

Attributing Useful Function in Polar Biotechnology

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Author approved release edition. Literature analysis and proposed research; no new VARUNÉ experimental results are reported.

Abstract

Polar organisms provide research leads for enzymes, extracellular polymers, molecular tools, and functional surfaces. Their origin, however, does not determine which constituent causes a reported effect or whether that effect remains useful after recovery and processing. This critical narrative report connects polar polymer studies, enzyme adaptation, functional metagenomics, natural-product attribution, and biomaterial interfaces. Its central question is what evidence allows a biological effect to be assigned to a defined research asset as the material moves between experimental contexts. The analysis distinguishes changes to the material, changes to access or expression, and changes to the observation system. Contrasting cases show why an ice-recrystallisation result is not a preservation result, why screening rank is not application rank, and why surface retention is not accessible function. A proposed interpretation record makes these distinctions operational without presenting them as a new scientific law. The principal VARUNÉ contribution is a staged comparison of candidate and comparator across a defined transition, supported by identity measurements, competent functional assays, and independent preparations. This would help an existing programme decide whether to improve manufacture, presentation, measurement, or the candidate itself. No new experimental results are reported; the framework and research questions require prospective evaluation.

1 Research question and scope

The question addressed here is: **when a polar biological preparation produces a useful signal, what must remain true for that signal to support development of a defined molecule, mixture, process, or component?** This wording deliberately permits several legitimate assets. A reproducible mixture might be useful even when no single constituent is sufficient. A molecule may be valuable only in a particular formulation. A measurement method may be the most useful output when the nominated material fails its original interpretation.

The report focuses on the evidential transitions between discovery and application. It does not attempt to rank all polar biotechnology markets. Arctic examples are labelled Arctic; Antarctic examples are labelled Antarctic. General methods studies are used to test reasoning, not to create evidence about polar candidates. “Polar” describes provenance or adaptation, not a shared mechanism or evidence of superiority. The six-report series treats purification, environmental sampling, interfaces, wet adhesion, and skin measurements in greater depth. This first report supplies the comparative argument that links them while preserving their separate claims.

An asset becomes scientifically clearer when its boundary is explicit. “A protective bacterial polymer” leaves the preparation, concentration, target, challenge, and endpoint undefined. “A characterised fraction that increases recovery of a specified enzyme’s useful activity after an agreed storage challenge” identifies a testable proposition. The latter still needs evidence, but a negative result can now change a decision. This is the author’s analytical position: development should be organised around the smallest useful claim whose alternatives can be discriminated, rather than around the broadest attractive description of the organism.

2 Sources and analytical method

This is a targeted critical narrative synthesis, not a systematic review, meta-analysis, or experimental study. The starting materials were the supplied textbooks, eight research papers, and the preceding VARUNÉ Bio reading dossiers. Relevant passages were revisited for this report rather than treating those dossiers as substitutes for primary evidence. One additional chapter main text was read continuously: Böttcher, Schmidt, and Bornscheuer’s *Screens for Active and Stereoselective Hydrolytic Enzymes*, in the supplied 2010 *Metagenomics* volume, printed pages 169-175, physical PDF pages 177-183. Its references were inspected as a source trail, not individually verified. The distinction between apparent and confirmed selectivity on printed page 172 was checked against the page image. [1]

Selected passages were also rechecked in *Psychrophiles* chapter 10, *Natural Products Isolation* chapter 1, and *Biomaterials Science* chapter 1.4.4, alongside the supplied *Polaribacter* and *Colwellia* papers. These are targeted revisits, not new complete-chapter or complete-book reading claims. The local extracts contain occasional unit-conversion errors, especially micro symbols rendered as ordinary letters; no extracted procedural quantities are offered as laboratory instructions. [2-7]

Online checks on 28 October 2026 searched named primary studies and specific challenges: “rufomyazine 0.24 residual complexity”, “McLaren Willis Callahan correctable bias”, “metagenomic library high-level expression Rich”, “PsyOmp38 coating uniform”, and the exact titles or identifiers of the polar studies. Publisher sources, PubMed, and accessible author manuscripts were preferred. Searches included counterexamples to simple assumptions, such as the simultaneous improvement of enzyme stability and low-temperature activity. They did not exhaustively cover every database or every paper published by the search date.

Evidence extraction distinguished the preparation tested, endpoint, comparison, access level, and inference supported. The *Colwellia* and *Polaribacter* full papers were locally available. The McLaren model and selected Rich full-text passages were inspected online. Choules was checked through its indexed primary abstract after direct full-text access encountered a browser check. PsyOmp38 coating results were checked through indexed primary text and figure-caption information, with the same access limitation on the direct PMC page. Hafner was checked through the primary abstract and figure captions. Miyazaki’s author-hosted primary PDF was inspected at its abstract, kinetic table, and activity methods. These access differences limit how much methodological detail can be concluded from each case. [8-13]

3 The material and the observation are separate objects

A central mistake in translation is to allow one name to identify several different experimental objects. A bacterial strain, its secreted material, an ethanol precipitate, a purified fraction, and a formulated product are related but not equivalent. Likewise, an environmental sample, recovered DNA, an

expression library, and an active recombinant protein are different objects. Evidence should follow the actual object at each stage.

Natural-product isolation provides a useful foundation. Its discussion of activity recovery lists physical retention, instability, precipitation, dilution across fractions, and separated cooperating constituents as different explanations for an effect disappearing after fractionation. It therefore does not license the inference that lost activity proves synergy. Nor does chemical purity alone identify the causal constituent. The research purpose must determine which identity and function measurements are necessary. [3]

The interface literature supplies a complementary distinction. Immobilisation changes the relationship between a molecule and its surroundings: retained material may have inaccessible sites, restricted motion, or impaired transport. A coating can therefore retain its nominal composition while losing its intended interaction. These possibilities need different measurements from those used to detect material loss. [4]

The resulting interpretation record is an author-developed organising device, assembled from established principles. Its purpose is to expose missing evidence, not to assign a validated score or predict commercial success.

Evidence question	What must be identified	What the observation alone cannot establish
What was tested	Preparation, batch, provenance, and composition	That the organism or dominant constituent caused the effect
What was available	Soluble, expressed, exposed, or otherwise accessible material	That retained quantity equals useful activity
What was measured	Endpoint, matrix, calibration, and uncertainty	That signal change equals the proposed mechanism
What survives transfer	Performance after the specified transition	That a convenient assay predicts the intended application
What decision follows	Comparator, acceptance, and remaining alternatives	That scientific interest demonstrates demand or ownership

The practical implication is not to measure everything. It is to identify which ambiguity can reverse the next decision. If a candidate's signal is indistinguishable from the blank, a detailed structure-activity claim is premature. If identity and assay competence are strong but performance fails only after surface conditioning, repeating discovery screens is unlikely to address the immediate problem.

4 Contrasting evidence cases

4.1 Arctic EPS and the boundary of the active preparation

Sun and colleagues investigated EPS from Arctic *Polaribacter* sp. SM1127. Their methods distinguish material purified for structural characterisation from crude EPS used in property and cellular tests. The fibroblast experiment exposed cells to crude EPS during a 20-hour challenge at

4 °C; it was not a freezing-and-thawing experiment. Its result cannot establish that a purified polymer is a cryopreservation additive, or that a finished topical formulation improves human skin. [5, physical PDF pages 3 and 9-10]

Cirella and colleagues subsequently characterised lipid A from the same strain and examined immune-signalling responses of LPS and EPS preparations. They explicitly could not exclude trace bacterial debris contributing to an EPS-associated TLR4 signal. This leaves attribution open; it does not establish that every EPS effect is caused by endotoxin or that all preparations are equivalent. [6, physical PDF pages 7-8]

The combined analytical consequence is that preparation identity must travel with each claim. Structural knowledge from one fraction cannot silently authenticate function measured in another. A useful next question is whether the relevant effect persists through a reproducible change in composition while delivered exposure and assay competence are accounted for. If it follows a minor constituent, the programme needs a different specification. If it requires a controlled combination, a mixture may remain a valid asset. Neither outcome is determined by the label EPS.

4.2 Polar EPS and the distance between an ice endpoint and preservation

Casillo and colleagues characterised EPS secreted by the Arctic-isolated strain *Colwellia psychrerythraea* 34H and measured inhibition of ice recrystallisation. The paper identifies its origin as subzero Arctic sediments and also reports occurrence in Antarctic sea ice; this broader polar occurrence does not change the strain's stated isolation provenance. Their structural and computational work supplies a molecular hypothesis, but the reported ice assay does not measure recovery of a useful enzyme reaction or viable cells after a complete preservation process. In the supplied figure, PVA gives stronger inhibition than EPS at the shared plotted concentration. Consequently, a development case cannot rely on a blanket claim of superior ice control. [7, manuscript PDF pages 1-10 and figure pages 18-20]

The author's inference is that the promising endpoint is application-dependent: recovery of usable function with acceptable interference, cost, and handling. A material could be less effective in the ice assay yet useful in one enzyme workflow, or effective against recrystallisation yet unsuitable for downstream analysis. These are hypotheses, not reported outcomes. The first justified comparison would ask whether the material changes the final accepted result relative to an appropriate incumbent formulation.

4.3 A minor constituent can overturn a major-component story

Choules and colleagues provide a non-polar counterexample. Isolated rufomycin appeared active against *Mycobacterium tuberculosis*, whereas synthesised material was inactive. The original activity was attributed to 0.24% by mass contamination with a highly potent rufomycin-related compound. This demonstrates why a dominant chemical identity need not be the active principle. It does not estimate the prevalence of such errors or diagnose a VARUNÉ preparation. [8]

The implication for this report is narrow but important: independent reference material can challenge attribution in a way that repeated testing of the same preparation cannot. A repeatable biological signal may be a repeatable mixture effect. Reproducibility of the signal and correctness of its molecular explanation are separate achievements.

4.4 Expression changes what discovery can observe

Rich and colleagues developed a metagenomic library strategy intended to improve expression of captured genes. Their comparison recovered activities inaccessible through the standard approach, while the design retained sequence and insert-selection constraints. Some recovered proteins also required transfer to another host to obtain soluble preparations. These findings support the distinction between failure to observe a function and absence of that function. They do not establish unbiased discovery or a universal probability of success. [9]

This is especially relevant when an Antarctic sequence resource is presented as an immediate enzyme portfolio. Sequence availability, representation, expression, biochemical activity, and useful process behaviour require separate evidence. A justified contribution could address one documented bottleneck in that chain. An indefinite series of alternative screens, without an explicit stopping rule, would not make every negative informative.

4.5 More recovered signal can still mean a distorted biological answer

McLaren, Willis, and Callahan developed and tested a multiplicative model of protocol bias using defined microbial communities. Under the model, observed proportions depend on both true composition and taxon-specific measurement efficiencies. Their work supports calibration where suitable controls and assumptions hold; it does not establish correction for an unfamiliar polar matrix. [10]

The normalised relationship is:

$$p_i^{\text{obs}} = \frac{p_i e_i}{\sum_j p_j e_j}$$

Equation 1 Observed proportions under a multiplicative measurement model adapted from McLaren and colleagues.

Here p is a dimensionless true proportion, e is a positive relative measurement efficiency, and the denominator must be non-zero. The model does not include all possible contamination or nonlinear interactions. Equal true proportions with efficiencies of 1 and 4 produce observed proportions of 0.2 and 0.8; doubling both efficiencies does not remove that distortion. This is an illustrative calculation, not a dataset. The relevant preservation endpoint must therefore include the intended inference, rather than total recovered quantity alone.

4.6 A functioning coating can remain spatially unreliable

Olimpo and colleagues examined Antarctic PsyOmp38 on PDMS surfaces under laboratory flow. Their report describes spatially uneven antibiofilm performance and identifies heterogeneous deposition as a possible explanation. Figure 5 reports two independent biological flow replicates and imaging at three positions; positions are subsamples, not additional independent preparations. Water contact angle demonstrates altered wetting, rather than quantifying retained functional protein. [11]

The proposed cross-domain lesson is to inspect where failure occurs. A high mean effect may conceal poorly protected regions. Conversely, local heterogeneity does not prove that deposition caused failure; spatial exposure or biological variability could contribute. Application-specific conditioning, retention, accessibility, and function need to be linked without converting laboratory evidence into a claim of clinical device protection.

5 What the new screening chapter adds

The newly read *Metagenomics* chapter separates an apparent selectivity screen from subsequent confirmation by chiral chromatography. It uses a coupled reaction to turn released acetate into an optical signal, and recognises that initial screening values require verification of conversion, kinetics, and selectivity. Its notes require checks for pre-existing acetate, linear response, and handling tolerance. [1, printed pages 170 and 172-175]

This adds an important refinement to the series: **an assay can move closer to the relevant substrate while becoming more dependent on auxiliary chemistry**. Avoiding a synthetic chromophore attached to the target substrate does not make every part of the resulting measurement direct. The coupling enzymes, matrix, and reporter response remain part of the observation system. A preservative or polymer might affect the target enzyme, the coupling cascade, or the optical signal. Their effects need not have the same sign.

The chapter's suggested checks are a historical methods foundation, not an executable specification for a polar candidate. Extending reaction time can reveal weak activity, but it can also change background, substrate depletion, or the relation between initial rate and endpoint. Nonlinearity is a diagnostic observation rather than proof that the target enzyme is excessively active. The author's proposed use of this reading is to name the coupling assumptions and confirm the relevant product through a sufficiently independent method before interpreting a ranking.

A second implication concerns preservation research. A formulation that improves a target enzyme's survival but inhibits the coupling reaction could appear ineffective. Removing that formulation immediately before measurement might reveal recovery but fail to answer whether the enzyme works in the intended formulation. Both comparisons can be useful, provided they answer different questions: recoverable intrinsic function and usable function in context. Treating either as a universal substitute for the other would conceal a development constraint.

6 Quantitative reasoning that changes the interpretation

6.1 Serial recovery concerns a defined entity

For a consistently defined target followed through an accounted sequence, overall mass recovery is the product of consecutive recoveries:

$$Y = \frac{m_J}{m_0} = \prod_{j=1}^J \frac{m_j}{m_{j-1}}$$

Equation 2 Serial mass recovery as an accounting identity.

The masses m are in the same units, each denominator is positive, and Y is dimensionless. The identity assumes that the named entity is consistently defined and each stage measures the material remaining in the accounted stream. It is not a conservation law for biological activity, and it cannot quantify unmeasured chemical transformation. Four stages each retaining 80% of the same target yield 40.96% overall. This constructed example shows why tolerable individual losses can become material in combination. [3]

The analytical consequence is to locate the loss before redesigning the candidate. If recovery improves while function per recovered target remains unchanged, a supply problem may be solved

without an intrinsic improvement in the molecule. If activity increases after purification, removal of inhibition or assay interference may contribute; activity need not obey the target-mass balance.

6.2 Enzyme ranking depends on the comparison conditions

A conventional initial-rate model makes substrate dependence explicit:

$$v = \frac{k_{\text{cat}}[E][S]}{K_M + [S]}$$

Equation 3 Michaelis-Menten initial-rate relation under its usual restricted assumptions.

Here v is $\text{mol L}^{-1} \text{s}^{-1}$, enzyme concentration $[E]$, substrate concentration $[S]$, and K_M are mol L^{-1} , and k_{cat} is s^{-1} . The relation assumes a suitable simple kinetic regime, controlled conditions, and negligible relevant depletion during initial-rate estimation. It does not automatically apply to a mixed extract, insoluble substrate, cooperative system, or transport-limited coating. [2]

For illustration, take equal active-enzyme concentrations and two hypothetical candidates. Candidate A has k_{cat} of 10 s^{-1} and K_M of 1 mM ; candidate B has 3 s^{-1} and 0.1 mM . At 0.01 mM substrate, their turnover rates per enzyme are approximately 0.099 and 0.273 s^{-1} . At 10 mM , they are approximately 9.09 and 2.97 s^{-1} . The ranking reverses. These values are constructed, not extracted from a polar study. Their purpose is to show that “faster” needs a substrate and operating concentration.

This reasoning also challenges an overly rigid stability-activity trade-off. Miyazaki and colleagues increased thermostability and low-temperature catalytic performance in an evolved Antarctic subtilisin under the reported assay conditions. Its kinetic measurements used the synthetic peptide s-AAPF-pNa. This is evidence that the properties can improve together in that setting, not proof of improved processing of every protein substrate. [12]

6.3 A transfer comparison should retain the comparator

A useful proposed diagnostic compares candidate advantage before and after the transition of interest:

$$D = (z_{C,1} - z_{R,1}) - (z_{C,0} - z_{R,0})$$

Equation 4 Change in candidate advantage across two contexts.

The endpoint z has the same declared units throughout; C is candidate, R is reference, and 0 and 1 are the starting and transferred contexts. D has the units of z . For an endpoint where larger is better, a negative D indicates reduced candidate advantage. This is a standard difference-of-differences contrast applied as a research diagnostic, not a validated mechanism test. The scale must be prespecified; nonlinear percentage endpoints can give scale-dependent interactions. Independent preparation, paired allocation where appropriate, and uncertainty estimates remain necessary.

A candidate may decline after storage while retaining a useful advantage if the reference declines more. Conversely, its absolute performance may remain stable while its relative advantage disappears in the relevant substrate. Testing only the candidate cannot distinguish these decisions. D alone also cannot identify cause: a changed matrix, dose, accessibility, or observation system could generate the interaction.

7 Varun analysis of the connections

7.1 Identity and context should be co-specified

The first synthesis is that material identity and context jointly define the claim. A molecular formula may be sufficient for one analytical question and insufficient for a polymer film whose molecular distribution, preparation history, and interfaces control behaviour. Conversely, requiring complete mechanistic understanding before a bounded empirical comparison would create unnecessary delay. The appropriate specification is the one that distinguishes reproducible success from the live alternatives at the next decision.

This resolves an apparent tension between purity and usefulness. The aim is not maximal purity as a universal commercial virtue. It is a controllable research object whose effect can be interpreted. If a mixture is the useful object, the programme must show that its relevant composition and performance can be reproduced. If a purified constituent is the claim, mixture-level evidence cannot substitute. The burden follows the claim, not a preference for either natural complexity or molecular simplicity.

7.2 Transitions are interventions rather than administrative steps

Recovery, formulation, immobilisation, storage, and assay transfer can alter the system being studied. A failed transfer should therefore generate a structured choice between material loss, state change, access limitation, and measurement failure. That does not mean these explanations are mutually exclusive. A polymer can aggregate an enzyme and also interfere with its reporter. A surface can lose some protein while masking what remains.

The research value lies in designing contrasts that change one important interpretation. A common measurement medium can test recoverable function; an in-context measurement tests actual use. Independent chemical recovery can test loss; a matched matrix control can test observation competence. No single rescue experiment settles all four explanations. The strongest study links contrasts rather than treating one successful rescue as the mechanism.

7.3 Negative evidence needs a finite boundary

The framework could be misused to protect every candidate from rejection: each failure can be blamed on expression, formulation, or the assay. That would make it scientifically weak. A negative result deserves reopening only when there is evidence for a specific unresolved limitation and a bounded comparison could resolve it. Otherwise, an interpretable negative should reduce confidence in the nominated application.

A practical stopping rule is to declare the application, comparator, feasible operating range, and maximum clarification effort before further optimisation. If the candidate repeatedly fails a competent assay under relevant conditions, additional narrative about its origin does not improve the result. A resource may remain scientifically interesting while the current product claim ends. Closing that claim is useful research output.

7.4 The strongest endpoint is the one the next user needs

An increase in retained mass, thermal half-life, or screening signal can be an enabling improvement. Its value depends on whether it changes a downstream decision. The relevant user may need

reliable product conversion, accurate community representation, a surface that remains functional, or an assay that produces an interpretable result. These are different acceptance criteria.

A non-polar example reinforces this point. Hafner and colleagues showed that conventional drug-response metrics depend on cell division history and developed growth-rate metrics for dividing-cell systems. A lower endpoint signal is therefore not automatically evidence of more selective killing. Their method does not supply a therapeutic result for any polar molecule; it illustrates why the meaning of the endpoint must be retained through comparison. [13]

7.5 The framework itself must earn its place

The proposed interpretation record has not been validated as an improvement over existing expert practice. Its usefulness could be evaluated prospectively by applying it to a bounded set of cases and recording whether it exposes a previously unrecognised decision-changing ambiguity. The comparison should include cases where it adds no value. Retrospective success stories alone would favour the framework unfairly.

A meaningful outcome would be a documented change in an experimental comparison, claim boundary, or development decision. Merely completing more fields would not demonstrate research value. This is the appropriate ambition for the present synthesis: a useful way of connecting evidence, tested against decisions, rather than a claim to have discovered the underlying scientific principles.

8 A bounded VARUNÉ research proposal

The most coherent first study would examine one accessible candidate across one consequential transition. A possible example is an independently characterised EPS fraction used with one defined enzyme during an agreed preservation challenge. Candidate choice is conditional on material access, a qualified scientific lead, funding, rights, and a real application owner. It is not selected or activated by this report.

The primary question would be whether the candidate improves an accepted downstream result relative to the best suitable comparator while preserving interpretable measurement. Secondary evidence would distinguish recovered amount, recoverable function, and usable function in context. Independent preparations, rather than repeated wells alone, should support claims of preparation reproducibility. A pilot would inform variance and a justified sample-size calculation; arbitrary replication counts are not proposed as proof of reliability.

Comparison	Decision it can support	Important alternative still to test
Candidate and reference before and after the same transition	Whether an advantage survives transfer	Unequal exposure or endpoint competence
Recovered material measured in a common medium	Whether useful function remains recoverable	Recovery process selectively removes or restores components

Comparison	Decision it can support	Important alternative still to test
Material measured in the intended use context	Whether the system actually performs	Target effect versus detection interference
Identity and recovery linked to function across preparations	Whether a reproducible specification is emerging	Shared unmeasured constituents or process dependence

The planned analysis would retain uncertainty intervals, unsuccessful preparations, and deviations. A positive result would support only the selected candidate-context claim. It would not establish a general preservation platform or human-use suitability. A negative result would direct the next decision: change the process if recovery is limiting, change presentation if access is limiting, repair the assay if observation is limiting, or stop the candidate claim if competent comparison shows no useful advantage.

9 Useful contributions to existing programmes

The most credible contribution is a bounded question that the originating team needs answered. A literature report can identify that question; it cannot establish that a programme wants the work or has a budget. Three possible contribution types follow from the evidence.

Programme context	Proposed useful contribution	Acceptance and rights to establish
Polar EPS or preservation research	Link preparation identity to final usable function in one workflow	Comparator, complete data, reproducibility, and permitted improvement ownership
Metagenomic enzyme discovery	Determine whether one negative or weak screen reflects expression or true functional failure	Confirmed bottleneck, independent confirmation, and sequence or material rights
Antarctic protein coating research	Connect local deposition and conditioned function across independent preparations	Relevant surface, agreed challenge, failure map, and background versus new rights

Potential funding structures include a programme-funded methodological work package, a sponsor-paid feasibility comparison, or an eligible collaborative research award. None is a confirmed funding opportunity here. The first commercial question is what decision the partner would pay to resolve. The first scientific question is whether the proposed uncertainty is genuinely unresolved. These questions should precede a price, an exclusivity request, or a claim that VARUNÉ owns a discovery.

The reusable output could be an agreed method, a comparison dataset, or a specified process improvement. Ownership is contractual and remains separate from scientific contribution. Existing investigators retain credit for their discoveries. This report supports choosing one funded research application; it does not create six simultaneous laboratory programmes.

10 Limitations and conclusions

The corpus is purposively selected and shaped by the earlier opportunity review. It can expose reasoning failures but cannot estimate their frequency across polar biotechnology. Several online cases were assessed through abstracts or selected passages, not complete methods and supplementary datasets. The historical textbooks offer foundations rather than current performance specifications. No patent novelty, freedom-to-operate, safety, efficacy, partner demand, or economic advantage is established.

The comparative argument also has a limit: enzyme kinetics, community composition, and surface bioactivity are not one physical mechanism. Their connection is evidential. Each requires a defined object, a competent observation, and a justified inference across context. Equations in this report clarify assumptions and accounting; they do not validate those assumptions for an untested candidate.

The conclusion is that useful polar biotechnology should be attributed to a specified preparation in a specified operating context, with the relevant alternatives actively tested. The most valuable next experiment is often the one that reveals why an effect fails to transfer. For VARUNÉ Bio, the strongest current contribution is a disciplined comparison that converts an attractive observation into a defensible decision about a molecule, mixture, method, or process. Which of those becomes valuable remains an empirical question.

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Authorship and research provenance

Varun Sharma is the sole author and approved this edition for release on 28 October 2026. No new experimental data are reported; published findings remain attributable to the cited investigators.

Competing interests. Varun Sharma founded VARUNÉ Bio, which may benefit commercially from applications discussed here. Funding and contributor declarations remain subject to author confirmation.

This report shares concepts and sources with the five companion reports dated 28 October 2026; it presents a distinct literature analysis.