing pushes the change past it. Runs that finished clean almost always stopped there.

MEASURED, EXPLORATORY The first paper saved the final network of 11,880 runs. In 2,014 of them the change had finished with something left over. Those were read again, looking only at dots far enough from any leftover to see clean flat pattern all around them, which shows how wide the tube is there.

Of 2,014 finished runs with something left over	runs
six around wherever it could be read	774
wider than six wherever it could be read	473
a stretch six around <i>and</i> a wider stretch	440
of those, the two stretches touch directly	0
the rest: too few clean dots, or counts that fit neither width	327

EXACT In all 440, a leftover lies between the stretch that is six around and the wider one.

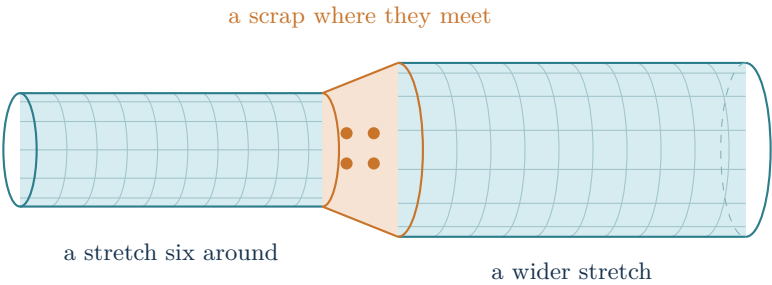


Figure 11. A scrap as a joint. **SKETCH, NOT DATA** Narrower on the left, wider on the right; the widths are drawn to suggest, not to scale. **EXACT** In every one of the 440 saved networks that hold both widths, the two never meet directly. A leftover always sits between them.

Two places a scrap can sit

So a scrap can sit in one of two places. A **free scrap** sits inside a stretch of one width, as the scrap of Chapter 2 does. A **joint** sits where a stretch six around meets a wider one: a seam, though not the kind Chapter 7 tested, since it needs no link reaching far across the tube. **MEASURED, EXPLORATORY** Free scraps are the common case. In about three of every five runs that kept a leftover, every leftover sat inside one width; about one in five holds a joint. The first paper’s sealed boxes with little room show the same thing on a larger scale: patchworks of stretches six around and wider, with flaws frozen in where the stretches meet [1].

OUR READING, UNVERIFIED How a joint might come to be: two starts whose stretches slipped by different amounts, say by two and by four, grow toward each other, and where they meet the wiring cannot match. A joint like that may not be removable at all while the two stretches keep different widths, which would be a reason for a scrap to last that has nothing to do with cooling. That is a reading of old runs, made after the fact. Which of the three kinds of scrap are joints has not been read. Before it counts, it needs its own prediction and fresh runs.

The point to keep: A scrap can be free, inside one width, or a joint, where a stretch six around meets a wider one. Free scraps are the common case. Where a run holds two widths, a scrap always sits between them.

9 WHAT WE HAVE LEARNED, AND WHAT COMES NEXT

The remainder that lasts is not the common one

What is established in the toy

A sharp change in this toy leaves small scraps of three kinds, each stuck on its own and each holding a fixed amount. Most are free, sitting inside the new tube; some are joints, where a stretch six around meets a wider one. One start leaves about one. More starts leave more, though fewer than one each, and a tube that starts itself leaves them in step with its length. A lone curled loop heals in any warm bath and is frozen in by cooling. Among many scraps, slow cooling removes the curled loops and leaves the double loops and twists, which hold most of the energy that stays.

OUR READING, UNVERIFIED For the question the author wants tested, whether a remainder can last, the toy's answer has a twist of its own. The scrap everyone counted first is the one that goes. The ones that last are rarer, and over the range we ran, how many there are depends on how the change started and not on how slowly its surroundings cooled.

What this does not show

- Anything about the real universe. A sweep of the toy is a bookkeeping step, and nothing ties it to a clock in the sky.
- That double loops and twists never heal. The slowest cooling took 300,000 fair sweeps. A slower one might remove them.
- A law for how leftovers fall with cooling time. Seven cooling speeds are enough to tell a cliff from a gentle slope and not enough to write a formula.
- That the list of three kinds is complete, or that scraps behave the same way when the toy has three large directions to work with instead of one.

Three predictions that failed

MEASURED They are part of the result. Scraps were predicted to grow with the tube, and they do not (Chapter 2). The curled loops were predicted to fall gently with slower cooling, and they fall off a cliff (Chapter 6). The leftovers that survive were predicted by the author to be seams, and by the registered test they are not (Chapter 7), though some scraps turn out to be joints of another kind (Chapter 8).

This has been studied before, in other materials

PUBLISHED People who study how order forms in materials have names for nearly everything in this paper. A change that starts at scattered places and spreads is nucleation and growth. A scrap is a defect. Healing is annealing. A system sealed with its energy is isolated, and one whose defects stop moving is arrested. A recent study of a sealed chain of atoms finds outcomes with the same outline as ours: order that spreads from scattered starts, and defects that either slowly disappear or freeze where they are [8]. **OUR READING, UNVERIFIED** The differences matter as much. Their defects are borders between two mirror-image versions of one pattern, and they vanish only in pairs. A lone curled loop heals by itself. And their sealed chain follows the laws of motion, where our toy follows a rule for trying swaps. The technical paper uses their vocabulary so that people from that field can check the work.

What comes next

Trace the path. The first costly swap is the same for the scrap that heals and the scraps that stay. The next step is to list, swap by swap, every route from each kind of scrap to the flat pattern, and find the lowest pass on any of them. That is an exact calculation, with no chance in it.

Test the joint. Chapter 8's reading becomes a prediction: in fresh runs, joints should outlast free scraps, and two starts that slip by different amounts should leave a joint where they meet.

A rule that pays for width. The first paper ends with a new price, on loops of six dots, which makes tubes go on widening past six around. **MEASURED** In those runs the wide result was full of flaws, with nine dots in ten having one within three steps. There the leftovers are no longer a rare remainder. They are the main thing standing between the toy and a clean wide space, and that is the subject of a later paper.

The scrap we counted first is the one that heals. What holds the others in place?

Continuing into the technical paper

This edition follows the technical paper [13], which holds the tables, the uncertainties and the full references. Every number above is taken from it or from the project's record. Its sections run in a different order from the chapters here, because it describes the three kinds of scrap first and this edition meets them in the order they were found: the model (Chapter 1), the kinds of relic (7), one seed (2), how many (3), lifetime in a bath (4), cooling (5 and 6) and the discussion (8 and 9).

A few translations for the next step

In the paper	What to keep in mind
“The model”	In the technical paper, our toy: the published model with the knob λ at 1.25. Only $\lambda = 1$ is the published model, combinatorial quantum gravity.
N, L	N is the number of dots. A $4 \times L$ torus is the curled tube: four around and L rings long, so $N = 4L$.
λ and g	Lambda is the knob. g is the bath’s warmth. People who study materials use both letters for other things, and the technical paper warns them.
d	The square-count signature: how many of the six pairs of links at a dot close no square. 2 where the pattern is flat, 1 on the curled tube, 3 where a square is missing.
Relic	A scrap.
Column	A curled loop: four dots in a loop that still closes a square, as a ring of the old tube did. It does not go around the new tube.
Double column	A double loop.
Knot of two kinds	A twist.
Seed, nucleation	A start: a place where the change begins.
Domain	A stretch of the new arrangement grown from one start.
Anneal	Heal.
Isolated, microcanonical	Sealed: total energy fixed, nothing in or out.
External bath	The bath of Chapter 3, as opposed to the stores inside a sealed box.
Arrested	Frozen in: the scrap can no longer move or heal because nothing can pay for the swap.
Size-fair sweeps	Fair sweeps.
Apparent exponent	A slope read off a short stretch of a curve, which need not hold beyond it.
Pre-registered	The prediction and the rules of the test were committed before the run.

Where the evidence is recorded

The technical manuscript is in [the project repository](#), with every configuration, random seed, result file and prediction. Experiment labels in that record: T10 and T11 (one start, and where the scrap sits), T17 (planted starts), T37 (tubes that start themselves), T19 (warm baths), T25 (cooling one scrap), T51 (the large test) and T55 (the three guesses). The reading of Chapter 8 is entry O116 of the project’s list of findings, and the curled loop’s wiring in Figure 2 is entry O126.

Disclosure

The author used Claude (Anthropic) and ChatGPT/Codex (OpenAI) to assist with code, analysis and writing, and is responsible for the result. This edition was drafted with Claude from the technical manuscript and the project’s record. Its comparisons and pictures introduce no new experiments or evidence. No physicist has reviewed any of it.

Sources

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- [13] E. Smith, *What the change leaves behind: relic defects of fixed size in a graph model of emergent geometry*, technical manuscript, draft of 14 October 2026, [in the project repository](#).

Sources 1 to 12 carry the same numbers as in the technical paper [13]; 13 is this edition's own.