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Strategic and Organizational Determinants of Biotechnological Innovation Adoption in the Saudi Pharmaceutical Industry

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Abstract

Biotechnological innovation is increasingly important to pharmaceutical localization, manufacturing resilience, product differentiation, and higher-value industrial development. Yet adoption cannot be interpreted as a simple decision to acquire equipment, license a platform, or introduce a new manufacturing technology. This article develops a non-empirical strategic-organizational analysis of biotechnology adoption in the Saudi pharmaceutical industry. It distinguishes technology availability from organizational readiness, readiness from adoption, adoption from implementation, and implementation from routinized organizational use. The analysis integrates six domains: strategic prioritization, leadership and governance, cross-functional coordination, resource and absorptive capability, external knowledge networks, and regulatory-institutional conditions. Saudi-specific evidence is separated from regional and international evidence to prevent inappropriate geographic transfer. The central argument is configurational: favorable conditions in one domain can be neutralized by weaknesses elsewhere, while apparently resource-constrained firms may advance when governance, knowledge integration, partnerships, and institutional alignment compensate effectively. Two proposed scientific architectures are developed. The first represents biotechnology adoption as a cross-layer organizational readiness field with alignment gates and mismatch channels. The second represents external knowledge acquisition as a permeability problem in which partnership-generated knowledge must cross governance, absorptive, and implementation boundaries before it becomes organizational capability. These architectures are conceptual rather than empirically validated and are intended to support firm-level hypothesis development and future empirical investigation in Saudi pharmaceutical organizations.

Keywords: Biotechnology adoption, Pharmaceutical innovation, Organizational readiness, Absorptive capacity, Strategic governance, Saudi pharmaceutical industry

Introduction

Technological transformation in pharmaceutical firms increasingly involves changes in strategy, organizational structures, manufacturing systems, quality management, workforce capability, and external stakeholder relationships (Roberts *et al*., 2025). A management-focused review of pharmaceutical digital transformation shows that technological change spans operational, strategic, organizational, and stakeholder domains rather than functioning as an isolated technical intervention (Miozza *et al*., 2024). Biotechnology creates an even more demanding organizational problem because scientific development, process engineering, manufacturing control, quality assurance, regulatory documentation, supplier relationships, and investment decisions may become interdependent.

Saudi pharmaceutical firms also operate from heterogeneous technological starting points. Evidence examining advanced pharmaceutical and nanomedicine capabilities indicates variation in local manufacturing capacity and involvement with technologically demanding product classes (Halwani *et al*., 2023). A separate analysis of pharmaceutical localization in Saudi Arabia identifies R&D capability, human-capital development, regulatory conditions, governance, and industrial support as important components of domestic manufacturing development (Tawfik *et al*., 2022). These studies establish relevant national context but do not provide a validated causal model of biotechnology adoption.

International biopharmaceutical evidence similarly indicates that adoption barriers arise across business justification, technology, regulation, organizational processes, and people (Schaefer *et al*., 2023). Regional pharmaceutical-manufacturing research involving MENA firms, including Saudi Arabia, further shows that advanced-technology adoption can be associated with infrastructure, production-management processes, and supply-chain capability (Al-Shboul, 2024). Because this regional evidence concerns artificial intelligence rather than biotechnology and does not isolate Saudi-specific effects, it is used here as evidence that sophisticated technology adoption is organizationally conditioned rather than as proof of a biotechnology-adoption mechanism.

The analytical problem is therefore not whether Saudi firms encounter individual "barriers" or "drivers." Lists of determinants are insufficient when the usefulness of one condition depends on the state of another. Strategic commitment without absorptive capability may not become implementation (Giang *et al*., 2026; Ha *et al*., 2026). External technological access without knowledge integration may create dependence. Scientific expertise without decision authority may remain organizationally stranded (Lee & Park, 2025; Meyer *et al*., 2026). Strong internal capability may still encounter institutional delay when regulatory expectations are uncertain.

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This article consequently develops a cross-layer interpretation of biotechnology adoption. Strategic orientation, governance, coordination, absorptive capacity, partnerships, and external institutional conditions are first examined separately and then recombined into a proposed strategic-organizational adoption architecture. The objective is not to predict adoption probability but to clarify how organizational conditions can align, conflict, or become disconnected during biotechnology evaluation and implementation.

Biotechnological Innovation in the Saudi Pharmaceutical Context

Biotechnology does not represent one homogeneous innovation class. Relevant pharmaceutical applications include biological products, biosimilar-related manufacturing capability, bioprocessing platforms, cell- or molecule-based production technologies, advanced analytical systems, and biotechnology-enabled quality or process-control methods. These differ in knowledge intensity, capital requirements, development timelines, manufacturing complexity, regulatory evidence requirements, and dependence on external expertise (Boshkayeva *et al*., 2026).

Experience from pharmaceutical Industry 4.0 demonstrates why technology possession should be separated from technology integration. Smart pharmaceutical manufacturing requires coordinated development of digital infrastructure, automation, manufacturing controls, workforce practices, and regulatory systems rather than installation of isolated equipment (Arden *et al*., 2021; Larsson *et al*., 2025). Biotechnology differs scientifically from digital manufacturing, but the organizational implication is transferable: technological resources become useful only when connected to operating systems and decision structures (Larsson *et al*., 2025; Riyanta *et al*., 2025).

Empirical pharmaceutical evidence also indicates that organizational processes can mediate the value derived from emerging technologies and that implementation barriers can weaken those relationships (Saha *et al*., 2022). Research on Industry 5.0 in pharmaceutical manufacturing similarly identifies interacting technical, standardization, organizational, and implementation constraints rather than independent obstacles (Sharma *et al*., 2024). Such findings argue against treating financial capital, technology availability, workforce skill, or leadership support as individually sufficient indicators of readiness (Dat *et al*., 2025).

Regulatory conditions create an additional organizational boundary. Industry analysis of advanced pharmaceutical manufacturing indicates that fragmented regulatory expectations and limited regulatory coordination can slow the translation of technically feasible innovations into implementation (Cauchon *et al*., 2026). Research concerning innovative analytical technologies further shows that validation, comparability, evidence-generation, and regulatory-integration requirements vary across technological classes (Salih *et al*., 2025; Wang *et al*., 2025a). A firm may therefore be highly capable in one technological domain yet inadequately prepared for another.

For Saudi firms, biotechnology adoption should consequently be understood as a cross-layer alignment problem. A firm may possess investment capacity but insufficient internal scientific absorption. It may possess specialist scientists but weak manufacturing integration. It may obtain access to international technology partners yet lack internal governance for technology transfer (Meyer *et al*., 2026). It may have strategic ambition but no mechanism for converting that ambition into resource-protected implementation (Giang *et al*., 2026).

These distinctions require a visual architecture that makes cross-layer dependencies and mismatch states explicit rather than reducing the argument to a generic sequence of boxes.

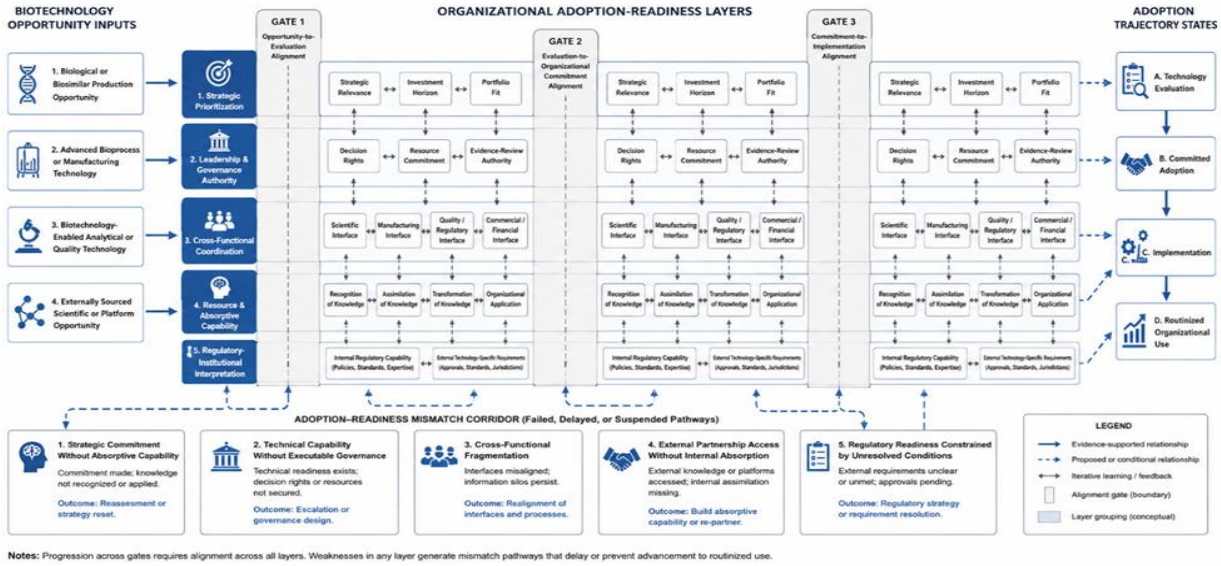

Figure 1. Cross-layer biotechnology adoption-readiness field with alignment gates and organizational mismatch channels

Strategic Orientation and Innovation Prioritization

Strategic orientation determines whether biotechnology receives durable organizational attention rather than episodic enthusiasm.

Research on digitalization orientation indicates that strategic posture extends beyond willingness to purchase technology and can encompass openness, data awareness, customization, perseverance, and employee involvement (Kessler *et al*., 2025). These dimensions are not treated here as a biotechnology-adoption scale, but they illustrate why formal strategic declarations may fail when they are disconnected from implementation behavior.

Strategic priorities also interact. Evidence from manufacturing firms suggests that strategic orientations do not necessarily contribute additively to innovation and that technology can strengthen some combinations while weakening others (He *et al*., 2024). Pharmaceutical firms may simultaneously pursue localization, cost efficiency, supply resilience, regulatory compliance, international expansion, product differentiation, and technological modernization. A biotechnology opportunity may therefore be attractive in principle while competing with shorter-term investment priorities or exceeding the organization's implementation horizon.

A useful distinction is therefore made between strategic signaling and strategic commitment. Strategic signaling identifies biotechnology as desirable. Strategic commitment connects that preference to a defined technology opportunity, portfolio rationale, investment horizon, decision authority, protected resources, and implementation responsibility.

National industrial priorities can increase the legitimacy of biotechnology investment, but they cannot determine firm-level adoption. Domestic manufacturers, multinational affiliates, contract manufacturers, and firms at different stages of technological maturity may respond differently to the same institutional conditions. Strategy establishes direction; it does not substitute for organizational capability.

Leadership Commitment and Governance

Leadership becomes consequential when a technology must be evaluated under uncertainty and competing organizational interests. Research on top-management-team diversity and business-model innovation demonstrates that heterogeneous leadership can broaden information while simultaneously increasing conflict under uncertainty and technological change (Angelshaug *et al*., 2025). Biotechnology decisions may produce similar governance tensions because scientific, manufacturing, regulatory, and commercial assessments can legitimately generate different interpretations of the same opportunity.

Governance also determines how organizations respond to failure and uncertainty. Qualitative research on radical innovation indicates that uncertain innovation failure may require governance different from that used for routine operational error (Gomes *et al*., 2025). Pharmaceutical biotechnology projects can encounter uncertain biological behavior, scale-up limitations, incomplete comparability, regulatory ambiguity, or changing commercial assumptions. Governance that interprets all uncertainty as operational failure may terminate potentially viable projects prematurely. Conversely, uncertainty cannot justify indefinite expenditure or weak quality oversight.

The relevant distinction is therefore not whether leaders "support innovation," but whether leadership creates executable decision architecture. Decision rights must specify who can initiate formal evaluation, commit resources, reconcile contradictory evidence, authorize progression, and determine when a project should be paused, redesigned, or terminated.

Table 1 separates several governance postures without treating them as a maturity sequence.

Table 1. Governance conversion conditions between biotechnology priority and executable adoption decisions

Governance posture	Strategic commitment	Decision architecture	Principal failure signature
Symbolic sponsorship	**Signal —** Biotechnology is publicly prioritized **Resource commitment —** Episodic	**Authority —** Diffuse **Evidence governance —** No stable progression threshold	Strategic importance without executable ownership
Technical delegation	**Signal —** Opportunity owned by scientific specialists **Resource commitment —** Functionally bounded	**Authority —** Strong within technical function only **Evidence governance —** Enterprise evidence reconciliation occurs late	Technical feasibility becomes organizationally stranded
Executive authorization	**Signal —** Senior authority is explicit **Resource commitment —** Protected	**Authority —** Centralized **Evidence governance —** Cross-functional evidence is reviewed formally	Decision bottleneck at senior level
Distributed cross-functional governance	**Signal —** Priority is shared across affected functions **Resource commitment —** Jointly negotiated	**Authority —** Defined across technical and managerial interfaces **Evidence governance —** Scientific, manufacturing, quality, regulatory, and financial evidence are reconciled	Coordination burden can slow progression
Uncertainty-sensitive governance	**Signal —** Strategic value is maintained conditionally **Resource commitment —** Reconfigurable	**Authority —** Adaptive **Evidence governance —** Scientific uncertainty is distinguished from preventable implementation failure	Excess tolerance or excess control can distort continuation decisions

Note: These are proposed governance configurations, not empirically validated Saudi organizational types or performance rankings.

Organizational Structure and Cross-Functional Coordination

Biotechnology adoption typically crosses organizational boundaries. Research and development may establish scientific

feasibility, but manufacturing determines scalability, quality functions determine control requirements, regulatory teams interpret evidence expectations, procurement and engineering support infrastructure, and financial or commercial functions evaluate resource exposure and market relevance.

Research on university–industry collaborations demonstrates that formal contracts and relational governance have different functions depending on collaboration configuration and phase (Lee & Miozzo, 2024). Although external collaboration differs from internal coordination, the broader principle is relevant: coordination mechanisms must match the uncertainty and interdependence of the task.

Longitudinal research on radical innovation also indicates that new initiatives frequently depend on resources located within established organizational structures and therefore require mechanisms for mobilizing mainstream capabilities into emerging activities (Salerno *et al*., 2025). Creating a specialist biotechnology unit may concentrate expertise without solving the interface problem if manufacturing, quality, regulatory, data, procurement, and finance remain disconnected.

Organizational structure should therefore be evaluated through interface capacity rather than through organization charts alone. Cross-functional readiness exists when knowledge can move between scientific evaluation, process development, manufacturing design, quality assessment, regulatory interpretation, and strategic decision-making without being repeatedly reconstructed at each boundary.

This interface requirement is likely to vary across firm size and ownership structure. Large firms may possess specialized internal functions but experience coordination complexity. Smaller organizations may have fewer boundaries but depend more heavily on external expertise. Neither structure can be assumed inherently superior.

Resource Availability and Absorptive Capacity

Resource availability is frequently treated as a central determinant of innovation adoption, yet biotechnology requires more than capital, equipment, or specialist staffing. Organizational capacity depends on whether resources can be converted into learning and coordinated action.

Pharmaceutical evidence concerning divestitures and innovation highlights managerial attention as a limited organizational resource (McCarthy & Aalbers, 2024). The implication for biotechnology is not that divestiture should be prescribed, but that firms managing multiple localization, modernization, regulatory, and commercial initiatives may possess financial capacity while lacking sufficient senior attention to integrate another complex technology.

Existing experience can also be double-edged. Research on investment in emerging technologies shows that experiential knowledge can become a competency trap when previous success anchors decision-makers to familiar technological trajectories (Mu & Jiang, 2024). In biotechnology, prior manufacturing competence may accelerate absorption when new knowledge is related to established capabilities, but it may inhibit evaluation when novel platforms challenge entrenched routines.

Biopharmaceutical evidence on open innovation further shows that technological cooperation interacts with internal absorptive and alliance-management capabilities (Wang *et al*., 2024). External expertise cannot indefinitely substitute for internal ability to evaluate what a partner is supplying, translate it into manufacturing or quality requirements, and retain knowledge after the collaboration ends.

Absorptive capacity is therefore treated here as a transformation process rather than a resource category. Relevant capabilities include recognizing valuable knowledge, assimilating it, reconciling it with existing routines, translating it across functions, and applying it to organizational decisions and implementation.

Table 2 differentiates configurations that may contain similar quantities of resources but differ substantially in their ability to convert those resources into biotechnology readiness.

Table 2. Absorptive-capability configurations and biotechnology adoption failure signatures

Capability configuration	Internal capability profile	Translation and dependency mode	Likely organizational consequence
Capital-rich, knowledge-thin	**Resource condition —** Strong financing and infrastructure **Knowledge state —** Limited internal biotechnology understanding	**Cross-functional translation —** Weak **External dependence —** High	Technology acquisition can outpace organizational comprehension
Specialist-rich, interface-poor	**Resource condition —** Strong localized expertise **Knowledge state —** Deep but functionally concentrated	**Cross-functional translation —** Weak across organizational boundaries **External dependence —** Moderate	Technical capability remains disconnected from enterprise implementation
Experience-rich, adaptation-constrained	**Resource condition —** Strong established manufacturing knowledge **Knowledge state —** New knowledge filtered through familiar routines	**Cross-functional translation —** Moderate **External dependence —** Low to moderate	Emerging technologies may be undervalued or forced into unsuitable legacy practices
Network-rich, absorption-limited	**Resource condition —** Extensive partner access **Knowledge state —** Large inflow of external knowledge	**Cross-functional translation —** Inconsistent **External dependence —** High	Collaboration volume increases faster than internal learning

Integrated adaptive capability	**Resource condition —** Resources and expertise are sufficiently aligned **Knowledge state —** Knowledge is recognized, assimilated, transformed, and applied	**Cross-functional translation —** Strong **External dependence —** Selective rather than substitutive	Firm can conduct more coherent evaluation and implementation without implying successful performance

Note: The configurations represent proposed analytical states and must not be interpreted as a quantitative readiness scale.

External Partnerships and Knowledge Networks

Biotechnology-intensive pharmaceutical innovation frequently extends beyond the boundaries of the focal firm. Universities, biotechnology companies, contract development and manufacturing organizations, technology suppliers, specialist laboratories, research institutes, and multinational partners can provide knowledge or infrastructure that firms cannot efficiently reproduce internally.

However, external sourcing is not inherently beneficial. Longitudinal evidence from 2,971 biopharmaceutical R&D projects shows higher termination risk among externally sourced projects, while familiarity with the underlying knowledge reduces that risk (Purdy *et al*., 2023). This establishes an important boundary: external access increases opportunity but can simultaneously increase coordination and integration risk.

University alliances also demonstrate conditional value. Research involving therapeutic biotechnology firms found stronger associations between university alliances and exploratory innovation than with exploitative innovation, with internal technological breadth influencing those relationships (Slavova & Jong, 2021). Partnership benefits therefore depend on the objective pursued and the knowledge already available inside the firm.

At a broader level, bibliometric analysis shows that university–industry R&D relationships and technology transfer are persistent components of pharmaceutical innovation systems (Ma *et al*., 2022). Evidence from the Chinese pharmaceutical industry further indicates that interregional industry–university–research collaboration can contribute differently to technological diversification across organizational actors (Li & He, 2024). These findings cannot be transferred directly to Saudi Arabia, but they demonstrate that partner type and network position matter.

External scientific knowledge also displays nonlinear characteristics. Research on US biomedical and life-sciences firms found positive effects from scientific knowledge-flow intensity but inverted-U relationships involving breadth and novelty (Lian *et al*., 2025). Beyond some point, additional knowledge diversity may increase interpretation and integration burden.

Innovation intermediaries may partially reduce such burdens. Comparative evidence on research and technology organizations in the United States and United Kingdom identifies technology demonstration, workforce development, and ecosystem coordination as mechanisms through which intermediaries can support advanced manufacturing adoption (Anzolin & O'Sullivan, 2025). Similar functions could be relevant to Saudi pharmaceutical biotechnology, but their effectiveness cannot be assumed without local evidence.

Boundary-spanning search itself can become excessive. Research on open innovation identifies nonlinear relationships between external search and innovation, with organizational resilience and analytical capability altering those relationships (Jin *et al*., 2025). A broader manufacturing review also characterizes open innovation as involving organizational, technological, human-resource, and strategic dimensions rather than a simple increase in partner numbers (Obradović *et al*., 2021).

The key construct is therefore network permeability, not network size. External knowledge must cross several organizational boundaries before becoming usable capability. Partnership governance determines whether information can be exchanged. Technological familiarity determines whether it can be interpreted. Absorptive capacity determines whether it can be integrated. Cross-functional coordination determines whether it can influence manufacturing, quality, regulatory, and strategic decisions.

Figure 2 represents these boundaries explicitly.

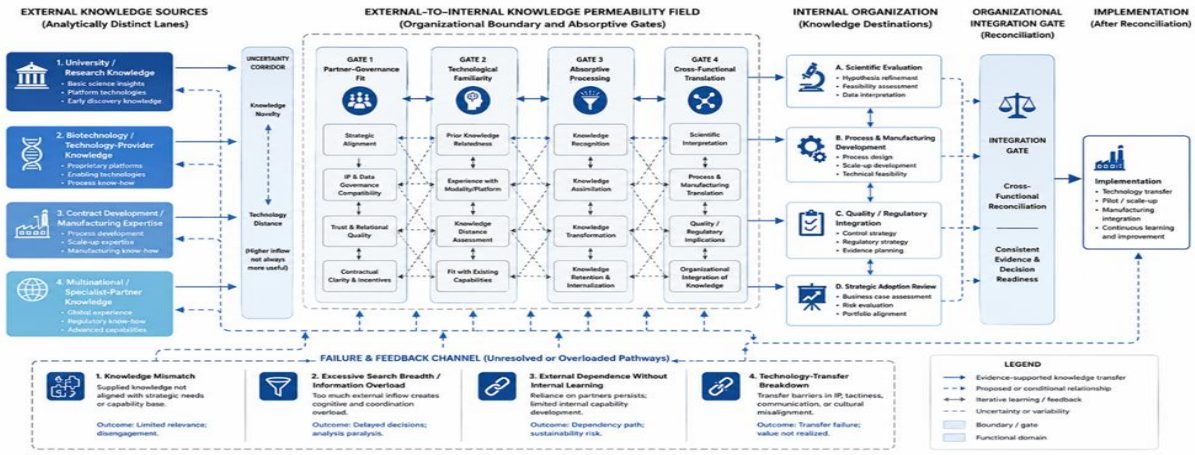

Figure 2. Interorganizational knowledge-permeability field with absorptive gates, transfer failure states, and learning feedback

Regulatory and Institutional Environment

Biotechnology adoption takes place within a regulated institutional environment. Technical feasibility does not remove the need for validation, documentation, regulatory interaction, manufacturing comparability, and quality-system integration.

Industry evidence indicates that fragmented regulatory expectations can slow advanced pharmaceutical manufacturing innovation even when firms possess substantial technical capability (Cauchon *et al*., 2026). Technology-specific research similarly shows that innovative analytical technologies can face distinct validation and implementation requirements (Wang *et al*., 2025a). Regulatory readiness should therefore not be treated as a single generic firm characteristic.

Saudi pharmaceutical localization evidence also identifies regulation, R&D infrastructure, human capability, and industrial support as components of the broader environment affecting local manufacturing (Tawfik *et al*., 2022). These conditions may increase or constrain opportunity, but they do not determine firm behavior.

Institutional conditions can also interact with knowledge-network structure. Pharmaceutical evidence from China demonstrates that regional and interorganizational collaboration patterns relate differently to technological diversification (Li & He, 2024). The Saudi institutional context therefore needs to be interpreted together with firm-specific governance, capability, and network position.

Table 3 distinguishes external–internal alignment states without treating policy, market opportunity, or regulation as deterministic.

Table 3. External–internal alignment states at the Saudi pharmaceutical firm–institution boundary

Case	Boundary side	Condition	Interface or decision state	Uncertainty or interpretation boundary
1	**External**	Strong localization or biotechnology policy support	**Interface requirement —** Capability-building and technology interpretation	**Principal uncertainty —** Whether incentives can be converted into organizational capability
1	**Internal**	Limited internal capability	**Decision state —** Strategic interest without executable adoption	**Interpretation boundary —** Policy opportunity is not firm readiness
2	**External**	Clear technology-specific regulatory expectations	**Interface requirement —** Internal reconciliation of scientific, quality, and investment evidence	**Principal uncertainty —** Whether authority can be coordinated
2	**Internal**	Fragmented governance	**Decision state —** Technically feasible but organizationally delayed	**Interpretation boundary —** Regulatory clarity does not guarantee implementation
3	**External**	Strong internal scientific capability	**Interface requirement —** Regulatory engagement and evidence planning	**Principal uncertainty —** Technology-specific acceptability
3	**Internal**	Uncertain regulatory pathway	**Decision state —** Organizationally prepared but institutionally delayed	**Interpretation boundary —** Internal capability cannot remove external uncertainty
4	**External**	Extensive international partnership access	**Interface requirement —** Internalization of partner knowledge	**Principal uncertainty —** Sustainability of capability after collaboration
4	**Internal**	Weak absorption and transfer mechanisms	**Decision state —** Externally enabled but dependent	**Interpretation boundary —** Network access is not organizational capability
5	**External**	Higher cross-layer alignment	**Interface requirement —** Continuous evidence reconciliation	**Principal uncertainty —** Residual technical and market uncertainty
5	**Internal**	Strategy, governance, capability, networks, and regulatory interpretation are sufficiently coherent	**Decision state —** More informed progression toward implementation	**Interpretation boundary —** Alignment does not establish successful outcomes

Note: These configurations are proposed interpretive states rather than validated Saudi adoption categories.

An Integrated Strategic–Organizational Adoption Architecture

Pharmaceutical innovation develops through temporally differentiated scientific, technological, and commercial transitions. Computational analysis of pharmaceutical innovation trajectories shows that movement from scientific discovery to technological development and marketable products can be prolonged and variable (Wang *et al*., 2021). Biotechnology adoption decisions therefore occur at different stages of technological maturity.

Multi-level research on industrial digital transformation similarly emphasizes interaction among technological, organizational, and market domains rather than isolated technology acquisition (Wang *et al*., 2025b). Although that evidence comes from another industry, it provides a useful multi-level logic for distinguishing technological opportunity from organizational conversion.

The proposed architecture developed in this article consequently contains six interacting domains: strategic prioritization, governance, cross-functional coordination, absorptive capability, external networks, and regulatory-institutional interpretation. None constitutes an independent determinant whose value can simply be added to the others.

This distinction is supported by contradictory and nonlinear evidence across the reviewed literature. Strategic orientations can interact negatively. Experience can become a competency trap. External technology sourcing can increase termination risk. Scientific knowledge breadth can exhibit diminishing or negative

returns. Excessive boundary-spanning search can create overload. These findings argue against a cumulative model in which more leadership, more resources, more partners, and more technology automatically produce stronger adoption.

Instead, the proposed architecture is configurational. Strategic prioritization establishes why the technology deserves organizational attention. Governance determines whether the organization can commit. Coordination determines whether evidence can move across functions. Absorptive capacity determines whether knowledge can become internal capability. Networks extend the knowledge boundary. Regulation and institutions define external interpretation and implementation conditions.

The cross-layer alignment gates in **Figure 1** and the permeability gates in **Figure 2** represent different but connected problems. **Figure 1** addresses whether internal organizational domains align sufficiently for progression. **Figure 2** addresses whether external knowledge can become internal capability. Their combination produces several proposed mismatch states: strategically committed but capability constrained; technologically capable but governance constrained; network rich but absorption poor; organizationally ready but institutionally delayed; and technically progressing but cross-functionally fragmented.

These mismatch states are not classifications of actual Saudi pharmaceutical firms. They are theoretical states intended to sharpen empirical investigation. Future studies can test whether particular configurations are associated with evaluation continuation, adoption decisions, implementation duration, technology-transfer stability, or routinization, while preserving distinctions among biotechnology modalities and organizational contexts.

Implementation Priorities for Saudi Pharmaceutical Firms

Implementation should begin with diagnosis rather than a universal checklist. Saudi organizational-change research demonstrates why analytical level is critical. Validation of an Arabic Readiness to Organizational Change instrument showed that readiness can be measured meaningfully at the individual level within a Saudi healthcare context (Alasiri & Zhang, 2025). That instrument cannot simply be converted into a pharmaceutical-firm biotechnology-readiness score because workforce attitudes and organizational implementation capability are distinct constructs.

A second Saudi healthcare study found associations between participation in transformation planning, awareness, and concerns regarding organizational change (Bin Abdulrahman *et al*., 2024). These findings are not pharmaceutical biotechnology evidence and do not establish causality. They nevertheless reinforce the importance of communication, participation, and perceived organizational consequences when large-scale change is implemented.

For pharmaceutical firms, the first implementation priority should therefore be technology specificity. Organizations should define the exact biotechnology opportunity rather than assess readiness for “biotechnology” generically. Scientific platform, product modality, manufacturing process, analytical method, and regulatory pathway determine different capability requirements.

The second priority is mismatch identification. Firms should determine whether the dominant constraint lies in strategy, authority, coordination, absorptive capability, external knowledge integration, or regulatory interpretation. The same intervention should not be prescribed to firms experiencing different mismatch states.

Third, strategic sponsorship should be converted into explicit governance. Decision rights, evidence thresholds, resource responsibilities, escalation pathways, and termination conditions should be specified before implementation becomes resource intensive.

Fourth, firms should develop absorptive capacity in parallel with external partnership activity. Innovation intermediaries can potentially contribute technology demonstration, workforce development, and ecosystem coordination (Anzolin & O'Sullivan, 2025), but external capability should reinforce rather than permanently replace internal learning.

Fifth, implementation should be treated as recursive. Regulatory expectations change, external partnerships evolve, technical assumptions fail, and strategic priorities shift. Evaluation should therefore continue through implementation rather than ending when the initial adoption decision is made.

The practical implication is that biotechnology adoption does not require every organizational domain to be maximized. It requires sufficient coherence among the domains most relevant to a particular technology. That proposition remains to be tested empirically across Saudi pharmaceutical firms differing in size, ownership structure, multinational affiliation, technological maturity, workforce capability, biotechnology modality, and regulatory exposure.

Conclusion

Biotechnology adoption in Saudi pharmaceutical firms is fundamentally an organizational conversion problem rather than a technology-purchasing decision. Strategic opportunity must be converted through governance, cross-functional coordination, absorptive capacity, external knowledge integration, and regulatory interpretation before implementation becomes organizationally sustainable.

The article therefore replaces additive barrier-and-driver logic with a proposed configurational architecture. Its principal contribution is the distinction between cross-layer alignment and knowledge permeability. The first determines whether internal organizational conditions can support progression; the second determines whether external scientific and technological knowledge can become internal capability.

The proposed alignment gates, permeability gates, and mismatch states are theoretical constructs, not validated Saudi firm categories or causal predictors. Their value is analytical: they identify where biotechnology adoption can become stranded even when individual conditions appear favorable. Empirical research should

now test these configurations across heterogeneous Saudi pharmaceutical organizations and biotechnology modalities before stronger claims regarding adoption determinants, implementation performance, or organizational outcomes are made.

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