



PART 2

Read the text below and answer questions 14–26.

NATURE'S INGENUITY: CASE STUDIES IN BIOMIMETIC DESIGN

Biomimetic design often sounds persuasive in a pitch deck because it borrows the authority of nature. Yet the credibility of a biomimetic idea is not decided at the moment of inspiration; it is decided after launch, when a concept is exposed to manufacturing tolerances, safety regulations, user habits, and the slow erosion of performance caused by wear, dirt, and imperfect maintenance. In other words, biomimicry is constrained by implementation. A biological strategy must survive translation into industrial materials, repeatable production, and real environments that rarely resemble laboratory conditions. Case studies therefore function less as triumphalist stories than as technical evidence about what does—and does not—scale.

A well-known transport example comes from Japan's high-speed rail, where early prototypes of the Shinkansen encountered an unexpectedly loud "tunnel boom." As a train entered a tunnel at high speed, pressure waves built up; as it exited, those waves discharged abruptly, producing a sharp noise that disturbed nearby communities and signalled wasted aerodynamic energy. Engineers initially tried conventional mechanical remedies, but the problem was fundamentally aeroacoustic: it arose from how the train displaced air. The breakthrough came when designers examined the kingfisher, a bird capable of plunging from air into water with minimal splash. The relevant insight was not aesthetic resemblance but the management of pressure gradients. By reshaping the train's nose into a more elongated profile, engineers weakened the pressure wave at tunnel exits, thereby reducing noise while also improving energy efficiency through lower aerodynamic drag.

Ventilation offers a different class of lesson, in which the biological model is not a single surface or shape but a system of flows. Termite mounds can maintain relatively stable internal temperatures despite sharp external swings, using networks of channels that move air by exploiting pressure differences and thermal buoyancy rather than constant mechanical input. Architects and engineers have adapted this principle in buildings seeking passive cooling or reduced reliance on air-conditioning. However, projects that copied termite-mound forms too literally sometimes underperformed because the governing variables were different: local climate, prevailing winds, occupancy schedules, and construction materials changed the heat and airflow balance. Better outcomes emerged when designers treated the mound as a hypothesis about airflow, then used



modelling and iterative adjustment to tailor ventilation pathways to local conditions. The case thus illustrates a recurring theme: functional emulation outperforms literal imitation.

A third category of biomimetic projects focuses on surfaces, where microscopic structure produces macroscopic behaviour. Lotus leaves, for example, are associated with superhydrophobicity: water forms near-spherical beads that roll away, carrying particles of dirt and thereby creating a self-cleaning effect. Coatings inspired by the lotus effect can reduce cleaning effort and lower the use of detergents in settings ranging from glass to exterior panels. Yet performance depends on micro-topography. If the tiny surface features are damaged by abrasion—through wiping, grit, or everyday wear—the effect can fade even if the coating still looks intact. The engineering challenge is therefore not merely achieving the initial hydrophobic response but maintaining it under realistic handling, where durability becomes as important as first-day performance.

Hospital applications illustrate the same principle—microstructure as a form of control—while also demonstrating the limits of a single technical intervention. Researchers have explored surfaces inspired by shark skin, whose fine-scale patterning can make it harder for organisms to attach and form films. The goal is not chemical sterilisation but physical discouragement: a micro-topography that reduces opportunities for adhesion. Trials have reported benefits in some settings, but outcomes vary with cleaning routines, the types of microbes present, and the broader hygiene system. A coating that performs well in one ward may contribute little in another if cleaning practices, moisture levels, or microbial populations differ. The biomimetic surface therefore functions as a component within a larger remediation regime rather than as a standalone substitute for standard infection control.

Adhesives provide perhaps the clearest illustration of how biomimicry can be simultaneously elegant and difficult. Gecko feet can cling to surfaces using countless tiny structures that exploit intermolecular forces, enabling dry adhesion without liquid glue or residue. Engineers have replicated aspects of this mechanism in synthetic materials that demonstrate impressive grip in controlled tests. However, scaling the technology to heavy loads and messy environments is challenging. The microscopic structures that enable adhesion are vulnerable to contamination: dust can block contact points, reducing performance, and repeated use can degrade effectiveness unless cleaning is cheap, reliable, and integrated into the product's lifecycle. Laboratory success, in other words, does not guarantee robust field performance, because the environment actively interferes with the very mechanism being exploited.

Across these diverse examples—transport, ventilation, coatings, and adhesives—a pattern emerges. Biomimicry tends to succeed when teams define the function precisely, build



prototypes iteratively, and measure outcomes against clear baselines rather than against the romance of the story. It tends to fail when nature is treated as decoration, when the operating context is ignored, or when marketing claims outpace empirical performance. For this reason, some organisations require teams to document the biological principle being used, the constraint it addresses, and the evidence supporting the final design. Such discipline is not bureaucratic ornament; it is a safeguard against technophilia and a method for separating genuine performance gains from attractive narratives.

Case studies therefore matter less as recipes than as reminders of method. Nature can suggest directions, but translation requires engineering judgement, attention to context, and long-term maintenance planning. The broader lesson is a shift away from biomorphism—looking like nature—toward functional emulation, where success is demonstrated through evidence rather than asserted through analogy. In that sense, biomimetic design is not a shortcut to innovation; it is an exacting way to earn it.

Questions 14–17

Select the correct answer.

14 What was the main problem solved by reshaping the bullet train's nose?

- A** overheating in passenger cabins
- B** corrosion caused by salt air
- C** a loud noise linked to pressure changes at tunnel exits
- D** wheel slippage on wet tracks

15 What does the passage suggest about termite-mound-inspired building designs?

- A** copying the mound's shape exactly is usually the best approach
- B** adapting the idea to local conditions is more effective than literal imitation
- C** the approach works only in cold climates
- D** the approach removes the need for airflow modelling

16 Why can lotus-effect coatings become less effective over time?

- A** their microscopic texture can be worn away
- B** they attract dirt in humid weather
- C** they require frequent chemical treatment
- D** they stop working when exposed to sunlight

17 What point is made about shark-skin-inspired hospital coatings?

- A** they make cleaning routines unnecessary
- B** they are effective against all microbes in all settings



- C** they work only in laboratory trials
- D** their impact depends partly on hygiene practices and context

Questions 18–21

Look at the following statements and the list of biomimetic designs below.

Match each statement with the correct biomimetic design, **A–E**.

List of Biomimetic Designs

- A** bullet train nose redesign
- B** termite-mound-inspired ventilation
- C** lotus-effect coatings
- D** shark-skin-inspired hospital surfaces
- E** gecko-inspired dry adhesives

- 18** The design improvement produced both reduced noise and better energy efficiency.
- 19** Performance may drop when tiny surface features are damaged by abrasion.
- 20** Results can vary depending on cleaning routines and the microbes present.
- 21** The technology performs impressively in laboratories but struggles to scale in dusty environments.

Questions 22–24

Choose **YES** if the statement agrees with the claims of the writer, choose **NO** if the statement contradicts the claims of the writer, or choose **NOT GIVEN** if it is impossible to say what the writer thinks about this.

- 22** The passage suggests that real-world conditions are a decisive test for biomimetic designs.
- 23** The passage suggests biomimicry succeeds mainly when nature is treated as decoration for marketing purposes.
- 24** The passage states that companies should delay marketing biomimetic products until long-term performance evidence is available.

Questions 25–26

Answer the questions below. Choose **ONE WORD ONLY** from the text for each answer.



25 What can block the tiny structures of gecko-inspired dry adhesives in real environments?

26 What do some organisations require to support the final design?

Answer Key

14. C

15. B

16. A

17. D

18. A

19. C

20. D

21. E

22. YES

23. NO

24. NOT GIVEN

25. dust

26. evidence