

The Future of Biotech

The innovations that are coming, where they get stuck, and what a theory of closure adds

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0. What was found

Thirty-eight lines of innovation in red and green biotechnology were mapped as they stood on 25 October 2026. For each line the map gives what it is, what it changes, who leads it, its stage and its next milestone.

Several lines cross a threshold in 2026-2027:

- **Gene editing inside the body.** The first such product is under review, with a decision due in March 2027.
- **Cancer vaccines.** A personalised cancer vaccine succeeded in phase 3.
- **CAR-T in autoimmune disease.** Its first approval is likely in 2027.
- **Brain-shuttle drugs.** The first drug carried across the blood-brain barrier was approved.
- **Gene-edited livestock.** A gene-edited pig is approved in five countries.
- **Gene-edited crops in the EU.** The new rules apply from July 2028.

Innovation does not come from where the money goes. Two thirds of new US medicines in 2024 came from small companies. Large firms buy about half of their pipelines from outside. China now starts a third of new drug candidates, but only 3 percent of those with a genuinely new mechanism. Europe holds about 30 percent of those.

The vacuum.net theory was applied to each of the 38 lines in the way the essay *Read Before You Remove* applies it to the melanoma vaccine. For each line: where it gets stuck, which rule of closure or order touches that point, what concrete move follows, and what the literature already says.

The result:

- **Thirty moves.** Of the 38 lines, 30 get a move: an ordering, structure or design rule.
- **Practice already agrees with sixteen.** Examples: stack resistance genes at once, bridge a graft with a third plant, image before treating, treat before surgery.
- **Twelve are partly known,** with a new element.
- **Three moves are open.** A cancer vaccine on what tumours share, so no factory per patient is needed. Microbial medicines chosen by function rather than species. Starter cultures added in stages in their natural order.
- **One is contradicted.** Stacking RNA targets does not stop pests, because they resist uptake itself.
- **Eight get no move.** All are questions of dose, yield, energy, cost or approval: the sizes the theory does not claim.

Four predictions remain where the theory says something ordinary biology does not:

- three-cell corners;
- crystal faces;
- stability as closure above chance;

- the ring of three.

Each can be tested with means that exist today, several in Leiden.

1. The occasion

On 25 October 2026 the Leidsch Dagblad reported an investment agenda of about 2.5 billion euros for the Leiden Bio Science Park (LBSP), over ten years. Of that sum, 1.754 billion is for conditions: mobility, real estate and talent. Another 633 million is for “innovation engines” and shared research infrastructure. The agenda itself is not public.

This essay does not judge the agenda. It asks the prior question. Which innovations are coming in red and green biotechnology? Where do they come from? And which ones does a theory of closure add?

2. The theory in brief

The vacuum.net theory describes everything that stays as one strand that crosses itself. The image is a fishing net: knots where the strand meets itself, meshes in between.

Each meeting of the strand with itself is a *touching*. Each touching carries a trit, +1, 0 or −1. Three successive touchings form a *window*. A window *closes* when its trits add up to zero modulo three. The selection rule is simple: what closes stays, and what does not close passes on as tension.

Four counting results carry this essay:

1. **The seam rule.** A window closes if and only if its three trits are all equal or all different. Two equal and one different never closes. So where three structures meet, AAA and ABC close and AAB stays open. This is proven by enumeration of all 27 windows.
2. **Open directions.** Read as trit triples, the crystal directions close as follows: $\langle 100 \rangle$ in 0 of 6 cases, $\langle 111 \rangle$ in 2 of 8, $\langle 110 \rangle$ in 6 of 12. The $\langle 100 \rangle$ direction never closes, so it is the most open. Open directions carry passage. In one battery material this order matched the measured capacities; in a second it matched only in part.
3. **The chance baseline.** For independent trits with probabilities (p_0, p_1, p_2) , a window closes with probability $(1/3) \cdot [1 + \hat{p}(\omega)^3 + \hat{p}(\omega^2)^3]$, with $\omega = e^{(2\pi i/3)}$. For equal probabilities this is 1/3. Closure above this baseline measures order that chance does not give.
4. **The ring of three.** A window is three touchings. A configuration persists when it closes on itself. Three partners that each pass something to the next form one window. Two partners cannot.

The theory’s own record is plain about its reach. Where it counts closures, it has held. Where it fixes the size of a quantity, it has not yet shown anything beyond chance. So this essay uses it only to say *which* configurations close, never *how much*.

3. Where innovation comes from

Small companies. In 2024, 36 of the 54 new medicines approved by the FDA came from small and emerging biotech companies. These companies hold 55 percent of all clinical programmes. Large pharma aims at about half internal and half external innovation, and most of the top 25 sit close to that split.

China. China was home to 33 percent of new drug candidates entering pipelines in 2024, against 8 percent in 2015. Among candidates with a genuinely new mechanism,

China holds 3 percent. The United States holds about half and Europe about 30 percent.

Universities. About one in ten new medicines, and one in five important ones, comes directly from public research institutions. Of the new molecules approved in 2000–2009, 48 percent cite academic research in their patents. A citation is a link, not proof of origin.

Leiden. Ruconest from Pharming, Joenja from Pharming (approved for children in September 2026), and the Janssen covid-19 vaccine developed in Leiden. Johnson & Johnson closed most of its Leiden vaccine research unit in 2023, while keeping manufacturing.

What this means. A science park adds value where small companies grow out of academic work, and where that work is sold or licensed onward. Large manufacturing plants make what already exists.

4. The map

4.1 Red biotechnology

Line	What changes	Stage, October 2026	Next step
Gene editing in the body	One infusion instead of lifelong treatment	Intellia's lonvo-z under review; hereditary angioedema attacks –87%	FDA decision 10 March 2027
CAR-T made inside the body	No cell factory needed	Phase 1; 4 of 5 myeloma patients responded, one death	Autoimmune trials
CAR-T in autoimmune disease	A reset of the immune system	Kyverna: 92% off immunotherapy after one year	First approval likely 2027; LUMC treated a first Dutch patient in 2025
Personalised cancer vaccines	A vaccine built from each tumour	Moderna/Merck positive in melanoma phase 3, August 2026	Filings
ADCs and bispecifics	Targeted chemotherapy, dual targeting	Moving into first-line use	PD-1×VEGF decision November 2026
Radioligands	Radiation delivered to the tumour itself	Pluvicto approved earlier in prostate cancer	Actinium-225 phase 3; Petten supplies about a third of world lutetium-177
Oral peptides and incretins	Pills instead of injections	Oral GLP-1 and oral IL-23 peptide approved in 2026	New combinations 2026–2027
RNA drugs	Silencing or editing a message, not the gene	siRNA approved; RNA editing proven in people	ProQR (Leiden): phase 2 mid-2027, with Lilly
Automated cell manufacturing	Lower cost per patient	First fully automated CAR-T dosed, April 2026	Allogeneic pivotal results
Organ-on-chip	Human tissue instead of animal tests	FDA draft guidance, March 2026	MIMETAS (Leiden), now majority-owned by Bruker
AI drug design	Faster design of candidates	First AI-designed drug in phase 3	Isomorphic's first trials
Multi-cancer blood test	Cancer found before symptoms	FDA panel 7–2 in favour of Galleri	FDA decision

Crossing barriers	Drugs into the brain, through the nose or gut	First brain-shuttle drug approved, March 2026	Leyden Labs (Leiden): nasal flu antibody safe in 143 volunteers
Crystal engineering	Drugs that dissolve and absorb better	Enabling technology; AI cocrystal screening	—
Microbiome therapies	Defined bacterial mixtures as medicine	One approved; an eight-strain mix passed a phase 3 interim	Results first half of 2027
Longevity drugs	Slowing ageing itself	No drug has shown it; a lead candidate missed its endpoint	Trials still recruiting
Xenotransplantation	Pig organs for people	Formal trials; a pig kidney working for 285+ days	Trial endpoints
Brain-computer interfaces	Speech and movement restored	Early trials	First approval estimated 2028–2030

4.2 Green biotechnology

Gene-edited plants of the simplest kind will count as conventional in the EU from 17 July 2028. In the EU no precision-fermented protein and no cultivated meat had been approved by October 2026.

Line	What changes	Stage, October 2026	Next step
Disease-resistant edited crops	Less spraying	Wageningen field trials with blight-resistant potato since April 2026	EU procedures open July 2028
Drought, heat and yield edits	Crops that hold in bad years	Quality traits on the market; yield edits in greenhouse (+20–25% rice)	Field trials
Better photosynthesis	More yield from the same light	Field trials, no product	—
Nitrogen-fixing cereals	Less fertiliser	Laboratory	“Years to decades”
Microbial nitrogen	Bacteria that supply nitrogen	On the US market; independent trials found gains in 2 of 61 site-years	New product 2027
Soil microbes and biologicals	Healthier, drought-resistant roots	Leiden (IBL): a root bacterium raises drought tolerance (Nature Plants 2026)	New EU microbe list 2027
RNA sprays	Pest control without chemistry	US and China; first EU emergency use 2026	EFSA decision
Seed coatings with microbes	Protection from the first day	On market and in pilots	—
Grafting	Resistance and vigour from the root	On market; why grafts fail is still a hypothesis	—
Perennial grains	No yearly ploughing	Niche; yield 20–40% of wheat	—
Precision fermentation	Milk and fat proteins without animals	On the US market; none in the EU	Nourish hub in Leiden (BioPartner 5)
Cultivated meat	Meat without slaughter	Small sales outside Europe; Meatable (Leiden) closed December 2025	EFSA opinions
Defined starter cultures	Reliable fermentation	A nine-strain culture reproduces fine chocolate flavour	—

Salt and sugar particles	Same taste, less salt	On the market (about 50% less sodium, company claim)	—
Fat and texture crystals	Cocoa butter and fat from fermentation	On the US market / research	—
Gene-edited livestock	Disease-resistant pigs	Approved in the US, Canada and three Latin American countries	Mexico, Japan, China
Molecular farming	Proteins grown in plants	Food proteins cleared in the US; drugs very limited	—
Vertical farming	Food in buildings	Shrinking; several bankruptcies	—
AI and genomic breeding	Faster breeding for climate	Tools in use; no AI-bred climate variety yet	CropXR (KeyGene, Wageningen)

4.3 Money against innovation

Forecasters give biotech 11.7 to 14.3 percent growth a year and agricultural biotech 7.9 to 9.4 percent. Over 2021–2025 capital moved the other way:

- **Biopharma venture capital** fell 39 percent.
- **Investment in alternative protein** fell by more than 80 percent.
- **Agrifood-tech funding** fell 69 percent.

On the LBSP, by contrast, venture capital rose from 220 million euros in 2024 to 350 million in 2025.

The lines that are actually moving in 2026 are mostly new kinds of treatment. Examples are editing inside the body, cell resets of the immune system, personalised vaccines, and drugs that cross barriers. These grow in small and mid-sized companies. They are rarely what the market forecasts measure.

5. The theory applied to each line

The method follows the essay *Read Before You Remove* (constable.blog, 25 October 2026). That essay takes one innovation, the personalised melanoma vaccine, and names where it gets stuck: a factory per patient, nine weeks of waiting, and 302 of 1,749 screened patients excluded. It then applies an ordering rule from the theory. Treat before you remove, and the tumour becomes its own vaccine without a factory. Finally it checks what the literature already says.

The same was done here for all 38 lines. Each line got four things:

- **The bottleneck.** Where the line gets stuck, stated concretely.
- **The rule that touches it.** One of the rules from Section 2, or the following:
 - closure: what closes stays;
 - first passage: the first passage fixes orientation, so order matters;
 - context: constants are state functions, so values are set locally;
 - scale: what does not close at one scale is the material of the next.
- **A plain move.** An ordering, a structure or a design rule, never a dose or a size.
- **A literature check.** What is already known about the move.

Where the theory gives only a label, the line says “no move”.

5.1 Red

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Line	Bottleneck	Rule	Move	Literature
Gene editing in the body	Delivery reaches the liver only; liver safety	Context	Switch the editor on only in the target cell state	Partly known
CAR-T made in the body	Where the vector lands; transient or lasting	Closure	Transient for an autoimmune reset, lasting for cancer surveillance	Already practised
CAR-T in autoimmune disease	Cost per patient; relapse after about 1.5 years	Closure	Target the whole shared B-cell line across compartments (CD19 with BCMA)	Partly known
Personalised cancer vaccines	Factory per patient; 9 weeks; 17% excluded	First passage, closure, context	Treat before surgery; target what tumours share; lift tolerance only locally	First move supported; second and third open
ADCs and bispecifics	Toxicity in healthy tissue carrying the target	Seam, ring of three	Kill only where two targets meet: a logic gate	Partly known
Radioligands	Isotope supply	First passage	Image the target before treating	Standard practice
Incretins and oral peptides	Tolerability, muscle loss, capacity	—	No move: a size problem	—
RNA drugs	Delivery beyond the liver; durability	Context, closure	Reversible editing for a disturbed state, permanent for a missing part	Already practised
Allogeneic cell therapy	Rejection: the donor-host seam	Seam	Autologous or in-body for cure, donor cells as a bridge	Already practised
Organ-on-chip	One chip cannot show the whole body	Scale	Link organ chips so passage between organs closes	Partly known
AI drug design	The bottleneck is clinical biology, not chemistry	—	No move	—
Multi-cancer blood test	Few true positives; no proof of fewer deaths	Chance baseline	Require a signal above the overdiagnosis baseline, not raw detection	Already the standard
Crossing barriers	Oral uptake below 1%; shuttles not yet proven	Open directions	Use routes that are already open instead of forcing the barrier	Already practised
Crystal engineering	Predicting stability	—	No move: an energy problem	—
Microbiome therapies	Narrow indication, unclear mechanism	Closure	Build the mixture by shared function, not by species	Partly open
Longevity drugs	No accepted ageing endpoint	Context	Local, per-organ endpoints instead of one body clock	Already argued

Pig organs	Rejection months later despite edits	Seam	Edits on the donor side alone cannot close the seam; add tolerance on the host side	Already practised
Brain implants	Lasting contact with tissue	Seam	Minimise and match the electrode–tissue seam; plan maintenance	Partly known
Leiden rare-disease drugs	Small groups; dosing in children	—	No move: size and economics	—

5.2 Green

Line	Bottleneck	Rule	Move	Literature
Disease-resistant crops	One resistance gene, broken by one mutation	Closure	Stack genes together; do not release them one by one	Already practised
Drought and yield edits	Gains do not carry across varieties	Context	Re-test each edit in each variety and environment	Partly known
Better photosynthesis	No yield gain in the field	Closure, scale	Carbon must close in a sink: engineer the sink with the source	Already argued
Nitrogen-fixing cereals	The plant must read the microbe as a partner	First passage	Engineer the first recognition step	Corresponds to current work
Microbial nitrogen	2 of 61 site-years positive	Context, chance baseline	Sort by soil nitrogen; report against the chance baseline	Partly known
Soil microbes	The inoculant loses to the resident community	First passage, context	Inoculate an open or disturbed community, or open a niche	Partly known
RNA sprays	Pests resist the uptake of all RNA sprays at once	Closure	Stacking RNA targets does not close: one uptake mutation opens all of them	Contradicted
Seed coatings	The coated microbe must reach the root first	First passage	Time the strain to colonise the first root, rather than raising the dose	Partly known
Grafting	Incompatible pairs do not unite	Seam, first passage	A bridge of a compatible third plant	Already practised
Perennial grains	Carbon split between grain and survival	Closure	Remove biomass in autumn, not spring	Already practised
Precision fermentation	EU approval, cost and scale	—	No move	—
Cultivated meat	Capital and cost	—	No move	—
Starter cultures	The natural order is yeast, then	First passage, seam	Add the cultures in stages, in the	Open

	lactic, then acetic bacteria		natural order, instead of all at once	
Salt crystals	Saltiness depends on dissolution speed	Open directions	Open, high-surface crystal forms (hollow cubes)	Already practised
Fat crystals	A new fat clashes with the fat in the blend	Seam	Match crystal type and fat family	Already practised
Gene-edited livestock	Export approvals, not biology	—	No move	—
Plant-grown proteins	Low yield; the protein breaks down	Closure	Pack the protein into closed compartments in the cell	Already practised
Vertical farming	Energy and capital	—	No move	—
AI breeding	One breeding value treated as universal	Context	Predict per environment, then validate	Partly known

5.3 What this shows

Of the 38 lines:

Outcome	Lines
Move already practised or supported	16
Partly known, with a new element	12
Open, not found in the literature searched	1 line, plus 2 open parts
Contradicted	1
No move	8

Where the theory moves, it lands on what works. In 16 lines, an ordering or structure rule from the theory points to what the best practitioners already do.

Examples:

- **Disease resistance.** Stack resistance genes at once.
- **Grafting.** Bridge an incompatible graft with a third plant.
- **Radioligands.** Image before treating.
- **Melanoma.** Treat before surgery.

This is correspondence, not discovery. Still, it says something: the rules are not arbitrary.

Where the theory is silent, the problem is a size. All eight lines without a move are questions of dose, yield, energy, cost or approval. The theory's own ledger says it has not yet shown sizes beyond chance. The silence is consistent.

Where it is new. Three moves were not found in the literature searched:

1. **Cancer vaccines on what tumours share.** Target features common to all melanomas, so no factory per patient is needed.
2. **Microbial mixtures chosen by function.** Build a medicine from bacteria selected for what they do, not for their species.
3. **Starter cultures added in stages.** Follow the natural order of yeast, lactic and acetic bacteria, instead of adding all at once.

Each has a direct test:

- *Vaccines:* a shared-antigen vaccine against a personal one, after treatment before

surgery.

- **Microbial mixtures:** a function-selected mixture against a species-selected one.
- **Starter cultures:** staged against simultaneous dosing, scored on flavour and stability.

Where it was wrong. For RNA sprays the natural move, stacking several RNA targets, does not work. Pests resist the uptake of RNA itself, so one mutation opens every target at once. The rule of closure must be applied at the right step: the uptake, not the target.

One number re-read. Microbial nitrogen products gained yield in 2 of 61 independent site-years. If 5 percent of trials come out positive by chance, one expects about 3 of 61. The chance of 2 or fewer is 0.41. The observed gains are therefore not above chance. The theory's move, to sort trials by soil nitrogen and report against the chance baseline, would make this visible in every trial report.

5.4 The sharp tests

Most moves above correspond to known practice. Four predictions remain where the theory says something that ordinary biology or chemistry does not.

1. **Junction corners.** Where three cells meet, AAA and ABC corners seal and AAB corners leak. Ordinary biology expects leak to rise with difference. *Test:* a barrier chip with three cell types (MIMETAS, Leiden).
2. **Crystal faces.** Cubic {100} faces dissolve faster per unit area than octahedral faces. Known practice uses open crystal shapes; the face-specific claim is the theory's own. *Test:* equal-area cubic and octahedral salt crystals.
3. **Closure above chance as an endpoint.** Stability is measured as the share of closed three-visit windows minus the chance share, and compared between trial arms. *Test:* re-analysis of existing trials, for example CAR-T in autoimmune disease.
4. **The ring of three.** Three microbes feeding one another in a ring persist; two do not, and an AAB mix fails. *Test:* serial transfer of triads, pairs and AAB mixes.

5.5 What the theory does not add

- **No market forecast.** The theory says nothing about market sizes.
- **No sizes.** It gives no dose, yield or rate.
- **No choice of hand.** Left and right close equally well, so the theory does not explain why life uses one hand.
- **Little news where practice is good.** In half of the lines it confirms what good practice already does. Its value there is as a checklist: a quick way to ask of any innovation whether it is ordered and structured so that it can close.

6. Leiden

The map places Leiden on several moving lines:

- **RNA editing:** ProQR.
- **Nasal antibodies:** Leyden Labs.
- **Rare immune disease:** Pharming.
- **Academic CAR-T:** LUMC.
- **Organ-on-chip:** MIMETAS.
- **Drought microbes:** the Institute of Biology.
- **Fermented fat:** the Nourish hub.

Galapagos, Batavia and Meatable left or closed. The grid at the park is congested until 2028 at the earliest.

The four sharp tests of Section 5.4 and the three open moves can be run with partners

already on or near the park: MIMETAS for the corner test, LUMC for trial endpoints and vaccines, the Institute of Biology for microbial rings, and the Nourish hub for fermentation. Each needs a laboratory, existing data or a field plot. None needs a building.

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