



PART 1

Read the text below and answer questions 1–13.

SELF-HEALING MATERIALS: MIMICKING BIOLOGY IN ENGINEERING

A

Materials that can repair themselves are no longer confined to science fiction; they have become a serious research programme inspired by the way biological tissue closes wounds. In engineering, a self-healing material is typically a composite or polymer system designed to recover structural integrity and functional performance after damage such as microcracks, abrasions, or delamination. The appeal is practical: in aircraft interiors, bridges, protective coatings, medical implants, and consumer devices, tiny defects can accumulate into catastrophic failure or expensive maintenance. Self-healing aims to extend service life, improve safety margins, and reduce inspection burdens by embedding repair capability directly into the material rather than relying on external intervention.

B

At the heart of the field is a distinction between intrinsic and extrinsic healing, which differs according to where “repair capacity” is stored. Intrinsic systems encode healing within the material’s own chemistry. Instead of treating cracking as irreversible, these materials are built around reversible interactions—weak bonds that can break under stress yet re-form under suitable conditions. Researchers often use polymer matrices with dynamic crosslinks, so that when a crack forms, broken connections can reconnect and re-knit the network. The goal is a material that behaves less like a brittle solid and more like a living tissue that can restore continuity without needing an injected liquid or a human-applied patch.

C

Extrinsic systems, by contrast, treat healing as a stored resource that is released on demand. The material contains microcapsules or vascular networks filled with a monomeric or resin-like substance. When a crack propagates, it ruptures these containers, and the damage event itself triggers the release of a healing agent into the fissure. Capillary action and pressure gradients help the liquid flow into the crack plane, after which it can polymerise—often because a catalyst is embedded nearby—bonding the crack faces together and restoring load transfer. This approach resembles a biological clotting response: the “injury” activates a local supply of repair chemistry precisely where it is needed, producing an autonomous, site-specific seal.

D



Yet designing a system that is both tough in use and effective in repair is difficult, and the key challenges differ between the two approaches. For intrinsic designs, highly reversible interactions can come at the cost of stiffness and strength, because bonds that readily rearrange may not resist deformation under sustained load. Engineers therefore face a trade-off between mechanical performance and healing efficiency: a network that heals quickly may be too soft for structural applications, while a rigid network may heal only partially. Extrinsic designs avoid some of these strength penalties, but they introduce their own constraints. Microcapsules must be distributed evenly, remain stable during processing, and avoid premature leakage; vascular networks must be engineered without compromising mechanical continuity. Most importantly, the supply of stored chemistry is finite, which can limit the number of healing cycles a material can undergo before its reservoirs are depleted.

E

Another practical barrier is the environment required for healing. Many intrinsic formulations need a stimulus—heat, light, pressure, or a change in pH—to mobilise polymer chains and allow bond reformation. Such triggers can be straightforward in a laboratory but unrealistic in a bridge deck or a consumer device. As a result, there is growing emphasis on systems that function under ambient conditions, where healing occurs without specialised equipment or high temperatures. The aim is not merely to make a material that can heal, but to make a material that heals in the same settings where damage actually happens: fluctuating humidity, temperature swings, repeated stress, and imperfect real-world maintenance schedules.

F

Applications illustrate both promise and limitation across disparate sectors. In civil engineering, self-healing concrete involves embedding bacteria that, when exposed to water entering a crack, precipitate calcium carbonate to fill gaps. In aerospace, self-healing polymer composites are being tested in non-critical components to reduce inspection frequency. Consumer products also offer a visible pathway to commercial adoption, primarily for surface protection. Self-healing coatings for smartphone screens and car paint can reduce the appearance of scratches, sometimes aided by mild warming. These products succeed because surface damage is frequent and shallow, whereas restoring the integrity of a deep structural fracture remains a formidable challenge, especially when the underlying substrate has been plastically deformed.

G



Looking ahead, research increasingly treats self-healing as part of a wider move toward adaptive materials. The “next generation” is expected to heal multiple damage modes, operate reliably across diverse environments, and integrate sensing elements that can detect and report deterioration. Some designs aim for materials that monitor microcrack growth, log stress exposure, or communicate a “health status” before failure occurs—an engineered analogue to pain signalling and immune response. In that vision, self-healing is not simply a repair trick but a shift in material philosophy: from passive components that degrade silently to active systems that detect, respond, and maintain performance over time.

Questions 1–5

The text has seven paragraphs, **A–G**. Which paragraph contains the following information? Choose the correct letter, **A–G**.

- 1** An explanation that the cracking process itself activates the release of a repair substance.
- 2** Reference to consumer products that mainly address surface damage rather than deep fractures.
- 3** A general definition of self-healing materials and why they matter across multiple industries.
- 4** A difficulty specific to intrinsic designs involving a trade-off between strength and repair performance.
- 5** A future direction in which materials may monitor damage and communicate their condition.

Questions 6–9

Complete the summary below. Choose **NO MORE THAN TWO WORDS** from the text for each answer.

Mechanisms and Applications

Self-healing materials can work in different ways. Researchers often use polymer matrices with **6** so that broken connections can reconnect after a crack forms. In extrinsic systems, the liquid released into a fissure is called a **7** In civil engineering, bacteria in self-healing concrete can precipitate **8** to seal cracks. Many researchers now prioritise designs that heal under **9**

Questions 10–13



Choose **TRUE** if the statement agrees with the information given in the text, choose **FALSE** if the statement contradicts the information, or choose **NOT GIVEN** if there is no information on this.

10 The passage gives an exact percentage by which self-healing materials can extend the service life of engineered products.

11 The passage suggests that intrinsic self-healing systems depend on releasing a liquid repair substance from capsules.

12 In extrinsic systems, the released substance can polymerise after contacting a catalyst within the material.

13 The passage states that self-healing coatings for consumer products are mainly useful for surface scratches.

Answer Key

1. C
2. F
3. A
4. D
5. G
6. dynamic crosslinks
7. healing agent
8. calcium carbonate
9. ambient conditions
10. NOT GIVEN
11. FALSE
12. TRUE
13. TRUE