

How can a seed remain alive without growing?

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A seed on a shelf can look unchanged while retaining the capacity to produce a seedling. Its stillness is not evidence that nothing can happen inside it, and its eventual germination is not the creation of life from dead material. The seed has preserved an organized embryo and the capacity to restart coordinated activity. The scientific question is what remains protected, what changes during storage, and what evidence demonstrates that the capacity is still there.

Three descriptions need separating: a seed may be viable, dormant or simply prevented from germinating by its surroundings. These are not interchangeable labels. A dry seed can fail to grow because water is missing. A dormant seed can fail to germinate even when conditions would allow a comparable nondormant seed to do so. A dead seed cannot complete the relevant recovery merely because those conditions improve.

1. A seed is more than a packet of instructions

An embryo inherits physical structures and stored resources as well as DNA. The seed coat and surrounding tissues can influence protection, exchange and the conditions under which the embryo emerges. The relative arrangement of reserve tissues differs among species, so a familiar diagram is not a universal inventory. Reviews of dormancy and seed maturation describe coordinated developmental and environmental regulation rather than a single on/off button. [1]

Preserving a sequence of DNA alone would not preserve an intact seed. The embryo must retain enough cellular organization to use that information, mobilize resources and continue development. Conversely, retaining an outwardly normal coat would not establish that the embryo inside remains viable. Appearance, molecular integrity and successful recovery are distinct observations.

2. Drying changes the physical problem

In desiccation-tolerant, or orthodox, seeds, substantial water loss during maturation can sharply reduce molecular mobility and metabolic activity. Protective systems help preserve cellular components, while storage damage and repair influence the eventual success of germination. Waterworth and colleagues review these processes with particular attention to genome maintenance. [2]

Reduced activity lowers some demands, but it does not guarantee indefinite preservation. Damage can accumulate even when growth has stopped. On rehydration, a seed must resume activity with components that have passed through that storage history. A seed that is slower to germinate and produces a less vigorous seedling may therefore have suffered damage before losing the capacity to germinate altogether. [2]

This account is deliberately restricted. Not all seeds tolerate drying in the same way, and desiccation tolerance is not identical to dormancy. A species whose seeds are damaged by drying cannot be understood by assuming that colder, drier storage must always help. Nor can a single measured metabolic rate serve as a universal dividing line between a living and a dead seed.

3. Dormancy is a condition of response

The technical definition of dormancy refers to failure to germinate under otherwise favorable conditions. In the intensively studied plant *Arabidopsis*, after-ripening or appropriate temperature treatments can alleviate dormancy; hormonal and genetic mechanisms influence the transition. Sajeev, Koornneef and Bentsink emphasize both the interacting controls and the difficulty of separating dormancy from germination experimentally. [1]

This changes how a negative result should be interpreted. Suppose seeds fail to germinate in one dish. At least three explanations remain: they are not viable, they retain dormancy, or the selected conditions are unsuitable. The observation alone does not choose among those explanations. Repeating the same test without changing its conditions may improve confidence in the observation while doing little to resolve its cause.

A useful comparison needs a reference group known to respond under those conditions and a treatment designed to distinguish plausible alternatives. If germination follows a dormancy-alleviating treatment, the earlier failure was not proof of death. If no tested treatment succeeds, that still needs interpretation within the species and the coverage of the tests performed.

4. Capacity and performance are different measurements

Consider an invented experiment with two groups of 100 seeds. In one group, 90 produce seedlings promptly. In the other, 90 eventually do so, but more slowly and with less subsequent growth. Both groups have the same eventual germination fraction, 0.90, yet they do not have the same performance. The endpoint hides the time course.

Now suppose a third group produces only 40 seedlings during a short observation window. Calling its viability 40 percent would assume that every viable seed had enough time and the right conditions to respond. Extending the window or resolving dormancy could change the inference. This example is not a protocol; it shows why the numerator, denominator, endpoint and duration belong in the claim.

A particularly old seed that germinates demonstrates that at least one seed survived its history. It does not establish a typical lifespan for its species, an indefinitely stable state, or the survival probability of all seeds stored alongside it. Extraordinary survivors and population longevity are different quantities.

5. What recovery tells us about the past

Successful germination is strong evidence of retained biological capacity, but it is also a retrospective test. Before the seed is challenged, investigators may measure indicators of damage or metabolism. After it germinates, they can observe whether those indicators predicted recovery. The best indicator depends on what outcome matters: radicle emergence, establishment of a normal seedling, or later growth.

An indicator need not cause the outcome it predicts. A chemical change could accompany deterioration while another lesion does most of the functional damage. Demonstrating a mechanism requires more than sorting good and bad seeds by a correlated marker. Repair studies are valuable because they connect particular forms of damage with interventions and subsequent performance, while still requiring care when moving between species or storage regimes. [2]

6. Waiting has limits

The seed remains alive without growing because active growth and retained developmental capacity are different states. In many dry seeds, protection and reduced molecular activity allow that capacity to persist; dormancy regulates whether favorable-looking conditions are sufficient to trigger the transition. Neither mechanism suspends every physical process or removes the possibility of deterioration.

The central mistake is to treat a visible behavior as the whole definition of the system. No growth does not prove death. Later growth does not prove that storage caused no damage. The informative question is how much of the capacity for coordinated recovery survived, under which conditions, and with what consequences for the seedling.

Related reading

Article 025, “Where does a tree get most of its dry mass?”, follows material acquisition after growth resumes. The comparison is optional and reciprocal.

References

- [1] N. Sajeed, M. Koornneef and L. Bentsink. A commitment for life: Decades of unraveling the molecular mechanisms behind seed dormancy and germination. *The Plant Cell* 36, 1358–1376 (2024). <https://doi.org/10.1093/plcell/koad328>
- [2] W. Waterworth, A. Balobaid and C. West. Seed longevity and genome damage. *Bioscience Reports* 44, BSR20230809 (2024). <https://doi.org/10.1042/BSR20230809>