Better bioprocessing for a changing world

Innovation at the speed of life™

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Introduction

Process intensification solutions for the future of medicine

Bioprocessing – using living cells or biological systems to make useful products such as biologic medicines at scale – has grown more complex than ever. Conventional production models are under strain as operational, technical, and economic constraints inflate costs and hinder progress. At the same time, biomanufacturers are under pressure to cut resource consumption, drive supply and meet sustainability goals. Incremental improvement won't be enough. Truly efficient and sustainable bioprocessing will require a transformation in how systems are designed, scaled, operated, and optimized.

Process intensification, or PI, is key to this transformation. PI is not simply a way of maximizing productivity through smaller systems and automation. It's a comprehensive redesign approach that can increase yield, decrease cost, simplify workflows, minimize space, and enable more consistent and predictable operations – all while maintaining high standards of quality.

Therapy manufacturing processes are constantly evolving, and even a minor change in batch size or volume size can entail a major change in complexity. For instance, to make smaller batches, manufacturers need to switch production lines more often and share facilities across different products. This makes scheduling harder, puts more pressure on staff and equipment, and makes it tougher to accurately predict demand.

Done right, PI can be a foundation for meeting these challenges – and enabling the regionalized manufacturing approaches and smaller-scale, higher-output, multiproduct facilities that are increasingly in demand. Conversely, done wrong, PI can add complexity instead of removing it. Improving one area can hurt another. For example, perfusion – continuously adding fresh medium to cells in a bioreactor while removing spent medium – may reduce footprint but increase consumable use. The broader economics aren't always straightforward, either: stubbornly high development costs, unpredictable clinical trial outcomes, changing regulatory frameworks, rising operational costs, and the need to address global markets are all additional sources of unpredictability.

That's why close partnership is critical to succeeding in PI – and in bioprocessing overall. And it's why Danaher operating company Cytiva takes a deeply collaborative approach, working hand in hand with customers. Over decades, the company has helped drive key advances that now form the backbone of many key processes that enable the production of cancer treatments, vaccines, and cell and gene therapies used around the world. Looking ahead, Cytiva is investing in next-generation PI approaches to lead the future of bioprocessing – helping customers achieve higher productivity, greater sustainability, and faster production of life-changing therapies.

Quantifying industry needs

Opportunities for improved bioprocessing

$25B

(USD) or more invested in global biomanufacturing in 2024.[3]

56%

of high-performing companies are investing in digital infrastructure to improve supply chain resilience[1]

$4.1B

(USD) estimated value of global Process Analytical Technology market in 2024.[2]

1. 2025 Global Biopharma Index. Accessed November 24, 2025. https://www.cytivalifesciences.com/en/us/behind-biopharma/biopharma-index
2. Process Analytical Technology Market to Hit USD 13.8 billion by 2033. Accessed November 25, 2025. https://dimensionmarketresearch.com/report/process-analytical-technology-market/
3. Next-Generation Biomanufacturing Market Scope Deep Study 2025. Accessed September 15, 2025. https://www.insightaceanalytic.com/report/next-generation-biomanufacturing-market-size-share--trends-analysis-report-by-medical-applications-monoclonal-antibodies-hormones-vaccines-recombinant-proteins-other-applications-by-products-by-workflow-by-end-user-by-region-and-by-segment-forecasts-2025-2034/1261

Upstream

Maximizing cell culture productivity

The cell culture stages of bioprocessing, also known as upstream bioprocessing, come first. Yields have increased by an order of magnitude in recent decades, but challenges remain. Because these steps involve living cells, they are complex and include many important factors that determine how much product can be made and what is needed to produce it.

Because of this, any efficiency gains made upstream – for instance, in cell growth, density, viability, and productivity per liter – can be extremely valuable. For instance, achieving higher cell density or titer can help biomanufacturers trim production timelines, operate smaller and more sustainable facilities, and make downstream operations more stable and predictable.

One of the strongest opportunities is found in cell culture bioreactors, which are key to making many biologic medicines. For many blockbuster biologics such as Avastin, Herceptin, Keytruda and Dupixent (to just name a few), upstream bioprocessing is performed in large bioreactors which can contain 20,000 liters of cell culture volume or more, and are run for up to 2 weeks before the product is harvested in one batch.

A key opportunity to intervene comes just before this mammoth step – expansion of the cell culture in a sequence of smaller bioreactors called the "seed train." There are several ways to intensify this stage. Bioreactors that use a perfusion process – where fresh nutrients continuously enter the system and waste products are continuously removed – allow cells to be maintained for many weeks, even months at a time. This reduces equipment downtime, increases potential cell density, and improves overall productivity. Performance can be further enhanced with dynamic perfusion, which adjusts flow rates based on real-time needs. Compared with conventional approaches, dynamic perfusion is easier to operate and delivers higher productivity.[4]

Additional gains can come from "feeding" cells a better diet and helping them grow. High-efficiency media provide cells with optimized nutrients, enabling faster growth and higher productivity while reducing the need for frequent media exchanges. High-density inoculation – starting production with a larger number of viable cells – reduces the time needed to reach peak productivity and further shortens manufacturing timelines. Intensified seed trains, which use advanced methods to rapidly expand cell populations before they enter the main bioreactor, help ensure consistent and reliable performance from batch to batch. And all of these approaches also support sustainability by lowering the use of energy, water, and consumables.

All told, upstream PI provides a way to do more with less – increasingly a mandate across the industry.

4. Falkman T. Upstream process intensification with dynamic perfusion. November 19, 2025. Accessed November 24, 2025. https://www.cytivalifesciences.com/en/us/insights/upstream-process-intensification-with-dynamic-perfusion

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Biomanufacturers need more than just a supplier; they need true collaboration. Danaher brings not just the products and the technology, but also the investment, scale and global expertise to best meet the needs of those manufacturing these important medicines."

Beate Mueller-Tiemann, Chief Technology Officer
Cytiva

Downstream

Streamlining purification and formulation

"Downstream" bioprocessing – in which proteins of interest are captured, and unwanted materials such as host cell proteins, DNA, and viruses are removed – has several more steps than the upstream stage. Each of these steps must be carefully designed to account for upstream intensification. Each also presents opportunities of its own for further optimization.

In downstream bioprocessing, molecules are separated based on how strongly they bind to a resin, which is a solid material made of beads packed inside a column. Some resins are designed to bind very specifically to the target product, such as protein A binding monoclonal antibodies. Other separation methods use basic properties of the molecule, like charge or hydrophobicity, as in ion exchange chromatography.

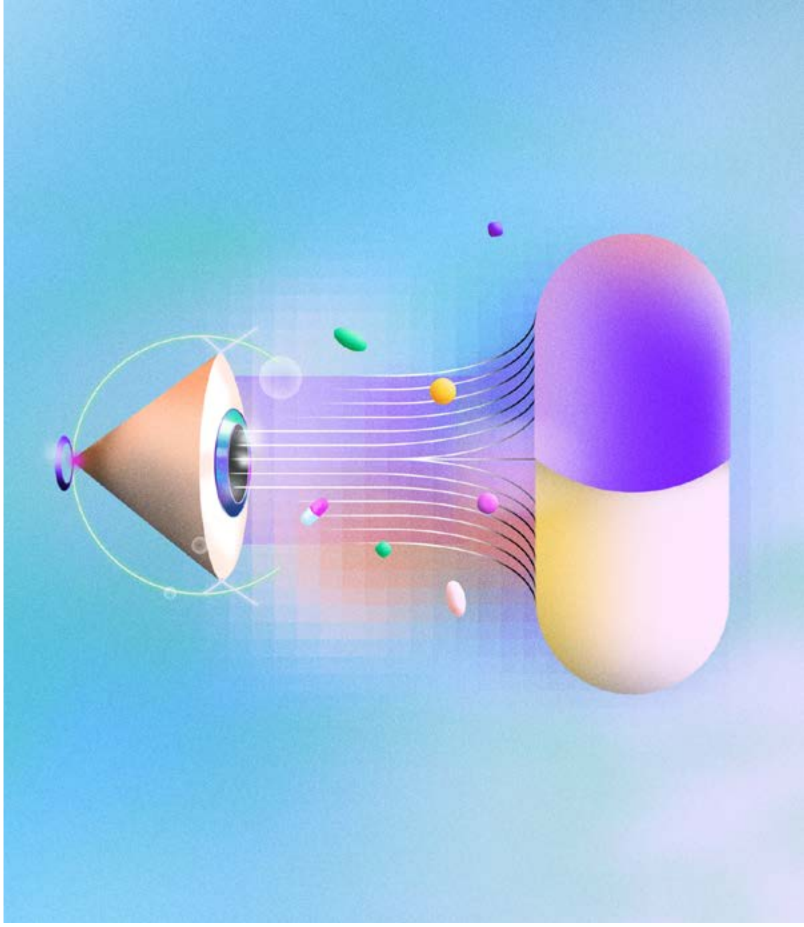
Traditionally, downstream bioprocessing is done in batches, with each batch coming from the upstream bioreactor. One way to improve efficiency is to run chromatography continuously instead of in batches. This approach is called periodic countercurrent chromatography (PCC). PCC uses multiple columns that work together and alternate between loading and regeneration, rather than relying on a single column that must be stopped and refreshed.

This allows protein capture to happen continuously, leading to higher productivity, lower costs, and better sustainability through reduced buffer use, fewer cleaning cycles, shorter campaigns, and lower overall resource consumption.

PCC does have some downsides: it adds process complexity of its own, and can be expensive to set up. Cytiva is working to address these challenges by building downstream purification platforms based on a set of simplified standard components, or "building blocks." These include established bioseparation hardware systems that control flow, pressure and other process parameters, specialized resins that separate molecules and can last through many regeneration cycles, and membrane technologies used for chromatography as well as filtration. In many cases, these components remain largely the same regardless of which specific therapy is being purified. This creates an opportunity to develop a comprehensive, modular toolkit – allowing manufacturers to select systems and technologies that have already been optimized for performance, quality, and manufacturing consistency, no matter what the end goal is.

Continuous Integration

Connecting the bioprocessing ecosystem



Good PI decisions start with careful planning – knowing what the most important constraints are and how changes could affect performance, cost, global needs, and regulatory readiness. But the need for meaningful predictive information doesn't end once an initial plan is in place. Given the complexity and potentially global scale of the process, real-time data on performance is more important than ever – particularly when upstream and downstream PI has already been implemented. This data isn't just necessary for sensing potential issues – it's key to predicting and preventing them.

Digital technologies that connect different operations are transforming how manufacturers approach process intensification, and standardization and automation elements enable seamless integration across the entire bioprocessing workflow. These connected systems allow manufacturers to monitor critical process conditions, optimize resource use, and respond dynamically to process variations. This dramatically enhances confidence in the safety and quality of therapeutic outputs, and could someday allow for the nearly instantaneous release of medicines from the end of the production line.

The key lies in Process Analytical Technology (PAT)—essentially, smart sensors and monitoring systems that offer real-time insights into the manufacturing process. Incorporating these analytical technologies to collect detailed data will enhance our understanding of critical manufacturing processes. With PAT, manufacturers can view statistics and information in real-time, track yields for each production run, measure the effectiveness of each process step and immediately detect mistakes and deviations from expected conditions. PAT is not just a monitoring tool—it's a cornerstone of digital integration, enabling predictive control, real-time optimization, and continuous verification of product quality. By strategically developing innovative sensor technologies that enable continuous measurements and data collection, we can enhance process intensification and allow therapies to be released to patients faster without sacrificing safety.

The outlook for PAT is promising. As sensor technologies become more sophisticated and data analysis capabilities expand, manufacturers will gain unprecedented visibility into their processes. This will enable predicting when equipment needs maintenance, optimizing processes in real-time, and continuously verifying that processes are working correctly – all critical elements for successful process intensification. The next era of PAT will rely on modular sensors, unified data models, and machine learning algorithms that enable "human-in-a-loop" or autonomous digital control of process conditions and continuous verification of product quality. These real-time sensors will guide operator decisions, improve consistency, reduce deviations, and enable faster, more confident interventions—ultimately reducing cost, improving compliance, and accelerating time-to-market for advanced therapies.

Conclusion

Manufacturing that meets the moment

Biomanufacturing is at an inflection point. The pressures facing the industry are real and accelerating, and the demand for more flexible and responsive factories are needed to meet the need of therapeutic portfolios with growing complexity.

Achieving this transformation requires collaboration. No single organization, technology, or approach can address the challenges of modern biomanufacturing alone. Real progress will depend on integrating scientific insight, engineering innovation, digital intelligence, and operational excellence across the full development and production continuum.

This is where Danaher companies, including Cytiva, are committed to leading. As we work alongside our partners across the industry, we are advancing tools, data and frameworks needed to create the next generation of manufacturing. Solving these problems is paramount for realizing the potential of today's medicines and ensuring that breakthroughs aren't hindered by technological limitations.

Too often, the cost and labor involved in manufacturing modern therapies prevent patients from accessing the highest-quality care available. Our goal is clear: to help create a future where high-quality, life-changing therapies can be produced sustainably, reliably, and made accessible on a global scale.

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