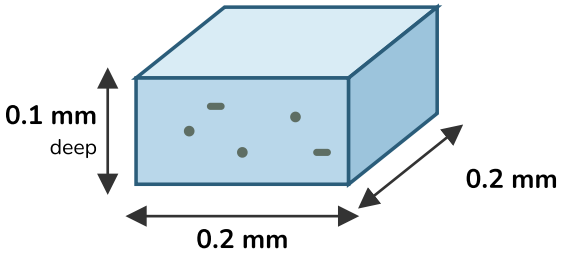
SCIENTIST · AGES 9-14 · SHEET 1

Counting Grid Math

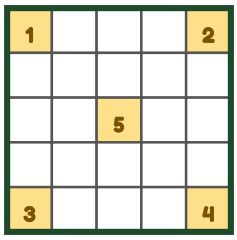
A gram of soil can hold billions of bacteria: far too many to count. So we count a few tiny squares of known size on a **counting grid** (a hemocytometer) and scale up. In the game, Dr. Dirt counts the standard **5 small squares**: the four corners and the middle of the centre square.

Where 250,000,000 comes from

1. One small square is **0.2 mm × 0.2 mm**, and the cover glass sits **0.1 mm** above it.
2. So it holds 0.2 × 0.2 × 0.1 = **0.004 mm³ = 0.004 µL** of water.
3. 1 mL = 1,000 µL, and 1,000 ÷ 0.004 = **250,000**: it takes 250,000 squares to fill 1 mL.
4. The drop was diluted **1:1,000**, so the soil held 1,000 times more: **× 1,000**.
5. 250,000 × 1,000 = **250,000,000**. Every bacterium in a square stands for 250 million in a gram (1 g of soil ≈ 1 mL).



0.004 µL = 1/250,000 of a mL



The 5 squares counted (shaded).

Worked example: the four steps

Counts in the 5 small squares of a 1:1,000 drop: 6, 3, 8, 8 and 6.

1.	**(6 + 3 + 8 + 8 + 6) ÷ 5 = 6.2**	Average bacteria per square
2.	**6.2 × 250,000 = 1,550,000**	Scale up to one full milliliter
3.	**1,550,000 × 1,000 = 1,550,000,000**	Reverse the dilution to find the total in the original soil
4.	**6.2 × 250,000,000 = 1,550,000,000**	Combined shortcut multiplier

Counting rule: bacteria on the **top** and **left** lines count; on the bottom and right lines they don't, so none is counted twice. A pair or a short chain counts as 1, the way the game counts it.

Quick check

1. On a 1:100 drop (tube 2) instead, what is the shortcut multiplier for a small square?

_____

2. A 1:1,000 drop averages 8 bacteria per small square. How many bacteria per gram?

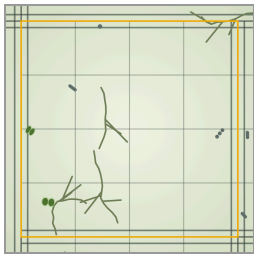
_____

Counting Grid: Your Turn

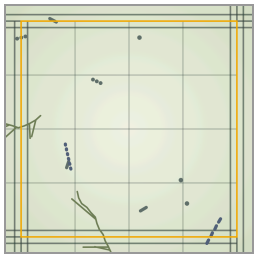
Count the game's own squares

Healthy garden soil, a 1:1,000 drop, the 5 standard squares (yellow). Write the count under each.

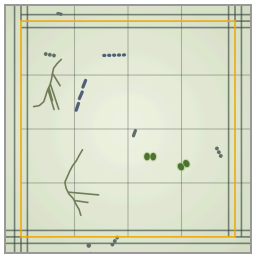
Healthy garden soil
Count it in the game



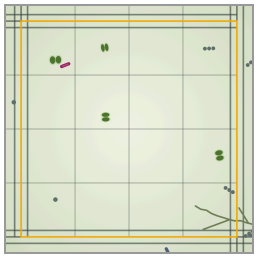
1 ____



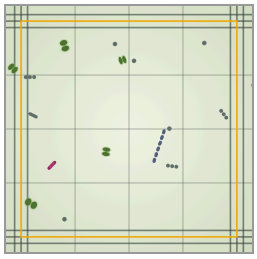
2 ____



3 ____



4 ____



5 ____

1.	(____ + ____ + ____ + ____ + ____) ÷ 5 = ____	Average bacteria per square
2.	____ × 250,000 = ____	Scale up to one full milliliter
3.	____ × 1,000 = ____	Reverse the dilution to find the total in the original soil
4.	____ × 250,000,000 = ____	Combined shortcut multiplier

Practice

P1. Forest soil, 1:1,000 drop, 5 small squares: 4, 2, 4, 9, 3. Bacteria per gram?

P2. Packed path, 1:100 drop, 10 tiny squares (0.05 mm × 0.05 mm × 0.1 mm deep = 0.00025 µL, so 4,000,000 fill 1 mL): 11, 16, 24, 9, 14, 18, 16, 10, 12, 18. What is the shortcut multiplier? Bacteria per gram?

P3. Fresh compost on a 1:100 drop has about 249 bacteria in each small square. More than 150 is too crowded to count, and more than 30 is hard work. Which tube should you use instead, and about how many will a square hold then?

P4. Healthy soil holds about 1 to 3 billion bacteria per gram; compost about 4 to 10 billion. Which of your answers look like soil, and which like compost?

Nematode ID Key

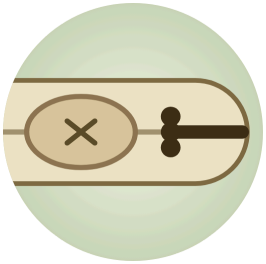
Nematodes are round worms, about half a millimetre long. Find one at **100x**, then look at its **head** (the end with the throat; the tail tapers to a point). Use the key.

The simulator
Zoom in on a nematode's head

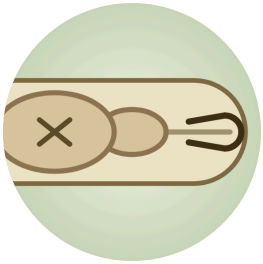
1. Is there a **spear (stylet)** in the mouth? No → go to 2. Yes → go to 3.

2. Open tube mouth, throat ending in a **round bulb with a valve** (two bulbs) → **bacteria-eater**. Wide mouth with a **tooth**, plain thick throat → **predator**.

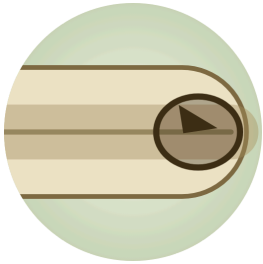
3. Three knobs at the base of a strong spear → **root-eater** (trouble). Thin spear, **no knobs**, big bulb mid-throat → **fungus-eater**.



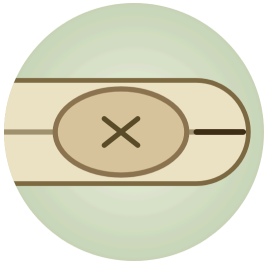
A Kind: _____
Eats: _____
Helper / trouble: _____



B Kind: _____
Eats: _____
Helper / trouble: _____



C Kind: _____
Eats: _____
Helper / trouble: _____



D Kind: _____
Eats: _____
Helper / trouble: _____

Why it matters

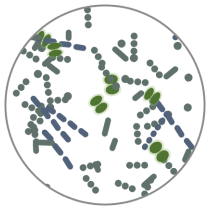
Kind	Job in the soil
Bacteria-eaters	Eat bacteria and release the extra nitrogen as plant food, right by the roots.
Fungus-eaters	Pierce fungal threads and drink them; they keep fungi in balance and release fungal nutrients.
Predators	Eat other nematodes (root-eaters too), protozoa and more: they keep the trouble-makers in check.
Root-eaters	Stab roots to feed. A few are normal; when they are a third or more of the nematodes, the game gives a warning.

A slide has 12 helpful nematodes and 6 root-eaters. What share are root-eaters? Is that a warning?

What Am I Seeing?

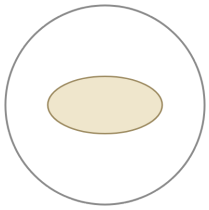
Every picture is from the game. Name each one and its group: **bacteria**, **fungi**, **trouble**, **protozoa**, **nematodes** or **not life**.

Actinobacteria | Bacteria | Ciliate | False fungus (lookalike) | Flagellate | Microfiber | Mycorrhizal fungus | Naked amoeba | Nematode egg | Pollen | Testate amoeba | True fungus



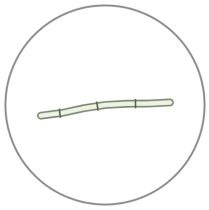
1.

_____ group: _____



2.

_____ group: _____



3.

_____ group: _____



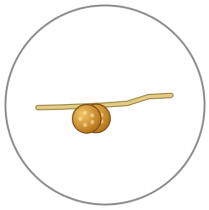
4.

_____ group: _____



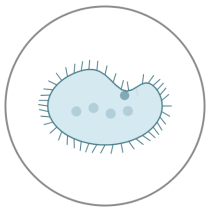
5.

_____ group: _____



6.

_____ group: _____



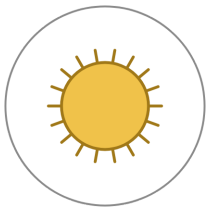
7.

_____ group: _____



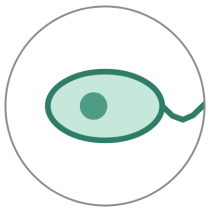
8.

_____ group: _____



9.

_____ group: _____



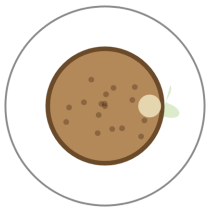
10.

_____ group: _____



11.

_____ group: _____



12.

_____ group: _____

Real fungus or lookalike?

	True fungal thread	Lookalike ("false fungus")
Width		
Cross-walls (septa)		

Who does this job? Write its number.

Eats bacteria and releases nitrogen by the roots (two answers)		Trades water and nutrients for root sugars	
Gives soil its earthy smell		Many of them mean the soil is short of air	
Breaks down woody stuff and builds crumbs		Litter that is not soil life at all	

SCIENTIST · AGES 9-14 · MYSTERY LESSON

Soil Detective: Gather Clues



1. Scan a mystery code. On the **Hard** level, make a slide, count bacteria in the counting grid and measure fungal threads. Find protozoa and nematodes.
2. Write your numbers in the table (the results page shows them per gram).
3. Turn each number into a clue with the Clue Key, then cross out the suspects that don't fit.
4. Name the soil. Look at more drops to be surer: one drop can be off.

Mystery A
Scan to open

Mystery B
Scan to open

Mystery C
Scan to open

Mystery D
Scan to open

My readings

Mystery	Fungi : bacteria	Bacteria (billion/g)	Fungal thread (m/g)	Protozoa (thousand/g)	Ciliates (/g)	Helpful nematodes (/g)	Root-feeders (/g)
A							
B							
C							
D							

Clue Key (the game's own clues)

Measure	When	Clue	Soils like this
Fungi : bacteria	3 : 1 or more	Fungi far ahead	Forest floors, mulched orchards, woody compost
	1 : 1.7 to 3 : 1	About even	Gardens fed with compost, old pasture, finished compost
	1 : 3.3 to 1 : 1.7	Bacteria a little ahead	Soils starting to struggle, compost tea
	under 1 : 3.3	Bacteria far ahead	Young hot compost; dug, packed, soggy, sandy or bagged soil
Fungal thread	under 10 m per gram	Almost none	Subsoil, packed paths, beach sand, bagged mixes
	300 m per gram or more	Lots	Forest, orchard, fungal compost
Bacteria	under 1 billion per gram	Few	Sand, sour ground, bagged mixes
	1 to 4 billion	Normal for soil	Most living soils: read the other clues
	4 billion or more	Very many	Compost and castings, or worn-out ground with nothing else
Protozoa	under 30,000 per gram	Not many	Packed, deep, sandy, bagged or salty ground
	200,000 or more	Lots	Compost and worm castings
Ciliates	25,000 per gram or more	Lots: short of air	Soggy or trampled soil, sour or young compost
Helpful nematodes	under 5,000 per gram	Hardly any	Packed, deep, sandy or bagged ground
	35,000 or more	Lots	Healthy, mature soils and finished compost
Root-feeding nematodes	30% or more of the nematodes	Warning	Stressed soils: waterlogged or salty

SCIENTIST · AGES 9-14 · MYSTERY LESSON

Soil Detective: The Suspects



One of these is each mystery sample. Cross out a suspect when a clue doesn't fit.

Fresh bacterial compost

Comes from: A young, hot pile with lots of greens.
Smell and feel: Warm, with a whiff of ammonia. Coarse, still has leaves.
Under the microscope:

- Packed with bacteria and yeast.
- Few fungi; few protozoa and nematodes (the heat keeps them down).

Mulched fruit orchard

Comes from: Under fruit trees kept mulched with wood chips.
Smell and feel: Earthy and woody. Loose under the mulch.
Under the microscope:

- More fungi than bacteria: brown threads in most views.
- Mycorrhizal threads and spores.
- Fungus-eating and predatory nematodes keeping things in check.

Packed path / dirt road

Comes from: A path walked and driven on until it is hard.
Smell and feel: Smells like dust. Hard as a brick; water runs off.
Under the microscope:

- Billions of bacteria and actinobacteria, but almost nothing else.
- Hardly any fungal threads, very few protozoa, no nematodes.
- Pale minerals and very few organic bits.

Wet compacted soil

Comes from: A patch that floods and gets walked on.
Smell and feel: Sour or rotten-egg smell. Sticky and grey.
Under the microscope:

- Ciliates zooming around (they like low air).
- Thin, clear "false fungi" and few real fungi.
- Root-feeding nematodes with a spear (stylet).
- Algae and diatoms from standing water.

My verdict

Mystery	It is...	The clue that proves it
A		
B		
C		
D		

1. Two soils can both have billions of bacteria. Which other clues tell compost apart from worn-out, packed ground?

2. Why look at more than one drop of the same soil?

SCIENTIST · AGES 9-14 · CLASS LESSON

Compare the Samples



Each person measures each sample. Then the class shares its numbers and writes the **class middle** (the middle number when they are put in order).

A: Healthy garden soil
Scan to open

B: Forest / fungal soil
Scan to open

C: Lifeless subsoil / construction fill
Scan to open

D: Finished compost
Scan to open

Measure	A: Healthy garden soil		B: Forest / fungal soil		C: Lifeless subsoil / construction fill		D: Finished compost	
	Me	Class middle	Me	Class middle	Me	Class middle	Me	Class middle
Fungi : bacteria								
Bacteria billion/g								
Fungal thread m/g								
Protozoa thousand/g								
Helpful nematodes /g								

1. Which sample is the most fungal? _____ The most bacterial? _____

2. Plants want different balances (fungi : bacteria): Vegetables 0.3 to 1; Berries & shrubs 1 to 5; Fruit trees & forest 5 to 100. Which sample suits a fruit tree? Which suits lettuce?

3. One soil has billions of bacteria but is still a poor soil. Which one, and why?

4. Children's numbers for the same soil are different. Why? Why use the class middle?

For Teachers and Parents



Five sheets that go with **Dr. Dirt's Microscope**, a free soil-microscope simulator (drdirt.earth/game/?mode=microscope; no sign-in). Children use the **Hard** level. Every organism picture and counting square on these sheets is drawn by the game itself, so it matches the screen, and every number in the answer key is worked out from the game's own soils.

The QR codes

- **The simulator** opens the microscope.
- **A named sample** opens the microscope straight on that soil.
- **Mystery A to D** open a soil with its name and story hidden, for the detective sheet.

The simulator
No sign-in needed

The sheets

1. Counting Grid Math (2 pages)	Where 250,000,000 comes from, the four steps, the game's own five squares to count, and practice with the game's real square sizes and dilutions.
2. Nematode ID Key	A three-question key from the mouth and throat, as the game draws them, and what each kind does.
3. What Am I Seeing?	Twelve things from the slide, their groups and jobs; real fungus or lookalike.
4. Soil Detective (2 pages)	Four mystery soils (QR codes open each with its name hidden). Measure, turn numbers into clues with the game's own Clue Key, match the suspects.
5. Compare the Samples	A class lesson: everyone measures four named soils, then the class finds its middle reading.

Running it

- One device for one or two students; 30 to 45 minutes a sheet. Counting is an estimate, so students' numbers will differ from each other and from the key; averaging several drops, and the class middle, brings them closer.
- **Teachers:** in the **Teacher Microscope**, the **Print worksheets** button prints these PDFs and a Soil Detective and Compare sheet with QR codes for *your own* class set (named or mystery).
- The math uses the game's counting grid: small squares 0.2 mm × 0.2 mm × 0.1 mm deep (0.004 µL, 250,000 to a mL), tiny squares 0.05 mm (4,000,000 to a mL), large squares 1 mm (10,000 to a mL), and the bench's 1:10, 1:100 and 1:1,000 tubes.

Answer Key (1 of 2)



Quick check

1. 250,000 × 100 = 25,000,000. 2. 8 × 250,000,000 = 2,000,000,000 (2 billion).

Sheet 1: Counting Grid Math

Your count (the game's squares): 8, 10, 9, 9, 15.

1.	**(8 + 10 + 9 + 9 + 15) ÷ 5 = 10.2**	Average bacteria per square
2.	**10.2 × 250,000 = 2,550,000**	Scale up to one full milliliter
3.	**2,550,000 × 1,000 = 2,550,000,000**	Reverse the dilution to find the total in the original soil
4.	**10.2 × 250,000,000 = 2,550,000,000**	Combined shortcut multiplier

P1 (forest): (4 + 2 + 4 + 9 + 3) ÷ 5 = 4.4; 4.4 × 250,000 = 1,100,000; 1,100,000 × 1,000 = 1,100,000,000; 4.4 × 250,000,000 = 1,100,000,000. That's 1.1 billion (careful game value 1.2 billion).

P2 (packed path): shortcut 4,000,000 × 100 = 400,000,000. (11 + 16 + 24 + 9 + 14 + 18 + 16 + 10 + 12 + 18) ÷ 10 = 14.8; 14.8 × 4,000,000 = 59,200,000; 59,200,000 × 100 = 5,920,000,000; 14.8 × 400,000,000 = 5,920,000,000: 5.9 billion (careful game value 6.1 billion).

P3: tube 3 (1:1,000): about 25 per small square (249 ÷ 10). **P4**: forest and your garden count are soil-like (1 to 3 billion); the packed path's 5.9 billion is as busy as compost: bacteria are all that's left there.

Sheet 2: Nematode ID Key

A root-eater (roots, trouble: spear with 3 knobs). B bacteria-eater (bacteria, helper: open tube, two bulbs). C predator (other nematodes, helper: wide mouth with a tooth). D fungus-eater (fungi, helper: thin spear, no knobs). Share: 6 ÷ (12 + 6) = 33%, more than a third (30%), so yes, a warning.

Sheet 3: What Am I Seeing?

1. Bacteria (bacteria); 2. Nematode egg (nematodes); 3. True fungus (fungi); 4. Naked amoeba (protozoa); 5. Microfiber (not life); 6. Mycorrhizal fungus (fungi); 7. Ciliate (protozoa); 8. False fungus (lookalike) (trouble); 9. Pollen (not life); 10. Flagellate (protozoa); 11. Actinobacteria (bacteria); 12. Testate amoeba (protozoa). True fungus: wide and even, evenly spaced cross-walls. Lookalike: thin, wispy, tangled or broken, with uneven or missing cross-walls (some are actinobacteria or water molds). Jobs: 10 and 4 (flagellate, naked amoeba); 6 (mycorrhizal fungus); 11 (actinobacteria); 7 (ciliate); 3 (true fungus); 5 (microfiber).

Soil Detective

A = Fresh bacterial compost. A careful reading: fungi : bacteria 1 : 7.4, bacteria 6.2 billion/g, fungal thread 39 m/g, protozoa 311 thousand/g, ciliates 37,726/g, helpful nematodes 62,483/g, root-feeders 1,179/g. Clues: Bacteria far ahead of fungi (fungi : bacteria 1 : 7.4). Very many bacteria (about 6.2 billion in a gram). Lots of protozoa. Lots of ciliates (the fast swimmers covered in hairs). Lots of helpful nematodes.

B = Wet compacted soil. A careful reading: fungi : bacteria 1 : 7.4, bacteria 3.4 billion/g, fungal thread 21 m/g, protozoa 57 thousand/g, ciliates 30,180/g, helpful nematodes 16,505/g, root-feeders 18,863/g. Clues: Bacteria far ahead of fungi (fungi : bacteria 1 : 7.4). A normal soil amount of bacteria (about 3.4 billion in a gram). Lots of ciliates (the fast swimmers covered in hairs). Many root-feeding nematodes (with a spear in the mouth).

C = Mulched fruit orchard. A careful reading: fungi : bacteria 5.2 : 1, bacteria 1.9 billion/g, fungal thread 456 m/g, protozoa 165 thousand/g, ciliates 5,030/g, helpful nematodes 56,588/g, root-feeders 1,179/g. Clues: Fungi far ahead of bacteria (fungi : bacteria 5.2 : 1). Lots of fungal thread (about 456 m in a gram). A normal soil amount of bacteria (about 1.9 billion in a gram). Lots of helpful nematodes.

D = Packed path / dirt road. A careful reading: fungi : bacteria 1 : 30.1, bacteria 6.1 billion/g, fungal thread 9.4 m/g, protozoa 27 thousand/g, ciliates 1,258/g, helpful nematodes 0/g, root-feeders 0/g. Clues: Bacteria far ahead of fungi (fungi : bacteria 1 : 30.1). Almost no fungal threads (about 9 m in a gram). Very many bacteria (about 6.1 billion in a gram). Not many protozoa. Hardly any nematodes.

Q1: protozoa and nematodes. Compost is full of both; packed or dug-up ground has billions of bacteria but hardly any protozoa or nematodes (the food web stops at bacteria). Q2: one drop is only a peek; numbers vary drop to drop, so average several.

Children's numbers vary around these: one drop is a peek, and counting is an estimate.

Answer Key (2 of 2)



Compare the Samples

Sample	Fungi : bacteria	Bacteria (billion/g)	Fungal thread (m/g)	Protozoa (thousand/g)	Helpful nematodes (/g)	The game's plant
Healthy garden soil	1 : 1.1	2.5	112	157	44,799	Vegetables (about 0.3 to 1)
Forest / fungal soil	10.6 : 1	1.2	609	138	44,799	Fruit trees & forest (about 5 to 100)
Lifeless subsoil / construction fill	no fungi	5.4	0.0	0.0	0	Vegetables (about 0.3 to 1)
Finished compost	1.1 : 1	4.0	197	269	66,020	Vegetables (about 0.3 to 1)

These are careful readings of each sample (what the game works out from a whole, well-counted slide); the class middle should land near them. Most fungal: Forest / fungal soil; most bacterial: Lifeless subsoil / construction fill. Billions of bacteria but a poor soil: Lifeless subsoil / construction fill: almost no protozoa or nematodes to eat the bacteria and release their food to roots, and few or no fungal threads. Different numbers for the same soil are expected: each drop and each count is a small sample; the middle of many readings is steadier than any one.