



# QUALITY BY DESIGN IN BIOLOGICS MANUFACTURING

How modern CDMOs build robust processes,  
analytical control, and regulatory confidence  
across the biologics lifecycle



# Quality by Design: The Foundation of Reliable Biologics Manufacturing

## Introduction

In biologics manufacturing, the way a therapeutic is produced is inseparable from the therapeutic itself. Unlike small-molecule drugs, biologic products are highly sensitive to the conditions under which they are developed and manufactured. Small changes in cell culture conditions, purification steps, or analytical methods can influence the structure, stability, and activity of the final product.

This is why the industry often says “the process is the product.”

For biopharmaceutical innovators, this reality places an enormous emphasis on quality. Robust manufacturing processes, well-characterized analytical methods, and disciplined quality systems are essential to ensuring that therapies are safe, consistent, and scalable.

Today, expectations for quality in biologics manufacturing continue to evolve. Regulators increasingly expect development programs to incorporate quality by design principles, risk-based decision making, and lifecycle analytical strategies. At the same time, the complexity of biologic molecules, from monoclonal antibodies to next-generation modalities, continues to grow.

For Contract Development and Manufacturing Organizations (CDMOs), maintaining a strong quality culture is therefore not simply about regulatory compliance, it is about enabling successful drug development.

This guide explores the role of quality across the biologics lifecycle and examines how modern CDMOs integrate quality systems, analytical rigor, and process understanding to support reliable biologics manufacturing.



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## Why Quality Determines Success in Biologics Manufacturing

**In biologics manufacturing, the process does not simply produce the drug it defines it.**

Biologics manufacturing is fundamentally different from traditional pharmaceutical production. Because biologic drugs are produced in living systems, their quality is influenced by a wide range of biological and process variables.

These variables include:

- ▶ cell line stability
- ▶ culture conditions
- ▶ nutrient feeds and metabolic profiles
- ▶ purification methods
- ▶ formulation conditions
- ▶ storage and handling parameters

Quality is the foundation that ensures every patient receives a therapy that is safe, effective, and worthy of the trust they place in it.



Even minor deviations in these variables can influence the molecular characteristics of a biologic therapy. Changes in glycosylation patterns, protein folding, or aggregation levels can ultimately affect drug safety, potency, and stability.

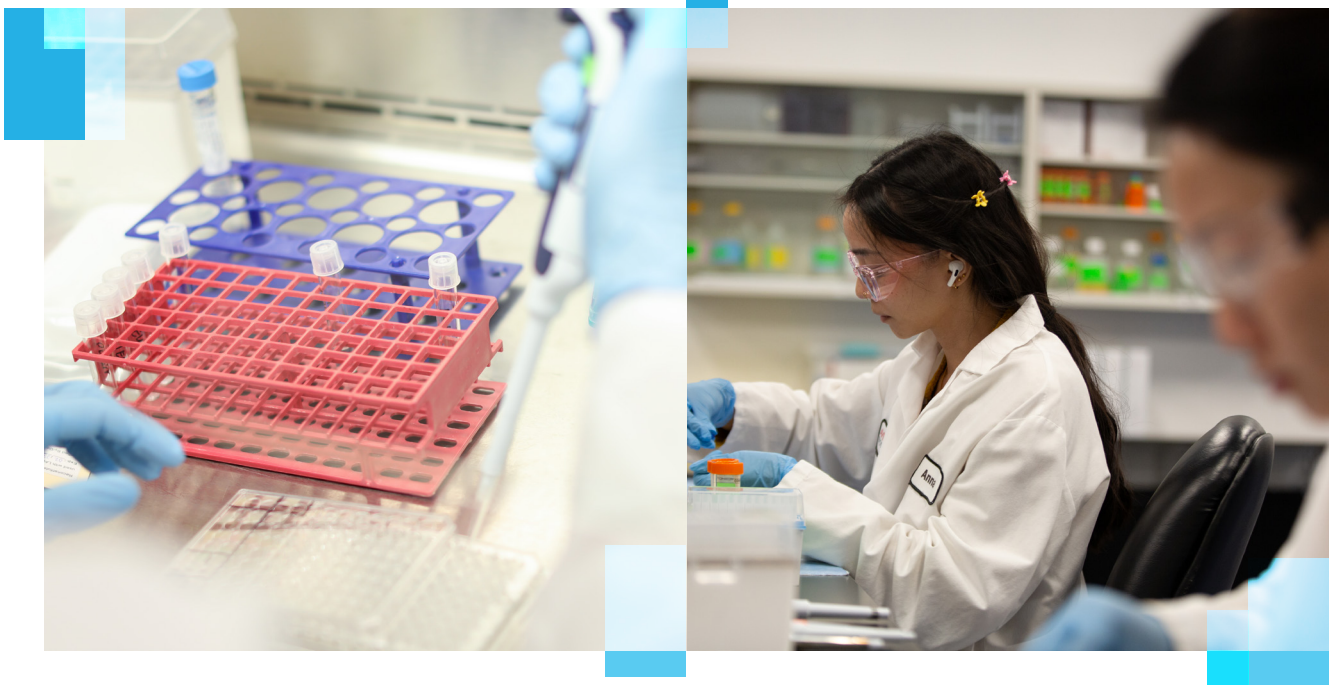
As a result, quality in biologics manufacturing must be built into the process from the earliest stages of development.

This begins with establishing a clear understanding of the molecule itself. Developers must identify the critical quality attributes (CQAs) that define the product's safety and efficacy. These attributes then guide the

design of the manufacturing process and analytical methods.

A strong quality framework ensures that development teams maintain control over these attributes throughout the product lifecycle. By designing processes that consistently produce molecules with the desired characteristics, CDMOs help reduce development risk and improve the probability of regulatory success.

Ultimately, quality is not simply a regulatory requirement it is the foundation that ensures every patient receives a therapy that is safe, effective, and worthy of the trust they place in it.



## Single-Use Manufacturing and Contamination Risk Reduction

**Modern single-use technologies help reduce contamination risk while enabling flexible, reliable biologics production.**

Manufacturing technologies play a critical role in maintaining quality in biologics production. Over the past decade, single-use technologies have become an increasingly important component of modern biologics manufacturing facilities.

Single-use systems replace many traditional stainless-steel components with disposable, pre-sterilized materials such as bioreactor bags, tubing assemblies, and filtration systems. These systems arrive pre-sterilized and ready for use, reducing the need for extensive cleaning and sterilization procedures.

From a quality perspective, single-use technologies offer several important advantages.

First, they significantly reduce the risk of cross-contamination between production batches. Because single-use components are replaced between runs, this eliminates the opportunity for residual materials from a previous process to contaminate a subsequent batch.

Second, single-use systems simplify manufacturing operations. The elimination of complex cleaning validation procedures reduces operational complexity and allows teams to focus more directly on process performance and product quality.

Finally, disposable systems provide greater manufacturing flexibility. Facilities can adapt to different processes or molecules more easily without extensive equipment modification.

While single-use technologies introduce their own considerations such as material compatibility and extractables/leachables evaluation they have become an essential tool for ensuring quality and consistency in biologics manufacturing.



## Quality by Design in Process Development

**Quality by Design ensures that processes are built to deliver consistent product quality long before manufacturing begins.**

Quality by Design (QbD) has become a central framework for modern biologics development.

Rather than relying solely on end-product testing, QbD emphasizes designing processes that consistently produce high-quality product from the outset. This approach relies on a deep understanding of the relationship between process parameters and product characteristics.

The foundation of QbD begins with identifying Critical Quality Attributes (CQAs) the molecular characteristics that determine a product's safety and efficacy. These attributes may include factors such as purity, potency, glycosylation profiles, aggregation levels, and higher-order structure.

Once CQAs are defined, development teams identify the Critical Process Parameters (CPPs) that influence these attributes. These parameters might include temperature, pH, dissolved oxygen levels, feed rates, or purification conditions.

Through structured experimentation often using Design of Experiments (DoE) methodology teams can explore how changes in these parameters affect product quality. This work enables the establishment of a design space, within which processes can operate reliably while maintaining consistent product characteristics.

By incorporating QbD principles early in development, CDMOs can build processes that are more robust, scalable, and predictable.

This deeper process understanding ultimately reduces commercial risk and supports smoother regulatory submission approvals.

Quality built into development prevents costly surprises later in the product lifecycle.

## Designing Processes That Scale Without Compromising Quality

**Successful scale-up begins with development processes designed for consistency across every stage of production.**

Scaling a biologic manufacturing process from laboratory development to commercial production presents significant technical challenges.

Processes optimized at small scale must ultimately perform reliably in manufacturing environments that may be thousands of liters larger. Differences in mixing dynamics, oxygen transfer rates, and shear forces can all influence process performance as scale increases.

If scale considerations are not addressed early, process performance may change

as production moves from development to manufacturing. These changes can introduce variability that affects product quality or yield.

Successful scale-up therefore requires careful process design.

Development teams must establish scale-down models that accurately reflect manufacturing conditions. These models allow scientists to study process behavior and evaluate potential risks before transferring processes to larger equipment.

In addition, maintaining alignment between development equipment and manufacturing systems can help minimize process variability. When equipment platforms and analytical methods are consistent across development and manufacturing environments, technology transfer becomes significantly more predictable.

By designing processes with scalability in mind from the beginning, CDMOs help ensure that quality attributes remain consistent throughout the entire product lifecycle.



## Analytical Strategy Across the Biologic Lifecycle

**Robust analytical strategies provide the visibility needed to ensure product quality from development through commercialization.**

Analytical characterization plays a central role in maintaining quality throughout biologic development and manufacturing.

Analytical methods are used to evaluate product structure, purity, potency, and stability. These methods help confirm that each batch of drug substance meets predefined specifications and maintains the molecular characteristics required for safety and efficacy.

Effective analytical strategies must evolve throughout the product lifecycle. During early development, analytical

methods focus on product characterization. Techniques such as mass spectrometry, chromatography, electrophoresis, and spectroscopy help scientists understand the molecular properties of the biologic molecule.

As development progresses, analytical methods transition toward quality control testing. At this stage, methods must be qualified and eventually validated to demonstrate that they are suitable for routine use in GMP environments.

Analytical methods must also be aligned with the product's Analytical Target Profile (ATP), which defines the performance characteristics required for the assay.

By establishing strong analytical strategies early in development, CDMOs can reduce the likelihood of costly rework later in the product lifecycle.

Ultimately, analytical rigor ensures that biologic therapies remain consistent from batch to batch and throughout the product lifecycle.



## Quality Systems That Enable Regulatory Confidence

**Strong quality systems transform regulatory expectations into disciplined, reliable manufacturing practices.**

Robust quality systems are essential to maintaining compliance with global regulatory standards.

Quality management systems (QMS) govern the procedures, documentation, and oversight mechanisms that ensure manufacturing processes are executed consistently and in accordance with regulatory expectations.

Key components of a strong quality system include:

- ▶ deviation management procedures
- ▶ change control processes
- ▶ corrective and preventive actions (CAPA)
- ▶ document control systems
- ▶ training programs
- ▶ internal audit programs
- ▶ raw material vendor management programs



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These systems allow organizations to identify and address potential issues quickly while maintaining full traceability of manufacturing activities.

For biologic therapies approaching commercialization, regulatory inspections represent a critical milestone. During Pre-License Inspections (PLIs), regulatory authorities evaluate whether manufacturing processes, quality systems, and facilities operate in alignment with the information submitted in the Biologics License Application (BLA).

Organizations with well-established quality systems are better prepared for these inspections. Thorough documentation, strong communication between teams, and disciplined operational practices help demonstrate that manufacturing processes are reliable and well controlled.

Strong quality systems therefore play a critical role not only in maintaining compliance but also in building regulatory confidence.



## Building a Culture of Quality

**True quality culture exists when every team member takes responsibility for protecting product integrity.**

While technologies and procedures are essential to biologics manufacturing, the most important element of quality is organizational culture.

A true culture of quality ensures that every member of an organization from scientists and engineers to manufacturing operators and quality specialists shares responsibility for maintaining product integrity.

In organizations with strong quality cultures, employees are encouraged to identify potential risks, raise concerns, and continuously improve processes. Communication between departments is open and collaborative, enabling teams to solve problems quickly and transparently.

Leadership also plays a critical role in establishing a quality culture. When senior leadership consistently prioritizes quality, teams throughout the organization recognize that maintaining product integrity is a core operational priority.

For CDMOs working with biopharmaceutical innovators, this culture of quality extends beyond internal operations. Transparent communication with clients helps ensure that development programs remain aligned with regulatory expectations and project goals.

Ultimately, a strong culture of quality allows organizations to consistently deliver reliable biologics manufacturing solutions.





## The Future of Quality in Biologics Manufacturing

**As biologics grow more complex, quality systems must evolve to provide deeper process understanding and lifecycle control.**

As biologic therapies continue to evolve, the role of quality in development and manufacturing will become even more important.

Emerging modalities including bispecific antibodies, antibody-drug conjugates, and next-generation biologics introduce new challenges in process development, analytical characterization, and manufacturing control.

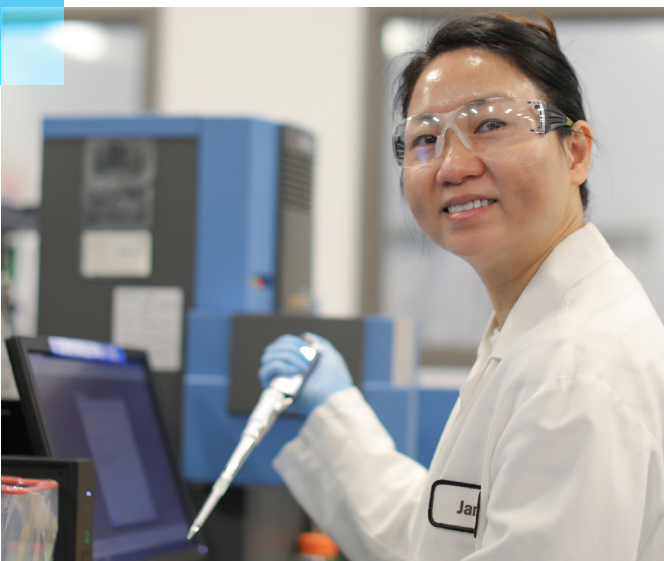
At the same time, regulatory expectations for process understanding, lifecycle management, and risk-based decision making continue to increase.

To meet these expectations, CDMOs must continue investing in advanced technologies, analytical capabilities, and highly skilled scientific teams.

By integrating quality into every stage of biologic development from cell line creation to commercial manufacturing modern CDMOs can help ensure that innovative therapies reach patients safely and efficiently.

In the complex and evolving field of biologics manufacturing, quality remains the cornerstone of successful drug development.

The difference between a promising molecule and a successful medicine often lies in the ability to manufacture it consistently.



# Quality Builds Trust

In biologics manufacturing, quality is not simply about compliance. It is about trust.

Patients trust that the therapy they receive today will perform exactly the same as the therapy manufactured tomorrow. Regulators trust that manufacturing processes are understood and controlled. And innovators trust that their CDMO partner will protect the integrity of their molecule every step of the way.

## At Avid Bioservices, we take that responsibility seriously.

Because behind every batch manufactured, every assay validated, and every process optimized is something much bigger than a production milestone. It is the opportunity to help bring new therapies to patients who are waiting for them.

When quality is built into every stage of development, innovation moves forward with confidence and life-changing medicines move closer to the people who need them most.

## Work with Avid Bioservices

If you are developing a biologic therapy and seeking a partner committed to quality at every stage of development, we invite you to connect with our team.

Learn how Avid's integrated development and manufacturing expertise can support your program from early development through commercial production.

Visit: [www.avidbio.com](http://www.avidbio.com)

Contact: [businessdevelopment@avidbio.com](mailto:businessdevelopment@avidbio.com)

## Avid Bioservices

- ▶ Decades of experience supporting biologics development and manufacturing
- ▶ Proven expertise across development, clinical, and commercial production
- ▶ Integrated teams spanning process development, analytical science, manufacturing, and quality
- ▶ A strong culture of quality supporting reliable biologics manufacturing