CAPTURE & FILTER

Passive Fog and Dew Collection: Surface-Energy-Driven Water Harvesting

How arid-adapted organisms collect water from fog without energy input

5	3	1–3	5
convergent strategies	principle clusters	TRL range	featured strategies

PROBLEM FRAMING

Fog precipitation can supply 1–10 L/m²/day in suitable climates. Conventional mesh collectors capture 1–5% of this potential; biological surfaces consistently achieve higher efficiency through wettability gradients that nucleate, grow, and transport droplets automatically.

Application domains: water_management, architecture, agriculture

Principle cluster: wettability gradient, hydrophobicity, capillary action

Physics & Mechanism

Underlying physics

[DRAFT] Droplet nucleation on a surface follows classical nucleation theory: heterogeneous nucleation is favoured on hydrophilic surfaces (low contact angle θ reduces the free energy barrier). Once nucleated, droplet growth is driven by vapour pressure gradients. Transport requires a driving force — on flat surfaces, gravity acts only once droplets are large enough (>1 mm). Wettability gradients provide an additional capillary driving force even for sub-millimetre droplets: a surface energy gradient $d\gamma/dx$ creates a pressure differential across the contact line that displaces the droplet toward higher surface energy. The Namib beetle's back alternates hydrophilic bumps (nucleation sites) with hydrophobic valleys (transport channels) — the two functions are spatially separated and optimised independently. Cactus spines implement the gradient along the spine axis: conical geometry creates a Laplace pressure gradient that drives collected water toward the base. Spider silk Spindle-knots implement the same principle with periodic knots of increased hydrophilicity. [END DRAFT]

Biological Strategies

Capture, Absorb, or Filter Liquids Namib desert beetle · TRL 3/9 · 36 genera

Organisms like the Namib desert beetle and certain plants passively harvest water from fog through specialized surface structures. The beetle's shell features a pattern of hydrophilic (water-attracting) bumps and hydrophobic (water-repelling) valleys that cause fog droplets to condense on the bumps, coalesce, and roll toward the beetle's mouth. Plant leaves employ similar strategies with textured …

Design principle: Design passive water-harvesting meshes by replicating the hierarchical surface textures found in fog-collecting organisms. Implement micro and macro-scale features that alternate between water-attract

Protect From Excess Liquids Various plants · TRL 1/9 · 136 genera

Plants develop sophisticated surface structures through their cuticles and epicuticular waxes to control how liquids interact with their leaves and stems. Over hundreds of millions of years of evolution, plants have created hierarchical textures at multiple scales—from cell-level sculptures to nanoscale wax crystalline formations—that produce either superhydrophobic surfaces that repel water or su…

Design principle: Engineer surfaces using hierarchical structures at multiple scales to achieve precise liquid control. Combine microscopic texturing with chemical surface treatments to create superhydrophobic or super

Protect From Excess Liquids Namib desert beetle · TRL 3/9 · 136 genera

Stenocara gracilipes, the Namib desert beetle, survives in an arid environment by managing water collection and protection through its specialized exoskeleton. The beetle's wing surface features a pattern of hydrophilic (water-attracting) bumps surrounded by hydrophobic (water-repelling) waxy regions. When fog rolls across the desert, water condenses preferentially on the hydrophilic peaks while b…

Design principle: Engineer surfaces with patterned wettability to simultaneously collect useful liquids and repel excess or contaminated ones. Create composite structures combining hydrophilic zones (for liquid attract

Capture, Absorb, or Filter Liquids Darkling beetles · TRL 3/9 · 36 genera

Several researchers are studying the beetles, as well as synthetic surfaces inspired by the beetle’s body, to uncover the roles that structure, chemistry, and behavior play in capturing water from the air. Micro-sized grooves or bumps on the beetle’s hardened forewings can help condense and direct water toward the beetle’s awaiting mouth, while a combination of hydrophilic (water attracting) and h…

Design principle: According to the World Wildlife Fund, 10% of all animals depend on freshwater habitats that occupy a mere 1% of the surface of our planet. And these scant resources are increasingly jeopardized by dev

Capture, Absorb, or Filter Liquids Marsh crabs

Marsh crabs have evolved tufts of water-attracting setae positioned at the bases of their legs. Such fine, hair-like appendages are hydrophilic, meaning they have a strong affinity for water molecules. When the crab positions these setal tufts against moist mud surfaces, capillary forces and the chemical attraction between the setae and water molecules enable direct water uptake into the crab's bo…

Design principle: This biological system suggests a passive liquid capture strategy using hydrophilic fibrous structures to draw moisture from porous substrates. Engineering applications could involve designing absorbe

Combination Intelligence

Strategies that address different aspects of the same problem and are not redundant when combined.

Capture, Absorb, or Filter Liquids + Protect From Excess Liquids

Shared principles: gradient materials, hydrophobicity, microfluidics, wettability gradient

These strategies share 4 underlying principles including gradient materials and hydrophobicity and microfluidics. They may not be alternatives — combining them could address different scale regimes of the same problem simultaneously.

Protect From Excess Liquids + Protect From Excess Liquids

Shared principles: capillary action, fluid dynamics, hydrophobicity, superhydrophobicity

These strategies share 4 underlying principles including capillary action and fluid dynamics and hydrophobicity. They may not be alternatives — combining them could address different scale regimes of the same problem simultaneously.

Protect From Excess Liquids + Capture, Absorb, or Filter Liquids

Shared principles: capillary action, enzymatic catalysis, hydrophobicity

These strategies share 3 underlying principles including capillary action and enzymatic catalysis and hydrophobicity. They may not be alternatives — combining them could address different scale regimes of the same problem simultaneously.

EXPLORE THE INTERACTIVE VERSION

This report is a static synthesis. The interactive version includes live strategy cards, the Design Brief generator, Combination Intelligence engine, and filtering by TRL, scale, and principle.

`https://atlasofnature.org/challenge/fog-water-harvesting`

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