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IN MY VIEW

Don't Get a Raw Deal

While you're busy scaling up your bioprocesses, don't forget about the secure supply of all critical raw materials – both in terms of quality and quantity

By Hunter Malanson, Senior Field Application Specialist at Thermo Fisher Scientific

Scaling up the biomanufacturing processes established during early phase development is an exciting, challenging – and critical – step in the journey of a biologic. After all, the scaled-up process will be used throughout the product lifecycle – and it must be developed to be both cost-effective and sustainable in the long term. That means decisions must be made to not only maximize productivity, but also to enable a secure supply of raw materials to reduce the risk of disruption and late-stage process changes.

Given that impurities in raw materials can be amplified during the scale-up process, the quality of the raw materials used during manufacturing should be a primary focus when scaling up. In particular, any impurities found in raw materials used in the cell culture medium can have a profound impact on performance parameters, including overall titers, cell growth, and consistency, which will likely result in variable product performance and batch-to-batch fluctuations. Even minor trace element contamination can dramatically impact the manufacturing process. For example, unexpected trace metals can alter protein glycosylation patterns, leading to aggregation, insolubility, and a subsequent reduction in overall protein yields.

In addition to improving process consistency, high-quality raw materials feed into the critical quality attributes of the biologic as production is scaled up. Any deviations in these attributes can change the molecule's biological activity, which can prevent a biologic from getting to (or staying on) the market.

Given the clear importance of maintaining high raw material quality standards, it is no surprise that, over recent years, the analysis of raw materials has been a growing focus within the bioprocessing industry. Subsequently, there has been an increased demand for companies that use sophisticated analytical techniques and electronic data sharing to monitor impurities and contamination in their raw materials, keeping manufacturers informed of any variations.

Another potential issue associated with raw materials is supply disruption. To avoid delays when working at a commercial scale, biologics manufacturers must maintain a consistent supply of all critical raw materials – both in terms of quality and quantity. How? Simply by choosing suppliers that offer supply redundancy – through, for example, multiple manufacturing sites. However, before a secondary supply can be qualified, vendors must be able to provide evidence that any secondary sites can meet the same specifications as the qualified primary site. To minimize the risk of variation when qualifying a secondary site, vendors should have a comprehensive and multi-faceted equivalency program, featuring equipment validation, staff training, and even their own raw materials supply (if they are supplying a complex raw material, such as pre-formulated cell culture media).

If you, as a manufacturer, are pursuing an animal origin-free process, you'll also need to conduct a careful assessment of the comparability of the facilities' contamination mitigation strategies to reduce the potential risk of transmission of viruses and other potential contaminants from animal-origin materials. Make sure your suppliers can detail equivalent risk reduction procedures, including the strategic clean room layouts and de-gowning procedures implemented at each site.

There is no doubt that scale up can be a complex period in any biologic's lifecycle, with numerous factors that need careful consideration. Furthermore, in an industry under extreme pressure – tight timelines, numerous suppliers, limited budgets – making the right decisions early on is becoming increasingly crucial for commercial success.

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IN MY VIEW

Welcome to the Microbe Factory

How can smaller companies navigate scale up and complexity in microbial biomanufacturing?

By Axel Erler, Director of Commercial Development at Lonza

With an increased focus on smaller next-generation biologics, such as antibody mimetics, novel scaffolds, vaccines (subunit, plasmid DNA, and conjugated), interest is shifting back to microbial biomanufacturing as an effective and cost-efficient platform. But the arena of microbial biomanufacturing comprises technical requirements that increase the already inherent complexity of biologic drug development. Unlike mammalian cell culture (where platform processes are routinely used), microbial manufacturing requires customized processes tailored to the characteristics of the specific molecule, leading to variations in product titer and yield.

Though microbial biomanufacturing can potentially reduce development timelines and costs, it also presents significant challenges. Emerging biopharma has become a driving force of innovation in the life sciences sector – transforming the R&D model and reshaping the competitive landscape. There is a growing number of small biotechs that choose to see their project through to market on their own to reap a larger ROI. However, with limited experience in late clinical and commercial project planning, limited understanding about the intricacies of planning (such as BLA filing), and little experience in scaling up from lab-scale process to commercialized production, these companies can run into many challenges.

It's important for a biotech to focus on early planning of process scale-up and BLA activities to maximize the chances of success. After all, in an increasingly competitive and faster-to-market landscape, it is critical to avoid delays by securing a right-first-time (RFT) approach.

Smaller biotechs sometimes think they need to finalize their chemistry, manufacturing, controls (CMC) activities and launch strategy before they engage a prospective manufacturing partner. However, a CDMO familiar with microbial-derived molecules often does not need the entirety of this information to begin planning for commercialization. A CDMO can also offer invaluable process and manufacturing insight. During scale up, issues not present at the clinical scale can emerge (steps like chromatography fractionations and protein refolding are notoriously difficult to scale). A good expert can look at a process as early as phase I and identify opportunities that may increase titer/yield, process robustness, and development speed.

It also goes without saying that quality by design (QbD) should be kept in mind. In my view, combining manufacturing experience with design of experiment approaches and automation facilitates the application of QbD principles. By establishing operating ranges during process characterization using design of experiments, you can increase process design space and, as a result, introduce optimization opportunities that will prevent BLA filing changes later.

Some companies develop unit operations suitable for R&D scale which may not be suited for large-scale manufacturing. Unoptimized processes with regard to raw material use (for example, expensive resins and membranes) will also add to the cost of goods. Early discussions and thought should go into the selection and combination of media/feeds and unit operations, including choices of membranes and resins. Operational limits of the anticipated large-scale manufacturing asset (for example, available column sizes, membrane holders, tank volumes, buffer prep capacities) must also be considered. Though some limitations can be solved with a capital investment, others may require partial or even sizable process adjustments to fit the anticipated manufacturing asset. And that can be particularly problematic when discovered too late and when the budget is no longer available.

Regulatory requirements for analytical data sets are also often underestimated, with a focus commonly on product quality but not on in-process monitoring, which is necessary to acquire the data needed for CMC validation.

Emerging and small biotechs are the engine for innovation. To help bring their innovations to market, they should consider collaborating with partners with commercial expertise who can provide insights on a scale-up and BLA strategy. Engaging a good partner, especially early in phase I, means the design of the strategy will be tailored to the specific product, process timeline, and risk tolerance without compromising RFT. And the more successful biotechs there are, the better public health becomes.

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Technologies and tactics that provide for first-to-patent with comprehensive sequence claims, and first-to-human opportunities, are of increasing interest to the biopharmaceutical industry. The speed with which a company can move from an idea to proof-of-concept for a therapeutic provides significant competitive advantages and allows resources to be focused on those approaches most likely to deliver beneficial clinical outcomes.

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- Gene-to-protein Strategies

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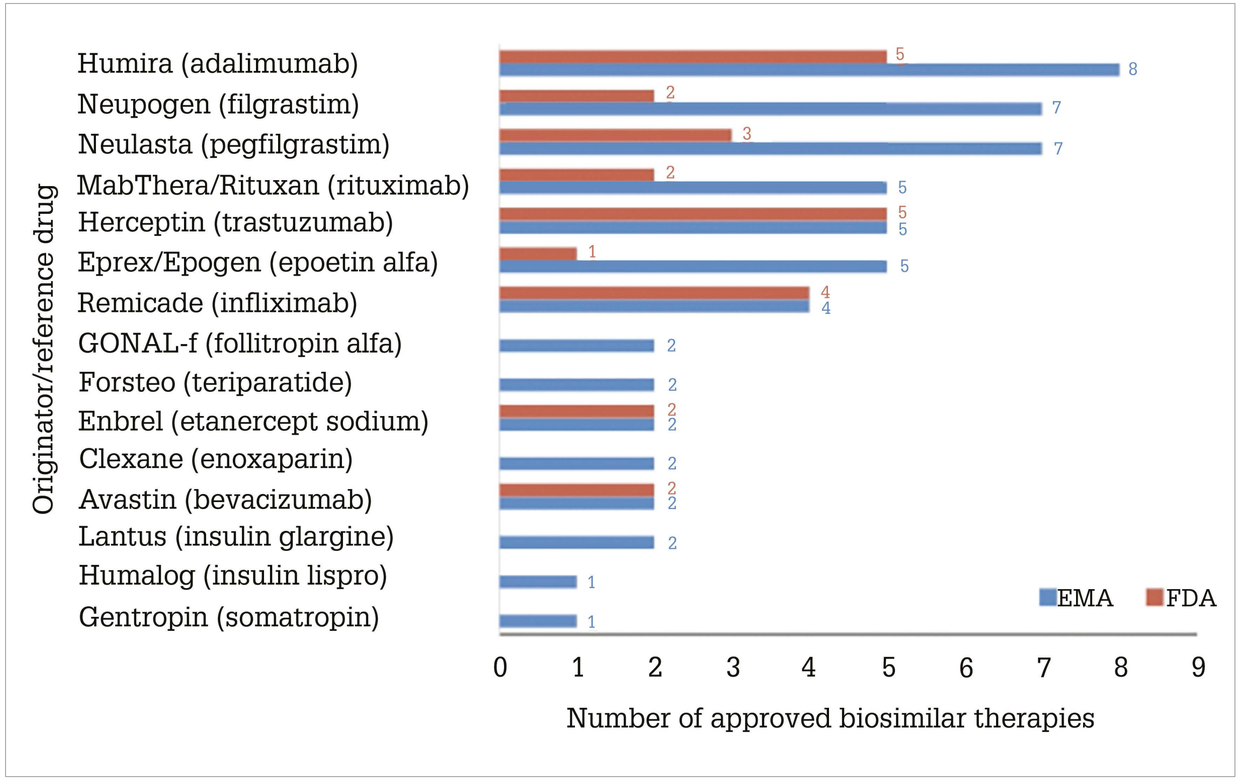
IN MY VIEW

Driving Down Biosimilar COGS

To keep biosimilars costs as low as possible, take a good look at your purification and characterization processes

By Amanda Turner, Senior Product Manager, Custom Antibody Products, at Bio-Rad Laboratories, CA, US and Khaled Mriziq, Senior Global Marketing Manager, Process Chromatography, Protein Purification Group, at Bio-Rad Laboratories, CA, US



The expensive, specialist methodologies that underpin the development and manufacture of important biological medicines typically result in associated costs being passed to healthcare providers, insurers, or the patients themselves. Biosimilars, therefore, are welcome players in the market. As originator therapies reach patent expiry, biosimilars aim to deliver on the promise of greater affordability and wider access to biological therapies. However, the world of biosimilars is exceptionally competitive – with many biopharma manufacturers racing to become the first to leverage the opportunity of blockbuster exclusivity loss.

Although biosimilars must only demonstrate equivalence to the originator/reference product to gain regulatory approval, standards remain rigorous, and interchangeability with the reference product needs to be shown regarding molecular structure, biological activity and efficacy, safety, and immunogenicity. Purification and bioanalytical characterization processes can comprise more than half of the total development cost for a biosimilar (1). In our view, upfront planning and access to the most effective protein purification and bioanalytical tools are vital to reduce the risk of failure, maximize the chances of timely regulatory approval, and ensure long-term drug quality during large-scale manufacture – and beyond.

Purification and recovery methods must achieve high protein purity and yield – but by cost-effective means, as costs need to be kept as low as possible to compete effectively in the biosimilars market. Removal of impurities, including host cell protein, DNA, viral contaminants, protein aggregates, isoforms, and other species, should use high specificity chromatography technologies that are able to withstand elevated throughput rates and variable pH conditions. The traditionally favored Protein A resins provide excellent specificity but are an expensive option. Alternative high-capacity resins, on the other hand, can offer opportunities to lower expenditure while also optimizing purification processes (2) (3) (4); for example, ion exchange resins have demonstrated comparable results to Protein A-based processes regarding the efficient clearing of impurities with good binding capacity and stability – and without the limitations of flow rate or pH conditions (3). Mixed-mode chromatography resins are unique in their ability to combine varying forms of molecular

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interaction (for example, hydrophobic, ion exchange) via a single-support matrix, and can reduce the number of purification steps required in some cases (4). Integration of such technologies within existing pathways allows efficiencies to be made with minimal disruption to the development plan.

Purification optimized? Check.

Next, let's look at the comparative clinical studies needed to determine pharmacokinetic and immunogenicity profiles of the reference product and biosimilar. You'll need to develop sensitive and selective ligand binding assays using specialized antibody reagents. Notably, the reliability and reproducibility of the data generated are contingent on the quality of the antibody reagents selected, so securing high quality, reproducible antibodies early in the development lifecycle is beneficial.

When the biologic is a monoclonal antibody, anti-idiotypic antibody reagents are critical for bioanalytical assays comparing biosimilar and reference product functionality. In vitro antibody generation methods (for example, antibody phage display) can selectively produce reagents demonstrating high specificity for defined regions of the drug, allowing assays to be designed to detect free drug, total drug, or the drug-target complex. In vitro technology offers the benefit of antibody generation within three months, while traditional animal immunization methodologies can be slow (approximately six to nine months) and may not result in the desired level of specificity. Recombinant antibodies are sequence-defined from the outset and well characterized, permitting an indefinite supply of reproducible capture and detection reagents. Through antibody engineering, technologies can be incorporated that enable site-directed conjugation and fast assembly of antibodies in monovalent or bivalent Fab and full-length immunoglobulin formats (for example, SpyTag-SpyCatcher technology) (5). Such innovations enable tighter control of critical reagents and speed up the assay design and optimization process, resulting in more sensitive and robust assays.

As with all biological products made in cellular systems, small molecular changes may arise between biosimilar batches and alterations are introduced over time as the manufacturing system evolves. Reliable bioanalytical assays are vital in demonstrating that molecular modifications do not deleteriously affect drug efficacy or safety, and in ensuring the success of the drug – long after regulatory approval.

As an increasing number of biopharmaceutical developers seek to maximize the opportunity of biosimilar medicines, robust and accelerated approaches to bioprocessing and bioanalytical data generation are becoming increasingly important for success. In our view, those companies that embrace technologies to enhance the efficiency and quality of their methodologies are most likely to avoid regulatory setbacks – and thrive in this hugely competitive marketplace.

REFERENCES AVAILABLE ONLINE

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Raman Spectroscopy, a PAT Tool Advancing Biopharma Manufacturing

Get in-line, real-time upstream (USP) and downstream (DSP) bioprocess monitoring and control

Process Analytical Technology (PAT) comprises a range of analytical tools used to facilitate the development of dynamic manufacturing processes that can account for variability in raw materials and equipment used to produce drug substances and drug products.

The goal of PAT is to build quality into biopharmaceutical manufacturing processes by monitoring and controlling the process in-line and in real time. Once the critical process parameters (CPPs) that impact the critical quality attributes (CQAs) of the drug substance or drug product have been identified and fully characterized, appropriate analytical methods are developed, and corresponding technologies are used to monitor those CPPs so that they can be controlled. Thus, both the CPPs and CQAs can be maintained within a specified design space. In this manner, quality is built into the process from the start, supporting the principle of quality by design (QbD), rather than assessing the quality of products after they have already been produced.

Raman spectroscopy is one of the most promising PAT tools in the biopharma industry. Raman is an optical spectroscopy technique that essentially provides a molecular fingerprint of a sample. As is the case with human fingerprints serving as unique and consistent identifiers of individual people, individual molecules have unique and reproducible molecular Raman spectra. With Raman spectroscopy, therefore, it is possible to identify which molecules are present in a sample at a very high resolution. When Raman spectroscopy is used as a PAT tool, it allows for monitoring of the molecular composition of a sample over time. As an optical method, this technology can determine chemical composition and molecular structure information in a nondestructive and reproducible manner avoiding the loss of chemical information due to degradation, instability, or sample preparation. In addition, there is no need to collect a sample and send it to the QC lab for analysis. It only requires the insertion of a probe into the process along with the other sensors that are already widely used.

For bioprocessing in particular, Raman spectroscopy also benefits from the weakness of the bands produced by water. The water peaks do not interfere with the peaks associated with the analytes of interest, which allows for high-quality analysis of aqueous bioprocess solutions. This feature — combined with the molecular specificity and nondestructive nature of Raman spectroscopy — has made it the primary spectroscopic technique employed to date as a PAT tool in the biopharmaceutical industry.

TALK TO A PAT AND RAMAN EXPERT

BUSINESS & REGULATION

Brace for Biosimilars!

Biosimilars are making waves in the US. What can we expect – and what more can be done to help biosimilars thrive?

By Jeff Baldetti, Director for Biosimilars at Cardinal Health

When I first joined Cardinal Health a few years ago, the company was just starting to develop its biosimilar strategy; in fact, my very first assignment was to work on this task. Very quickly, I fell in love with these products. Biosimilars are good for patients, good for the healthcare industry, and good for innovation because they promote competition – quite the triple-combo!

Although biosimilars may not be seeing the rapid proliferation in the US market that some might have expected, they are certainly still seeing successes. Biosimilars have been available in the US since 2015, but, until 2018 or 2019, we saw relatively slow uptake. Hesitancy defined the immediate response; decision makers had a range of questions about biosimilars. Foremost, they wanted to be certain that these products were safe and just as effective for patients.

Progress… During a pandemic

In the last few years, providers have become much more comfortable with biosimilars. Use has rocketed and 2019 alone gave us nine new FDA biosimilar approvals. The US has now approved more biosimilars than the EU did in its first seven years since opening the gates.

The COVID-19 pandemic's impact on the uptake of biosimilars is interesting. First, oncology and rheumatology (for which many biosimilars are indicated) were not hit as hard by the pandemic as other healthcare therapeutic areas, which provided these biosimilars more protection against the external market factors. Second, the pandemic triggered significant financial distress in almost every industry, including healthcare, which helped underline the curative powers biosimilars can bestow upon balance sheets. Lower cost biosimilars were welcomed by individuals in need of healthcare but also squeezed by pandemic effects.

It was during the pandemic that Cardinal Health began development of a report on the US biosimilars market (1). We wanted to gather a really comprehensive review of stakeholder perspectives across the healthcare ecosystem and made a concerted effort to survey not only prescribers across different therapeutic areas, but also pharmacists.

We wanted to offer a perspective on what's to come, as it's not enough to merely summarize the past seven years. As we round the turning point, biosimilars are going to be moving into new therapeutic areas and new classes of trade.

Nothing's easy

Of course, almost all changes bring new challenges. FDA approvals and launches won't magically guarantee smooth sailing for biosimilars. Right off the bat, the US presents a problem because it has different regulations in different states. From Ohio to Texas to California, biosimilar manufacturers have to handle managed care differently for different patients and different insurers. They have to adjust and deploy their commercialization strategies accordingly.

Two even more fundamental challenges that can hinder the development of biosimilars are time and money. Biosimilars are biologics, and manufacturing biologics costs a great deal of money, regardless of whether it is an innovator product or a biosimilar. It can take five to seven years and several hundred million dollars to bring a biosimilar to market. For products like biosimilars, which are intended to be less expensive, this can make formulating a pricing strategy difficult. Manufacturers must ensure their biosimilar has all of the

"Biosimilars have shed light on some of the hardest challenges posed by the American healthcare system – many of which are baked into its very design."

same characteristics as the branded product, including wraparound patient services, but will often have far fewer dollars at their disposal.

The Cardinal Health Biosimilars report does unveil a few surprises as well. One finding that I found particularly striking was the 97 percent positive correlation between managed care coverage and biosimilar adoption rates. The direction of that correlation makes sense – the surprise lies in the sheer strength of synchronization.

Another rather dramatic finding revealed in the report is the shift in oncologists' perceptions. Back in 2015, less than 20 percent of oncologists were comfortable with the idea of switching their patients to a biosimilar. Fast forward to today, and that figure has jumped to over 70 percent of oncologists being completely comfortable with the idea, and a further 20 percent feeling comfortable with the idea of switching for supportive care oncology products only. This change in attitude represents a major shift. Consider Humira – the number one selling drug in the world. Since its launch in 2003, over 19 years ago, Humira has garnered well over US$100 billion in sales. Now, there is a chance to bring the cost of the treatment down and vastly improve access for patients with Rheumatoid Arthritis, Crohn's, psoriasis, and several other diseases across the product's indication list. In the US, we already have seven biosimilars to Humira that are FDA approved and awaiting various launch dates through 2023. We expect this number will only continue to grow throughout the remainder of 2022. In 2024 onward, we will continue to see this shift from provider-administered, medical benefit products, to more retail, self-administered products in the immunology space.

Know thyself

We also need to get more knowledge into the hands of patients. If you are a patient being treated with an expensive biologic, it is absolutely in your interest to learn more about biosimilars. Across the world and in the US particularly, healthcare grows more expensive with each passing year. Most people are facing ever more severe financial pressure, and very often the sources of these pressures are totally beyond their control. Biosimilars offer one way for patients being treated with a biologic to take back a little control and alleviate some of that pressure. Unfortunately, there is a great deal of misinformation about biologics and biosimilars out there. More education needs to be done and made more accessible. As an industry, I believe we need to do a better job of educating patients and addressing their concerns. The more comfortable patients feel with how these products are approved and how they interact with their bodies, the better.

Our report is – I hope – one means for such an education. Cardinal Health works at the intersection of healthcare in the US and interacts with providers, pharmacists, life science companies, payers, and patients, which has uniquely positioned us to collect and share information about biosimilars with all stakeholders.

Biosimilars have shed light on some of the hardest challenges posed by the American healthcare system – many of which are baked into its very design. Delayed biosimilar entry and growing gross-to-net price gaps both have shown how misaligned incentives can lead to decisions that do not seem logical. I believe that new policies are needed to continue supporting biosimilars to ensure these products have a place in our market and to free up dollars to fuel the next stage of innovation. In the last three years, we have seen the beginnings of this shift in policy, but the benefits of these policies can often be a long time coming and heavily debated. Today, several states have begun proposing legislation to support biosimilar products, with some going as far as presenting laws that would require parity coverage in payer policies or formularies between reference products and their biosimilars. At the federal level, in a response letter to the Biden Administration from the Department of Health and Human Services (HHS), biosimilars were cited over 90 times in 27 pages as key tools to improving competition in the market. Additional policy suggestions like potentially increasing biosimilar reimbursement to ASP + 8% of the reference ASP (currently ASP + 6%) or streamlining the biosimilar approval process are all being heavily discussed and debated today. Various agencies and trade groups are becoming more and more invested in ensuring the promise of biosimilars comes to fruition, but policy alone is not a panacea. We need additional policy, robust provider and patient education, and alignment along the healthcare delivery chain to ensure that biosimilars in America maintain momentum and fulfill their triple aim.

At Cardinal Health we absolutely want to be cheerleaders for biosimilars, but we also want to see our entire system continue to come together and align behind what biosimilars really stand for: lower cost of care, increased access, and reduced expenditure for the entire health system.

READ THE FULL ARTICLE ONLINE

INTERVIEW

Getting to Grips with the E&L Threshold

Did you know the PQRI has released new recommendations on extractables and leachables in parenteral drug products?

Extractables and leachables (E&L) have been a headache for drug manufacturers for years. Identification and analysis of E&L is complicated – and the challenges aren't getting any smaller with an increasing diversity of drug modalities. Back in 2006, the Product Quality Research Institute (PQRI) issued recommendations on safety thresholds and best practices for E&Ls in orally inhaled and nasal drug products. Now, they have released new recommendations: "Safety Thresholds and Best Demonstrated Practices for Extractables and Leachables in Parenteral Drug Products (Intravenous, Subcutaneous, and Intramuscular)."

Given the complexity of the topic, the document has been years in the making. Here, we find out more from Diane Paskiet, Director of Scientific Affairs at West Pharmaceutical Services, who has been involved with PQRI for nearly 20 years.

How much work went into pulling these recommendations together? And how long did it take?

Developing a comprehensive recommendation document like this takes a long time. In this case, we needed nearly 10 years to gather data, you need a lot of input – and, ultimately, consensus on the final document. It's also worth remembering that PQRI relies on volunteers from industry, academia and regulators. To develop the document, we had to draw on volunteers with extensive backgrounds in toxicology and analytical chemistry. We had to develop a proposal and work plan, and get materials donated from different suppliers. We compiled a database of over 600 extractable and leachable chemicals as part of the safety assessment to support the threshold, and we had multiple sub teams that generated data on the donated materials, as well as toxicologists who developed the safety thresholds.

Gathering all this evidence and data has been a long journey! Well over a hundred people have been involved with this – which is a lot of people when you need consensus!

How have conversations around primary packaging changed in the last five years?

In general, the materials used in pharmaceutical packaging have remained the same for decades, except for aluminium silicate glass, which is a more recent development that improves strength and reduces the risk of delamination. However, drug modalities are changing significantly, and we need to know if traditional packaging materials are suitable. In particular, biopharmaceuticals can be very sensitive, and issues with E&Ls can affect product quality; for example, through degradation, modification, or aggregation. The increase in biologic product diversity and complex dosage forms introduces new risks for safety and compatibility, as well as challenges in packaging performance and protection of the contents.

In short, we need to consider the fact that traditional packaging solutions were never designed with antibody drug conjugates, RNA therapies, and other emerging modalities in mind.

Why is it so important to get packaging right?

Treatments and cures would not be possible without the right packaging – or without the right safety and compatibility studies. In some cases, you also need a device to administer the drug to the patient. There have been many conversations on the topic focusing on the scientific and regulatory issues surrounding drug-device combinations. The regulation here is evolving all the time. Add to that the fact that there are increasingly complex products coming down company pipelines and you can see there's still a lot of work to be done in understanding E&L risk.

The science of packaging is always evolving too. I've been working in this sector for over 30 years. At the time, you always think you know what you need to know but then everything changes; we are continually learning about how drug or biological products may need to be stored, protected, and delivered. The potential for chemical migration, leachable reactivity, or surface interaction may not be easily discerned and can affect product quality. The most important thing is to ensure that packaging remains both suitable and safe.

What's included in the new recommendations?

The document includes a framework for the toxicological evaluation of leachables for parenterals, and best practices for the analytical evaluations of E&Ls. Something that we have peppered throughout the document – because it's so important (and something that the regulators are keen on) – is that drug developers need to engage with regulators early on. There is increasing complexity in both parenteral products and closure systems – and justification and proper documentation are expected, including information on thresholds, extraction conditions, solvents, and so on. The E&L analysis should be discussed early with regulators so that drug developers can be sure that the regulators will have the information they will eventually need to review the final drug dossier for approval. You don't want to get to the end of your drug development program and then find out that there were risks in your packaging and analysis strategy that you overlooked or didn't approach in the right way.

One of the significant recommendations we make in the paper pertains to the concept of thresholds. There are three thresholds: the safety concern threshold, the qualification threshold, and the analytical evaluation threshold. The former two are safety related and the latter is for compound identification.

The safety concern threshold (SCT) is 1.5 µg/day and is used to derive the analytical evaluation threshold. The SCT value was justified from the evaluating of over 600 potential leachables using existing toxicological qualification approaches. Below this threshold, the dose is so low that the safety concerns should be negligible, but that does not guarantee it is safe! The threshold is just for identification and reporting for assessment. Above this threshold, you need to identify and assess your leachable for toxicological concerns. There are certain compounds that are known to be a high risk, which may be below the analytical evaluation threshold and may need to be specifically sought depending on the material chemistry.

The qualification threshold is recommended at 5 µg/day, providing there is no genotoxic or carcinogenic potential, but it is important to consider the potential for sensitization and irritation.

The paper provides best practices for extraction studies and assessments, covering materials for constructing finished components, and complete packaging systems. In the document and supporting publications, we show how to generate the extractable profiles and provide key considerations, such as the sample of solvent ratio, conditions of exposure, and technologies for analysis and their sensitivity. Once you have your extractables profile, you can evaluate and build out your leachables studies.

Overall, it's a difficult topic to summarize – the science is complex (and the paper is almost 100 pages)! I encourage people to read the recommendations for the full details in the hope that it helps applicants with their E&L studies.

Where else is there room for improvement?

There is always going to be a need for new best practices in this field. Science evolves, regulations change, and new modalities emerge. One area we are looking at in a focus group is combination products, which is tricky because you need to merge together qualification approaches for devices and drugs. We may have future recommendations in this area, but the working group is only in the planning stage.

What are the benefits of volunteering for an organization like the PQRI?

For me, the knowledge enrichment is very rewarding – and this comes from sharing information and listening to the experience of others. There is a growing diversity in the intended use for packaging and you can't experience everything yourself – you need to learn from others. For example, if you're working in a packaging company then it's important to hear opinions from drug manufacturers, and vice versa.

The world of E&L is dynamic. Simulation and modelling are emerging and it's possible that things may look very different five years from now. Even if we look back on the last two years, drug development has changed significantly – with new technologies and a move to digitalization. Having more data and being able to assess risks to products and patients early in pharmaceutical development could lead to changes in E&L analysis.

INTERVIEW

From Saving Patients to Saving the Planet

How can pharma help save the environment? We need to look at our processes – examining where we can apply green chemistry, reduce cleanroom sizes, and use less energy overall. If we're truly serious about patient health, we need to protect our home.

By Stephanie Sutton, Editor of The Medicine Maker

A handful of people (and corporations) still deny climate change, but it is happening. A report from NOAA and NASA showed that 2010 to 2019 was the hottest decade since records began 140 years ago (1). Polar ice is melting. Extreme weather, such as hurricanes, floods and droughts, is becoming more frequent.

Let's go back to 2010. When I used to ask medicine makers what they were doing to reduce their environmental footprint, I was often laughed at. Drug development is complicated enough, they would say. It's essential for human health, they would argue. Most companies didn't seem to feel compelled to consider the environmental impact of their operations.

Today, there is a growing realization that the planet is in danger, and – slowly – more companies are wanting to play their part. Company initiatives focused on the environment and sustainability are now commonplace in the pharma industry. And academic literature on the topic grows and grows.

Kristi Budzinski works for Roche Molecular Systems and is a member of the American Chemical Society Green Chemistry Institute Pharmaceutical Roundtable (Pharma Roundtable). The Pharma Roundtable was formed to encourage innovation in green chemistry and engineering – and to help companies incorporate more sustainable approaches into their processes. Budzinski was recently the lead author on a paper, conducted by the Pharma Roundtable, examining the life cycle assessment of single use technologies in biopharma manufacturing (2). Here, Budzinski discusses the paper, the Pharma Roundtable's efforts to encourage the uptake of greener manufacturing, and her views on how the industry can improve sustainability in both small molecule and biopharmaceutical manufacturing.

What's the story behind the Pharmaceutical Roundtable?

The Pharmaceutical Roundtable started in 2005. It began as a collaboration between the ACS Green Institute and the pharma industry about how to include green chemistry in their processes. Initially, there were only around five companies involved; back then, one of the main discussion points was how to collaborate in a competitive setting – because it is not easy to talk about green chemistry and small molecules without potentially infringing on intellectual property!

As the initial hurdles were overcome, the Roundtable has also focused on how to measure and assess the impact of green chemistry, resulting in the development of the process mass intensity metric, which has become the industry standard for how to measure process efficiency. It works by summing the mass of all of the inputs that go into synthesizing a product and then dividing this by the output (amount of API) – giving a numerical value.

The Roundtable has grown a lot over the last decade. Today, there are 23 full members (innovators and pharma companies), 16 associate members, and three affiliate members. Most of the growth has come in the last five years or so – and we are seeing burgeoning interest in the topic of environmental sustainability.

How have conversations and attitudes around green chemistry and sustainability changed over the years?

I've been participating in the Pharma Roundtable for ten years and the conversations have evolved. The Roundtable remains focused on measuring impact and developing tools to help move the needle in manufacturing, but it has also focused on early stage research and development. For example, the Roundtable has contributed significant funding to academic research activities on green chemistry topics and connecting this to industry. More journals are also recognizing the

importance of green chemistry – and there have been an explosion in the launch of new journals focusing on green chemistry implementation.

In 2012, when I joined the Roundtable, we formed a large molecule focus group which was challenging as biopharma has quite different challenges from traditional pharma manufacturing, but also a testament to the ability of the roundtable to adapt. The members welcomed the biopharma perspective and helped build on the existing tools for small molecules to develop similar approaches for biopharma. These tools and techniques are now being expanded to "medium" molecules, such as peptides and oligonucleotides.

What aspect of small molecule manufacture produces the most waste?

Solvents. The Roundtable performed a benchmarking exercise (3) to examine where most of the waste in small molecule manufacture comes from – and the answer was solvents, which is convenient because this is a very non-competitive space! The Roundtable has focused on guiding chemists towards choosing solvents that are better from an environmental, health and safety perspective, while also encouraging solvent providers to create new solvents by using renewable raw materials and creating solvents with better environmental profiles.

The biggest hurdle in finding replacement solvents is a technical one; finding replacements for chlorinated solvents like dicholormethane, or for dipolar aprotic solvents like DMF, NMP, THF, etc. is extraordinarily difficult. The combination of physical and molecular properties of these solvents, such as their boiling point, or their solvation of higher molecular weight molecules, etc., are key determinants of reaction and overall process efficiency. If a chemical company finds a potential technical replacement, it then needs to meet stringent environmental, safety, health, and sustainability requirements in addition to passing regulatory requirements for residual solvents in the final drug product or for meeting GMP requirements. While the pharma industry is a big user of solvents, it is not the biggest user of solvents, and the types of solvents that are used are not always high-volume commodity solvents, such as in other industries. This makes the cost to develop a new solvent, document its EHS/Sustainability bona fides, and meet drug manufacturing and regulatory requirements a daunting prospect.

There are also regulatory concerns with integrating a new solvent into GMP processes. Companies generally need a key reason and strong motivation to change an existing process. If it is a really inefficient process with a lot of waste for example, there may be cause to make improvements. But most companies would likely only use a new solvent for a new development – and it could take a while before a company hits on a commercially viable target that uses a particular solvent. And why should chemical companies make a new solvent that likely won't be used for years?

Despite the challenges, some new solvents have come to market but maintaining adoption is difficult. Some people may try it, get interested, and want to buy – only to find out there's a six month backlog… And then everybody forgets about it.

We also have to acknowledge that solvents aren't "sexy." Not all companies have the staff available to test new solvents, although larger companies may perform solvent screening in process development. Here, they may not only be looking at the reaction and process efficiency, but also looking to identify different polymorphs and protect IP.

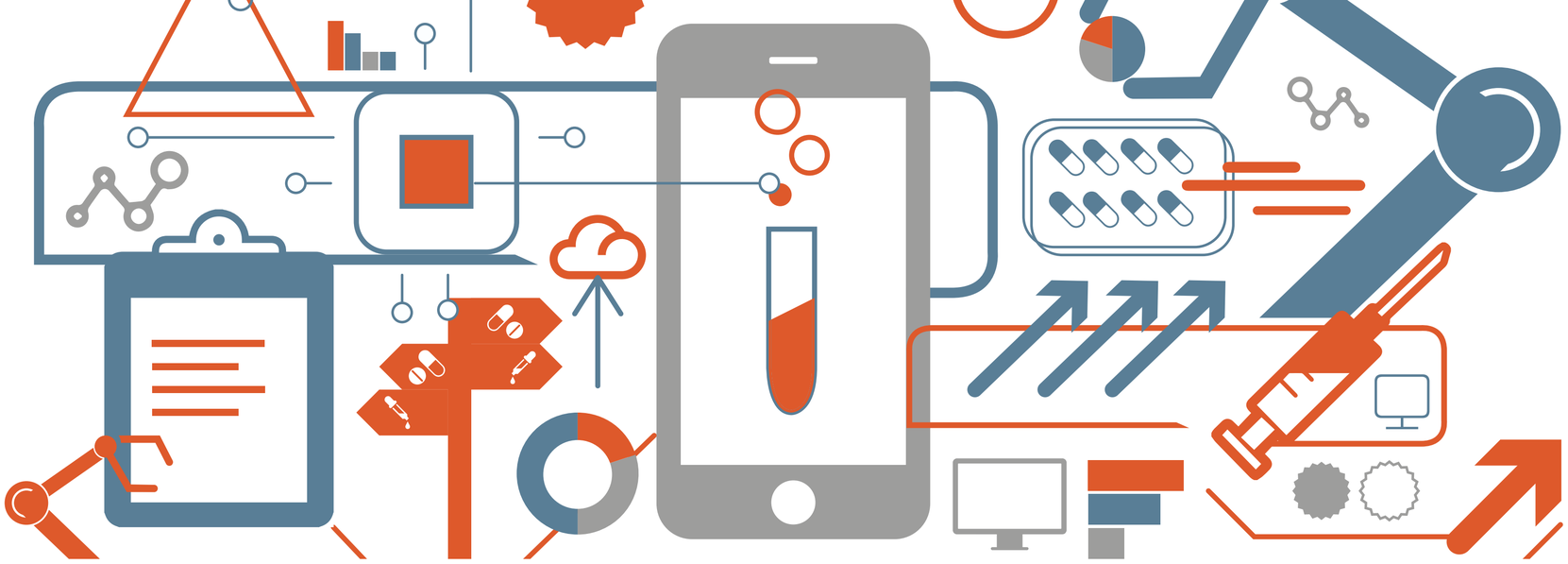
To help ease the adoption of new solvents for the industry, we need to get creative. And that's why it's really important to get this kind of work into academic settings. A great project for an up-and-coming student could be to explore where new solvents could be used and to help make it easier for industry adoption. Some companies are using interns for this type of work. For example, Genentech hosted a summer intern to look at solvent application – and the work was published so that it could be shared more broadly (4). However, just because a student does this work for a company, there is usually no mechanism to facilitate acceptance of alternative solvents in an academic setting. Secondly, investigation of new solvents isn't something of mainstream academic interest with the exception of ionic liquids and deep eutectic salts, both of which are non-starters in the Pharma industry.

READ THE FULL ARTICLE AND ITS REFERENCES ONLINE

MANUFACTURE

Delving into the Trends of the Biopharma Industry

The Medicine Maker and NIBRT present the Biopharma Trends Leaders' Report 2022



Since 2017, The Medicine Maker and NIBRT have collaborated on the annual Biopharma Trends report. The goal? To give readers an insight into the trends shaping the biopharmaceutical manufacturing industry. The report is usually based on a survey, but for 2022 we decided it was time for a change. After all – a great deal has changed in recent years. The COVID-19 pandemic has changed the world – and the biopharma industry. The industry has adopted new technologies and approaches to drug development – and has learned that it is possible to bring new therapies to patients in significantly reduced timelines.

Our 2022 report explores the views of leaders from across the biopharma industry through a series of exclusive interviews. The result? Insights into the trends that will shape biopharma in the coming years – from accelerating R&D in mRNA therapeutics and pushing the frontiers in cell therapy to finding new ways to deal with the increasingly competitive environment for talent.

The Biopharma Trends Leaders' Report 2022 features the thoughts of:

- Maik Jornitz (G-Con)
- Jan van de Winkel (Genmab)
- Amélie Boulais (Sartorius)
- James Morton & Chris Meier (Boston Consulting Group)
- Elizabeth Topp (NIBRT)
- Igor Splawski (CureVac)
- Catarina Flybourg (Cytiva)
- Fabian Gerlinghaus (Cellares)

And many more...

Sample insights

"The focus on vaccines and vaccine technologies cannot diminish or return to normal levels because the pandemic showed us just how utterly unprepared we were. The hope has to be that the global community looks into preparedness and protection against new, upcoming viral entities. The COVID-19 pandemic is far from over – and again a "new normal" has fallen into place."

"COVID-19 was a wake-up call for the industry in so many ways and across so many areas, including supply chain fragility, manufacturing capacity limitations, and staffing constraints. Many of these strains already existed, but the pandemic exacerbated the issues. It has motivated the industry to explore new solutions in a more robust manner, with a new emphasis on business continuity planning to avoid or minimize future disruptions."

"The fight against COVID-19 is continuing and this pandemic has highlighted the impact a global outbreak can have on all aspects of everyday life. The existing successful COVID-19 vaccines have shown just how effective a vaccination technology can be. Moreover, it is crucial to build on these experiences. For many of the vaccine companies, their standing and attention within the industry has been elevated and is now enabling them to act from a much stronger position."

"With science advancing at unprecedented rates, it would appear that innovation is not the rate-limiting step for new product introductions. Risk tolerance/aversion, an unharmonized global regulatory system, the increase in number and diversity of health technology assessments, and pricing create challenges for new product introduction."

DOWNLOAD THE REPORT

INTERVIEW

Chasing Harmony

An inside view of the pharmaceutical industry in China. Where has it been, where does it stand, and where is it going?

Hong Pan is the General Manager of Lonza China, where he leads the commercial functions of Lonza's business divisions in Capsules and Health Ingredients, Cell & Gene, Biologics, and Small Molecules. He has spent the bulk of his working life in large multinational pharmaceutical companies in the US, China, and the broader Asia-Pacific region – and that makes him a great person to catch up with on the latest trends shaping the pharma industry in China.

Give us an introduction to China's pharmaceutical industry…

Today, China is the second largest pharmaceuticals market in the world – and, in 2022, that market is estimated to grow to US$145-175 billion in value. Though many of China's domestic pharmaceutical companies have historically focused on generics, biosimilars, and biobetters, many companies in China are now moving to address unmet medical needs by investing in innovative R&D approaches, new drug formats, complex modalities, and digitalization. This change is being accelerated by a combination of pricing pressure, patient demand, and government initiatives aimed at driving innovation. Two other contributing factors are an increase in funding, thanks to economic growth, and an increased number of Chinese returnees from overseas, who are bringing back extensive experience in R&D and manufacturing from time spent working in western countries.

In China, there are pricing pressures in both volume-based pricing and bidding to be included in the National Reimbursed Drug List, so many biotech and biopharma companies are now looking to overseas markets – especially wealthier countries. Now, when high potential first-in-class and best-in-class molecules are developed here, it is with both Chinese and international filing in mind. Licensing in and out deals are also increasing to fill the unmet needs and pipelines of domestic companies.

More than 800 of innovative molecules are currently under development in China, and sophisticated know-how is needed to draw up the robust processes that they demand.

How does China's pharma field compare with those of other countries?

The pharmaceutical industry in China is growing quickly, but it remains less developed than those of Western countries. The in-depth, systematic know-how concerning pharma's foundation – drug discovery and development – remains behind that of other leading regions. Chemistry, manufacturing, and control experience in biomanufacturing is also a bottleneck because of the country's relatively short history of biopharma development and its smaller talent pool.

In particular, capital-intensive biomanufacturing and the required capabilities tend to be overlooked by leaders in Chinese biotech companies; they are more focused on drug discovery and clinical development. This challenge is even greater in the development and commercial manufacturing of products for export to the US and EU markets, and there remain significant gaps in regulatory and GMP requirements. When molecules enter the commercial phase, Chinese firms may also struggle with manufacturing capacity

management – too much or too little can hurt a company. For these reasons, we've seen more and more biotech companies realize that their core competency is not in manufacturing and then opt to leave it to CDMOs.

What does the future hold – both in the short term and the long?

In China, the ecosystem for the biopharma industry has developed rapidly and is very favorable to biotech growth. There are several reasons why global pharmaceutical companies are looking at China.

In the long term, China's people are growing wealthier. They hope to lead healthier, longer lives under better living conditions and the unmet medical needs here have created a solid demand for diverse drug products. In the same vein, the large patient pools conferred by China's dense population allow for faster clinical trial recruitment. We also see heavy investment in biotech from venture capital, private equity, and the public market.

More and more Chinese companies are turning to innovative, first-in-class, or best-in-class drugs – a trend that will see more new modalities, such as complex proteins, mRNA, ADCs, and cell and gene therapies. This trend is generally expected to continue and even accelerate thanks to government support, strong financial funding, increased capability, and a growing R&D and manufacturing talent pool.

Chinese bio and pharma companies' initial expansions into overseas markets are just the beginning. This trend will continue too, and China will become a key player in the global market in both drug innovation and drug supply.

Does the pharma landscape look the same across China?

Pharmaceutical companies are spread across all provinces in China, but its biotech and biopharma clusters are mainly concentrated in the Yangtze Delta Region, the Pearl River Delta Region, the Northern China region, and the mid-China region.

The Yangtze delta region includes well developed cities such as Shanghai, Suzhou, Nanjing, and Hangzhou. These cities host the largest number of biotech firms and research institutes. The northern region encompasses key cities such as Beijing and Tianjin, while the mid-China regions includes other key cities like Wuhan, Chengdu, and Chongqing

Lonza's Huangpu site lies in one of those concentrated regions – the Pearl River Delta that includes the Greater Bay Area of Guangzhou, Hong Kong, and Macao – a thriving megalopolis and economic heavy-hitter that is home to five percent of China's entire population.

At present, five major pharmaceutical industry city clusters have been formed in China - the Bohai Rim, the Yangtze River Delta, Chengdu-Chongqing, the Pearl River Delta and the central region.

The Bohai Rim region (Beijing, Tianjin, Shandong, Hebei) relies on the resources of top universities and R&D institutions in the region and is in a leading position in the field of new drug research and development.

The Yangtze River Delta region (Shanghai, Zhejiang, Jiangsu, Anhui) has the resource advantage, thanks to many multinational enterprises located there. The region has formed an industrial pattern driven by the innovation in Shanghai and manufacturing collaboration in its surrounding cities. Shanghai has intensive R&D centers for multinational biopharma enterprises and a good financing environment, gathering most of the world's top ten biopharma enterprises. Led by Shanghai and mainly composed of Jiangsu and Zhejiang provinces, the Yangtze River Delta industrial cluster is the region with the largest number of multinational pharmaceutical companies, the strongest R&D and transformation of enterprises, and the highest growth value and activity in China's biopharma industry.

"In the long term, China's people are growing wealthier. They hope to lead healthier, longer lives under better living conditions and the unmet medical needs here have created a solid demand for diverse drug products."

As the core hub of the Chinese government's "Belt and Road" strategy, the Chengdu–Chongqing region has a location advantage. Both cities' governments have successively issued implementation opinions to promote the development of the local biopharma industry and build an international pharmaceutical supply chain hub, serving as the first choice for international medical and health services.

Relying on the industrial advantages of information technology, the Pearl River Delta region has taken the lead in promoting the combination of the biomedical industry and a new generation of information technology, focusing on the layout of high-end medical treatment, high-performance medical devices, gene sequencing, bioinformatics analysis, cell therapy, and other subdivisions. As the leading cities in the regional biomedical industry, Guangzhou and Shenzhen have a solid industrial foundation and a complete industrial chain, driving the rapid upgrading of the biomedical industry in the Greater Bay Area.

The central region (Wuhan, Changsha) relies on the favorable planning of the Yangtze River Economic Belt and focuses on building a major, full-service health industry cluster.

Who makes up the workforce?

International companies have been able to operate in China since the Beijing government launched the first "Reform and Opening" policies in 1978. These policies gradually shifted the country from a centralized command economy to a mixed-market model, and have contributed significantly to China's economic development. Foreign pharmaceutical companies in China typically employ a diverse workforce with a range of backgrounds, including local professionals and skilled workers, returning Chinese students and experienced professionals, and Visa-holding citizens from many other countries. I like to think Lonza is a good example of such a company, and by providing a comprehensive training program and career development track, our turnover is lower than the Chinese market average.

What role, if any, does the state play?

The state, as in many other countries, regulates the pharmaceutical industry. In recent years, those regulations have been improved to allow for drug innovation and more rapid access by patients, and also to fall more closely in line with regulations in the US and Europe. In June 2017, China joined the International Council for Harmonisation, which allowed clinical data from China to be recognized overseas. This move enabled faster entry of high-quality global drugs and more collaboration in drug development and clinical trials between local and global biotech and pharmaceutical companies.

Also in recent years, the Chinese state and its local-level governments have identified biopharma as a national strategic industry. They now provide vital support to its infrastructure development including financing, R&D, manufacturing capability/capacity to upstream materials, consumables, and equipment.

What should our readers keep their eyes on?

Within the industry, I would keep an eye on high potential growth areas such as the development of new drug modalities, cell and gene therapy, CDMO large-scale manufacturing, and the relevant regulatory changes. At a broader level, it is important that the government's policies remain consistent and sustainable so as to ensure continued industry growth; after all, that is key to investment enthusiasm, drug innovation, and the maintenance of an uninterrupted supply chain within the country and beyond its borders.

curia

APPLICATION NOTE

Leveraging the PentaMice® platform for COVID-19 antibody discovery

Learn how Curia maximizes the discovery of high-quality leads

Hybridoma technology is a popular method for antibody discovery, but the conventional approach of using a single inbred mouse strain for immunization fails to generate the diversity and antibody titers needed to maximize the discovery of high-quality leads. Curia's new white paper introduces an alternative immunization approach – the PentaMice platform, a collection of five wildtype mouse strains bred in-house for increased MHC class II diversity – and highlights how Curia is leveraging it for COVID-19 antibody discovery.

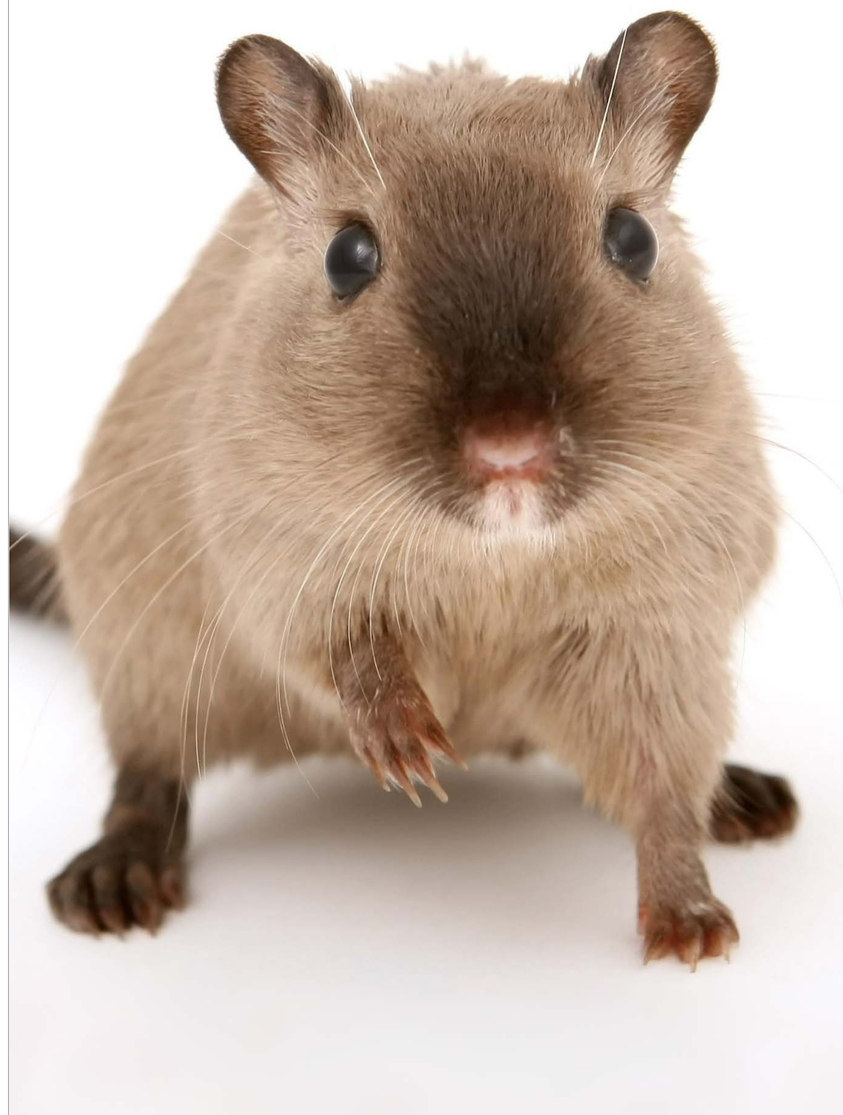
Most approved therapeutic antibodies on the market today were derived from hybridomas a technology that has remained largely unchanged since its invention by Köhler and Milstein 47 years ago. To create a hybridoma, animals are first immunized with a target antigen, after which their B cells are isolated and fused to immortal myelomas. Hybridoma clones are then screened and selected for target reactivity. After a target-specific clone has been identified, the originating hybridoma serves as an endless source for further production of the clonal antibody.

With hybridoma technology, antibody diversity and plasma titers, which are predictive of antibody discovery success, are generated by the B cells of immunized animals. These B cells use major histocompatibility complex (MHC) class II molecules to present the target antigen peptides to T cells, activating them and causing them to express costimulatory molecules and secrete cytokines. These signals converge to stimulate clonal B cell amplification and high affinity antibody production. Maximizing this response requires CD4 T cell help, which is driven by T cell receptor recognition of peptides presented by MHC II.

MHC II molecules are highly polymorphic, which means there is substantial within-species variation among MHC class II genes, and highly polygenic, which means that each allele in the MHC class II locus can harbor several different versions of the gene. These characteristics of the MHC class II locus likely contribute to differences in plasma titers observed between different strains of mice, as different MHC class II alleles (called haplotypes) confer different peptide-binding profiles. For example, one peptide may be effectively presented by most MHC II molecules, whereas another may be effectively presented by only one.

Conventional immunization strategies generate limited antibody diversity and titers because they typically use a single inbred mouse strain (e.g., C57Bl/6) of a single homozygous MHC II haplotype. To vastly improve antibody diversity and titers in hybridoma-based antibody discovery, Curia developed the PentaMice platform, a set of five wildtype mouse strains representing nine MHC II haplotypes. Curia's new white paper highlights the PentaMice platform and its application to the discovery of COVID-19 therapeutics including neutralizing antibodies.

LEARN MORE BY DOWNLOADING THE WHITE PAPER



APPLICATION NOTE

Multi-Column Capture Chromatography

Supports continuous and intensified manufacturing to reduce costs, increase productivity, and accelerate time to market

Continuous processing and single-use technologies offer important advantages for the manufacture of biopharmaceuticals, including increased productivity, reduced capital expense, easier tech transfers and scale-up, and higher product quality. By eliminating potential carry over between product processes, single-use technologies also increase process and facility flexibility while reducing bioburden risk.

An essential part of a continuous production workflow is a continuous downstream process. This application note describes the development and optimization of continuous multi-column capture chromatography, which was subsequently integrated into a continuous downstream monoclonal antibody purification process. The project was part of the European Union's Horizon 2020 initiative, which includes a workstream focused on creating a next generation downstream process that incorporates single-use technologies.

Results of the study showed that for primary capture chromatography, protein A resin in columns loaded in series was better utilized than in batch mode. These columns can be cycled up to the complete lifetime of the resin, leading to smaller required resin volumes via higher dynamic binding capacities. This reduces costs while increasing the performance and robustness of capture chromatography purification.

Once the continuous capture process was developed, the approach was evaluated using continuous whey protein capture over 24 hours at manufacturing scale using automated column switching. This proof-of-concept study demonstrated successful and effective continuous processing throughout the duration of the study. Continuous capture chromatography was then integrated into a continuous monoclonal (mAb) process to demonstrate whether the approach could reduce costs, increase productivity, and reduce environmental impacts. Four validation runs at a bioreactor scale of 1000 L were performed.

Clarified harvest was continuously loaded onto the Protein A resin utilizing the multi-column capture system over 2.5 days; elution peaks were continuously sent to viral inactivation. Continuous operations were performed using interconnected systems to trigger process actions and feedback alarms in the event of a deviation. Post-capture column UV sensors triggered the switch between loading columns based on breakthrough detection and the switch between waste and fraction during elution peak detection. A valve was installed on the inlet of the virus inactivation skid to divert fractions based on tank levels. Alarms for tank overloading could be sent to hold the multi-column capture system.

These validation runs demonstrated the ability to consistently process kilogram quantities of mAb on the multi-column capture system. By using the multi-column capture system, the Protein A volume could be reduced by up to 43 times compared to batch mode with a single cycle. The productivity was increased from 30 g mAb/L/resin/h for batch mode to 40 g mAb/L/resin/h for 46 cycles with the multi-column capture system. With the Mobius® Multi Column Capture system, it is possible to purify up to 3000 L of mAb at 4 g/L in 24 hours.

READ THE FULL STUDY

Key Potential Benefits

Productivity
- Capable of processing up to 3000 L harvest in 24 hours (12 kg mAb)

Footprint
- Complete DSP in 30 m² (10-15x smaller)
- Elimination of large intermediate hold tanks
- Flexibility (mobile equipment)

High Safety Assurance Level
- Reduce bioburden risk
- No carry-over issues
- No cleaning, regeneration, steaming
- Rapid change-over

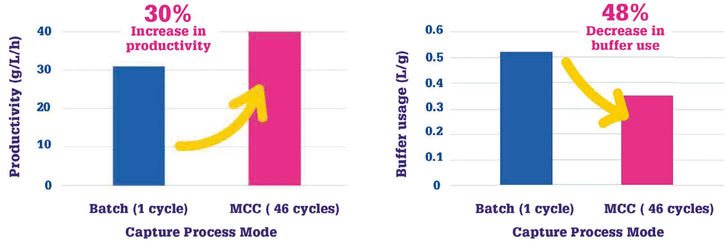
Economics
- Facility investment: ↘ 35%
- Running costs: ↘ 30%
- Cost of materials: ↘ 50%

Environmental
- CO_2 emissions: ↘ 25%
- Reduced water, buffer, resins consumption (water ↘ 10x)

MCC Productivity Benefits

We have been able to decrease the requirement of protein A volume by 43 times, an increase of productivity from 30 to 40 g/L/h compared to traditional single-column batch process.

Simulation analysis for different capture process modes
(Target -1000 L with 3.2 kg mAb)



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SPOTLIGHT ON...

Technology

The benefits of end-to-end formulation and fill-finish

By 2026, the global market for biologics is projected to increase to $537 billion. However, getting a promising drug candidate from formulation development to clinical phase production and commercial manufacturing can be daunting. Proper formulation development has a huge impact on whether technology transfer to clinical phase fill-finish is successful.

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SPONSORED FEATURE

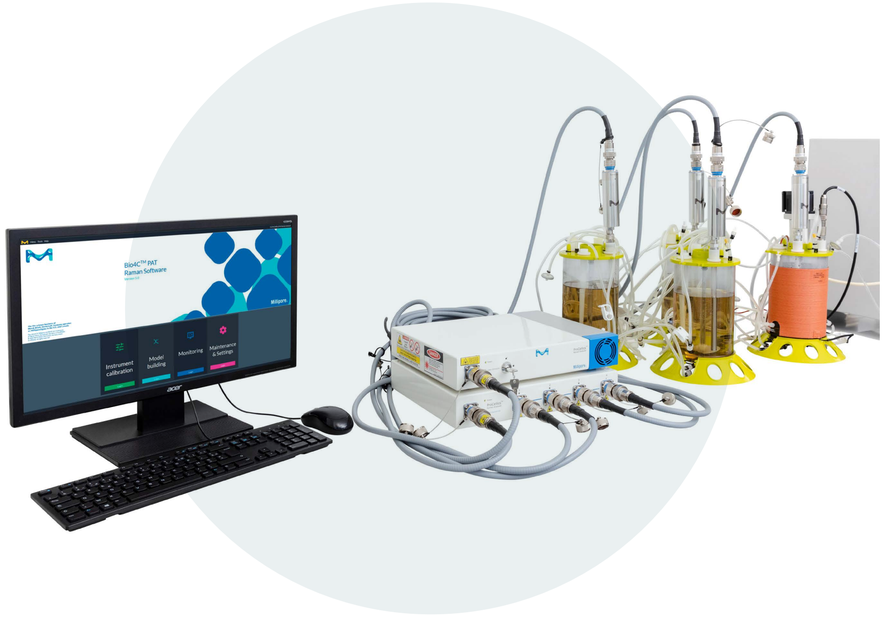
SPOTLIGHT ON...

Technology

Bio4C ProcessPad™ Software

Bio4C ProcessPad™ is a data visualization, analytics, and process monitoring platform that enables bioprocess lifecycle management, reporting, investigations, and continued process verification. Intelligently combining process data from batches, ERPs, MES, LIMS, historians, process equipment, and manual sources into a single, validated data source. Bio4C ProcessPad™ ensures data is current, complete, and contextual throughout the product lifecycle.

FIND OUT MORE



ProCellics™ Raman Analyzer with Bio4C® Raman Software

From process development to manufacturing, ProCellics™ Raman Analyzer with Bio4C® PAT Raman Software enables in-line and real-time measurement of mammalian cell culture CPPs and CQAs thereby helping to improve processes, save time, reduce the risk of contamination and batch failures, and even implement a nutrient control loop strategy – a first step towards automation.

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Bio4C Orchestrator™ Process Data Layer Software

Bio4C Orchestrator™ software is a process data layer and application control platform that connects to individual unit operations for complete visibility, monitoring, and oversight of biomanufacturing systems and processes. The software automatically acquires bioprocessing data from each skid, aggregates it, and makes it data-analysis ready.

ASK US A QUESTION