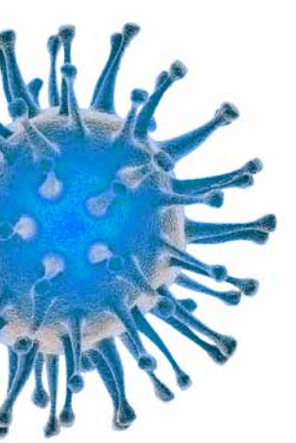
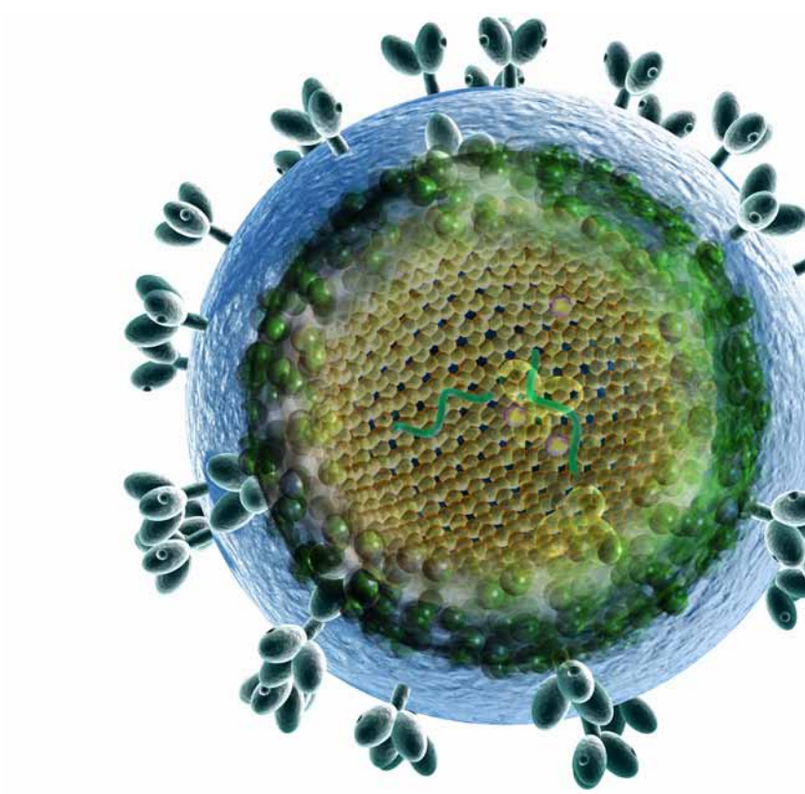
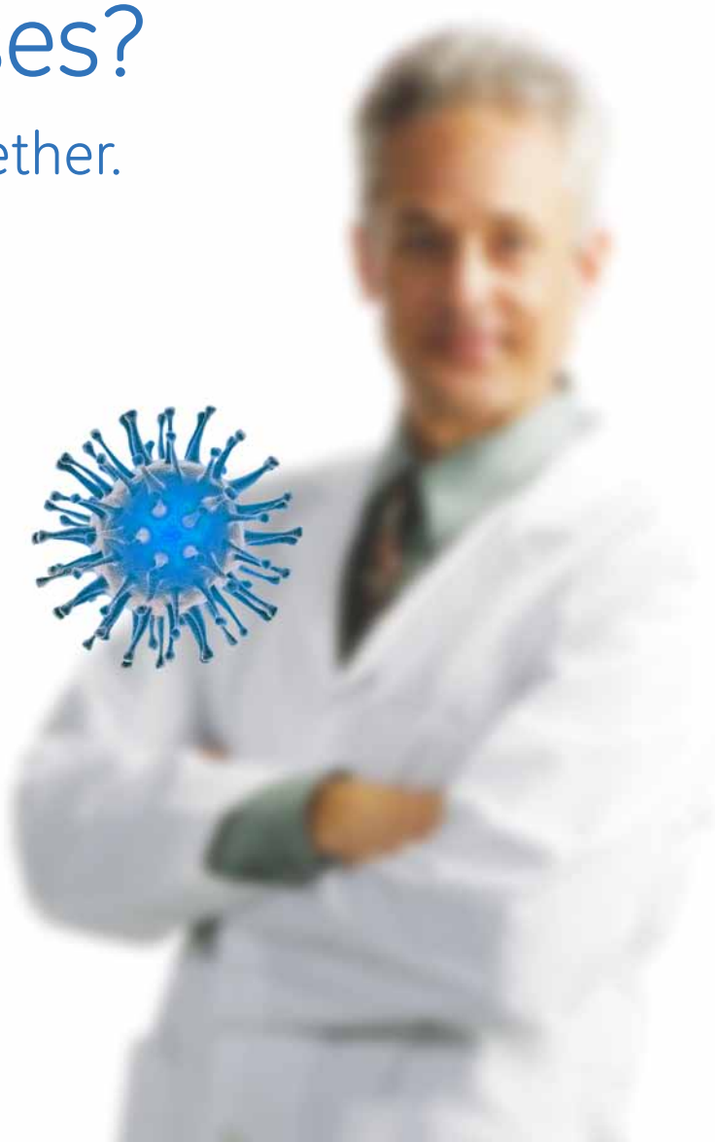
GE Healthcare
Life Sciences

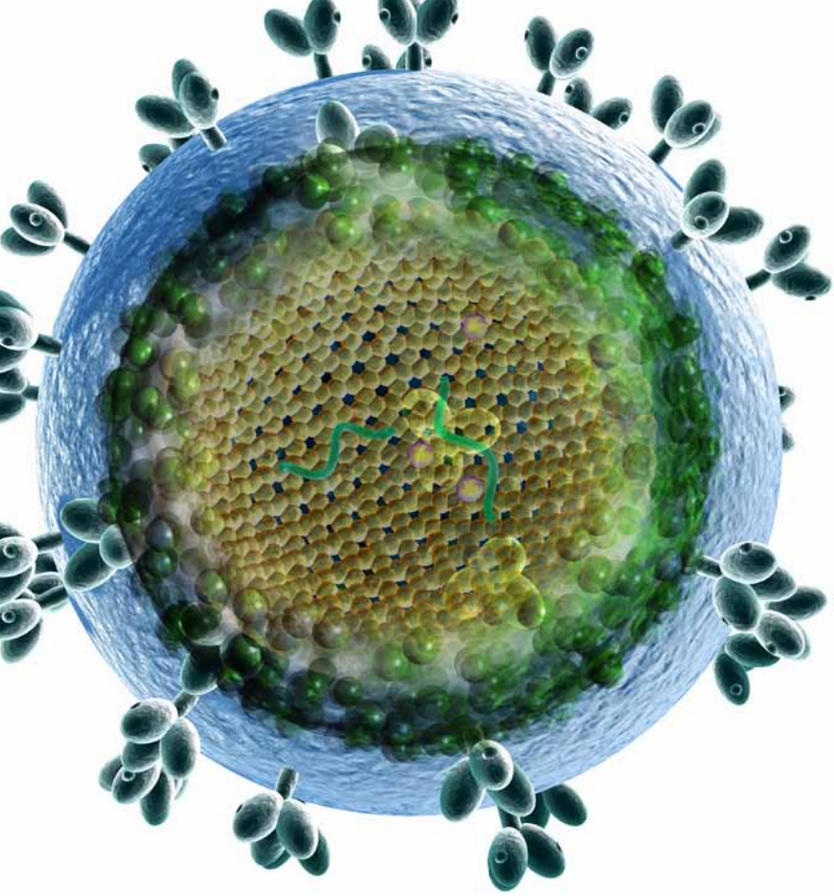


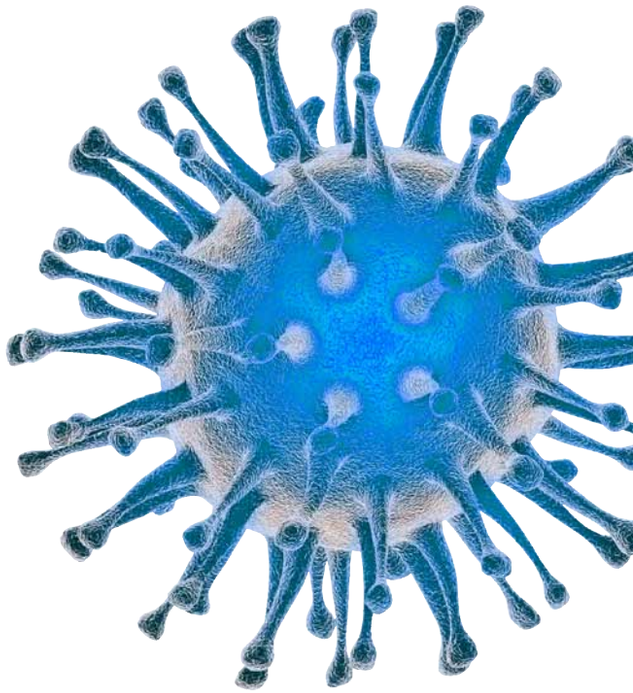


# Working with complex biomolecules in vaccine processes?

## Let’s meet the challenges together.



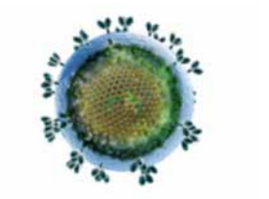




## Today's vaccine challenges:

# Minimize the risks Maximize the rewards

Vaccine development and manufacture is one of the most challenging tasks within biopharmaceuticals today. R&D projects are characterized by technical complexity, and production processes by methods that can be both inflexible and costly. In addition, local vaccine manufacturers do not always meet international quality standards.



And when the products are finally ready for introduction, intended marketplaces are often diverse. Different national recommendations and funding may slow introduction, for example. In addition, public healthcare systems are always looking to lower the cost of treatment.

But vaccines can also be highly rewarding, and one route to success is to enlist the help of GE Healthcare. Our expertise, technology platforms, and products help drive vaccine development forward, optimizing manufacturing processes and maximizing the rewards.

**We understand complex biomolecules**
Our unrivaled knowledge and understanding of the tools you need to screen, purify, and assure quality of even the most complex biomolecule will stand you in good stead when tackling 'difficult' vaccine fields such as HIV and malaria. Collaborative projects also speed vaccine development. We have wide experience of R&D models and are ready to share our know-how with you.

**Increased flexibility plus lower production costs**
Inflexible production methods can put producers at a real disadvantage, especially when millions of doses of new vaccines are needed at short notice. We can help solve this dilemma with flexible, ready to use platform technologies with plug and play simplicity.

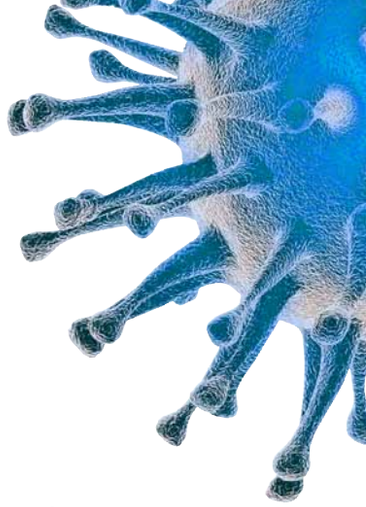
Our ReadyToProcess™ platform, for example, includes single-use bioreactors, ready to use chromatography units, and self-contained fluid management and filtration modules. As well as shortening time-lines, they help secure safety and quality standards wherever production is located.

**New commercial opportunities**
Our production technologies, well-supported by our bioprocessing and Fast Trak consulting services are both productive and economical. They open up exciting new commercial opportunities – disposable and/or portable vaccine factories set up when and where they are most needed.

**Increase development speed yet minimize economic risk**
GE Healthcare's vaccine manufacturing strategy solves the paradox of increasing development speed while at the same time minimizing economic risks. Our R&D tools and expertise help to fill your development pipeline with more potential vaccine products, and to select those candidates with the best chance of success. When it's time to manufacture, our production technologies offer a fast, flexible, and economical solution.

Vaccines remain the most successful medical intervention so far developed. Yet more are still needed – and quickly.

*Let's meet the challenges together.*



# Fast, high-productivity vaccine development with shorter time to clinic

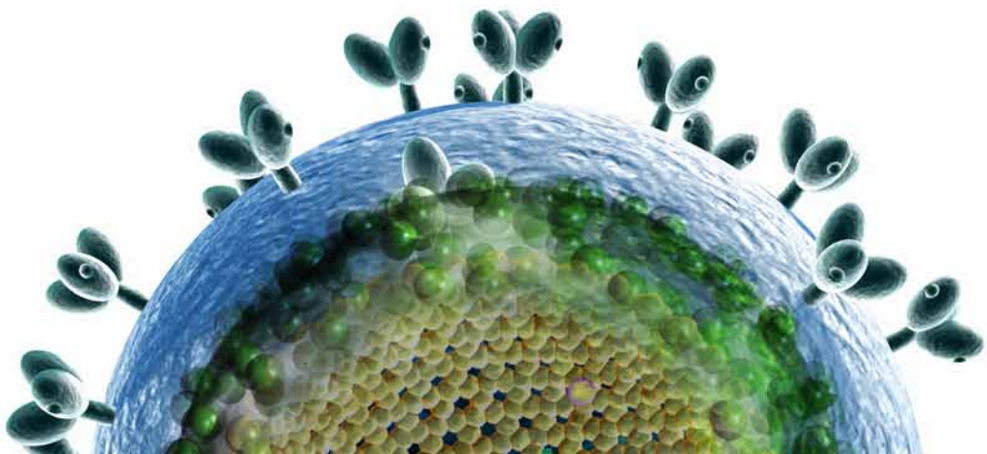
*Leading-edge techniques and fast analytics speed batch release*

As vaccine development becomes more complex, more leading-edge technology bases need to be leveraged to bring life-saving products to clinic and to market. The human papillomavirus (HPV) vaccines that prevent infections associated with the development of cervical cancer serve as examples.

Both HPV vaccines currently on the market are created by isolating a major protein of the viral capsid, assembling it into highly immunogenic structures and using these to trigger an antibody response that protects the recipients from becoming infected with the HPV types. As these structures (and thereby the vaccine) contain no viral DNA, they cannot cause an infection.

Similarly, the viral vectors used in gene therapy or vaccine development also utilize modern biotechnology techniques. In these fields, adeno-associated virus vectors and adenoviruses are making strong headway, offering the promise of a safe means of combating genetic disorders and a variety of pathogens, respectively.

Whatever technology base you choose, GE Healthcare's expert know-how and support will help you make the best use of it.



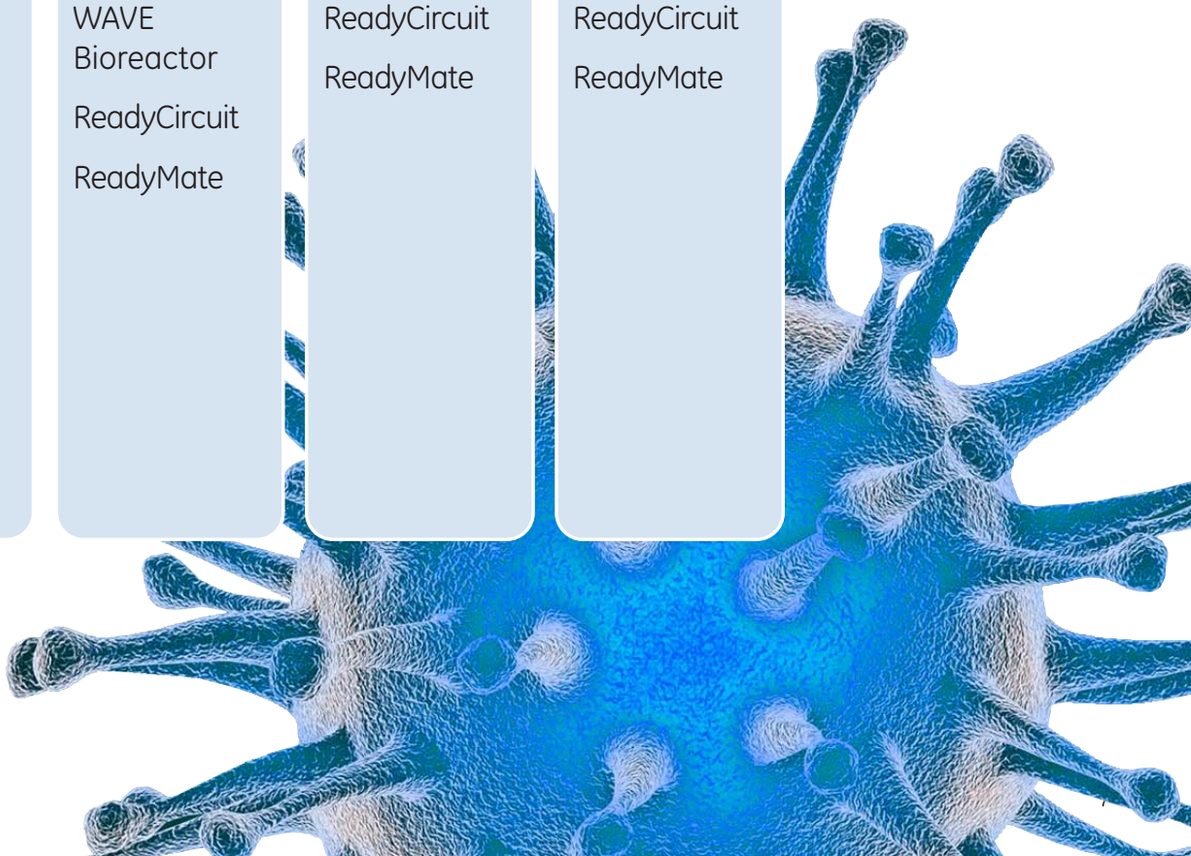

FLOW

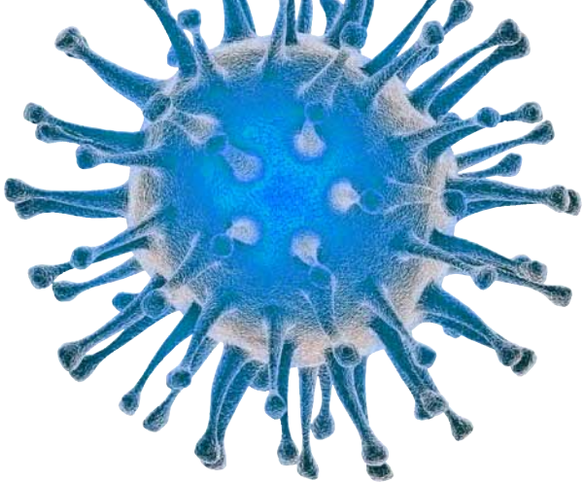
# Overview of GE Healthcare's product and technology offering for process development and production of vaccines.

| | | | | | |
|---|---|---|---|---|---|
| **Production system** | Bacteria | Bacteria | Bacteria | Bacteria | Eggs,<br>Cell culture |
| **Class** | Bacterial | Poly-saccharide | pDNA | Toxin | Viral |
| **Technologies and regular products** | Filtration | Filtration | Filtration<br>Chroma-tography | Filtration<br>Chroma-tography<br>Analytics | Micro-carriers<br>Filtration<br>Chroma-tography<br>Analytics |
| **ReadyTo Process products** | WAVE Bioreactor™<br>Filters<br>ReadyCircuit*<br>ReadyMate™ | WAVE Bioreactor<br>Filters<br>ReadyCircuit<br>ReadyMate | WAVE Bioreactor<br>Filters<br>ReadyCircuit<br>ReadyMate<br>ÄKTA™ ready<br>ReadyTo Process columns | WAVE Bioreactor<br>Filters<br>ReadyCircuit<br>ReadyMate<br>ÄKTA ready<br>ReadyTo Process columns | WAVE Bioreactor<br>Filters<br>ReadyCircuit<br>ReadyMate<br>ÄKTA ready<br>ReadyTo Process columns |

* ReadyCircuit is a trademark of GE Healthcare.

| | | Workflow 2 | Workflow 1 | Workflow 1 |
|---|---|---|---|---|
| *E. coli*, Yeast, Mammalian | Yeast, Insect cells | Cell isolation | Synthesis | Synthesis |
| Recombinant protein | Virus-like particles | Cells | Oligo-nucleotides, siRNA | Peptides |
| Micro-carriers<br>Filtration<br>Chroma-tography<br>Analytics | Filtration<br>Chroma-tography<br>Analytics | Density gradient separation media | Synthesis<br>Chroma-tography | Synthesis<br>Chroma-tography<br>Analytics |
| WAVE Bioreactor<br>Filters<br>ReadyCircuit<br>ReadyMate<br>ÄKTA ready<br>ReadyTo Process columns | WAVE Bioreactor<br>Filters<br>ReadyCircuit<br>ReadyMate<br>ÄKTA ready<br>ReadyTo Process columns | WAVE Bioreactor<br>ReadyCircuit<br>ReadyMate | ReadyCircuit<br>ReadyMate | ReadyCircuit<br>ReadyMate |

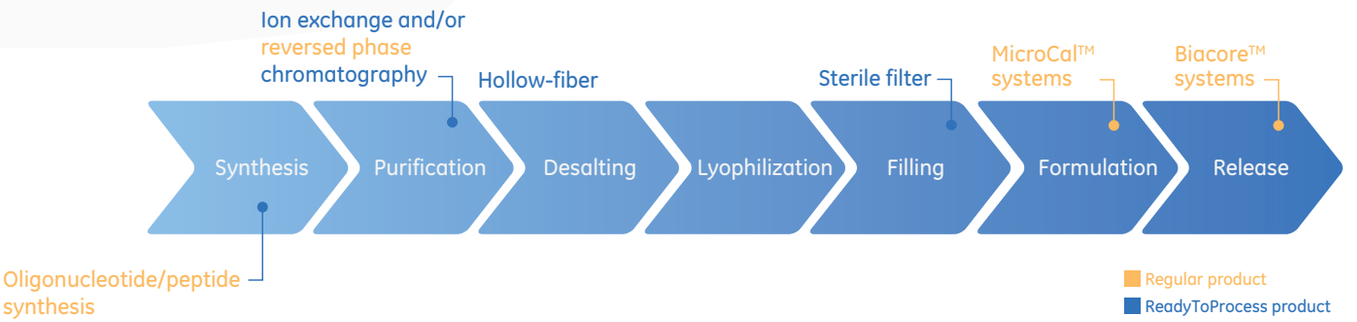




# Application-based processing platforms reduce both production costs and time to market

*Fast and effective vaccine workflows with analysis and support services*

A rapid increase in vaccine manufacturing capacity is expected due to the development of therapeutic vaccines for new applications such as cancer prevention. Revised recommendations for seasonal flu prevention and the ever-present concern of a pandemic are also major drivers. Whatever the reason, fast method development and sure scale-up to optimized cGMP-compliant manufacturing processes are required.




Workflow 1: Synthesis

GE Healthcare's bioprocessing platform comprises a wide range of vaccine workflow options from cell culture and filtration to chromatographic purification and rapid, highly accurate analysis. Modern equipment includes AxiChrom™ columns and ÄKTAprocess™ systems, chromatography media for high-volume vaccine production, such as the Capto™ platform and custom-designed media, and the ReadyToProcess single-use platform. We also have tools and solutions for peptide and oligonucleotide synthesis, as well as for analysis.

Scalability and end-to-end service provisions help reduce production costs. Sudden increases in production capacity can be achieved without excessive capital expenditure through our ReadyToProcess platform.

Access to our accumulated know-how is also available through Process Development Support courses and consulting from Fast Trak BioPharma Services. Examples include Virus Vaccine Process Design, a two-week feasibility study at a GE Healthcare Fast Trak center followed by two weeks process design at the vaccine producer.

# Influenza virus vaccine

*Flexible production strategy reduces costs and time to market*

Most people recover from an influenza attack without medical treatment, but for the very young, the elderly, and people suffering from certain medical conditions, influenza poses a serious risk. Annual vaccination is the principal measure for preventing the infection and reducing the impact of epidemics.

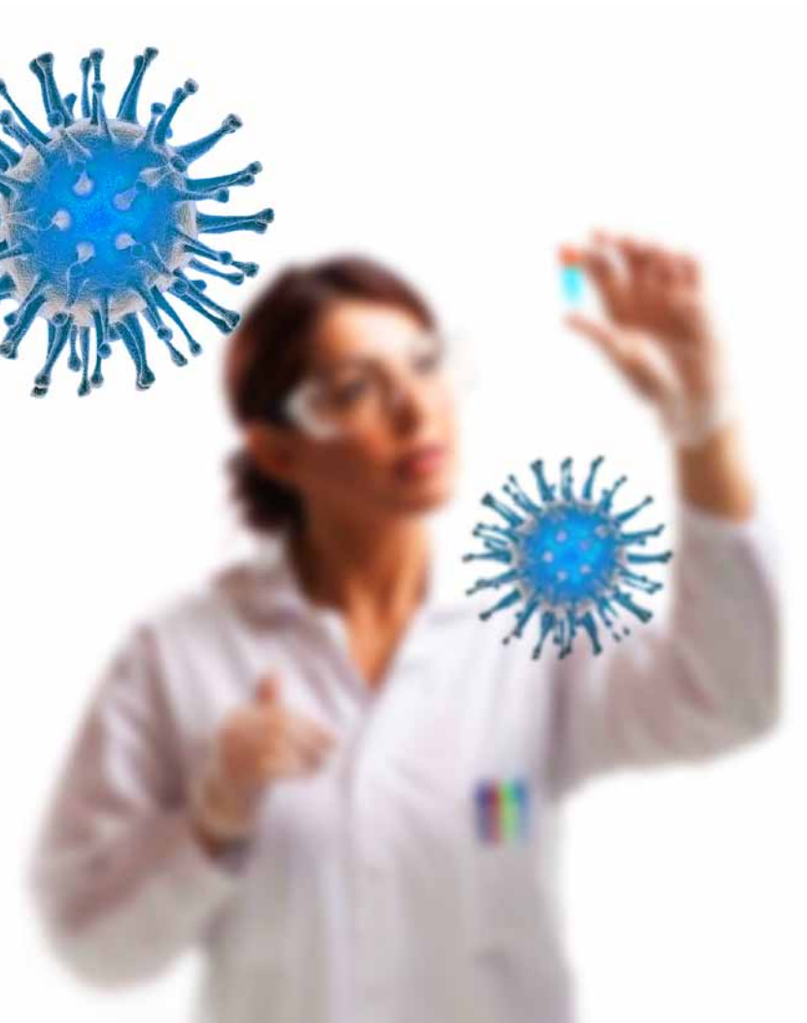
The majority of influenza vaccine is still produced in embryonated chicken eggs, but there are risks associated with the open handling of up to 100 000 eggs. Closed handling via mammalian cell culture, filtration, and chromatography systems better meets the higher safety demands now being required by the FDA and EMA. Closed handling is also much faster and more economical.

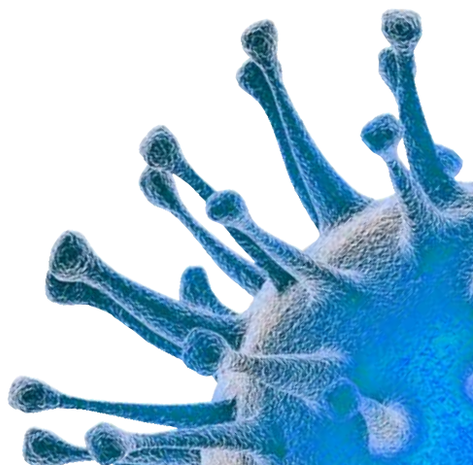
Authorities favor vaccine production in cell cultures. Recently, the US Department of Health and Human Services awarded $220 million to a leading drug manufacturer for product development and facility design to mass-produce an influenza vaccine that would help the nation respond quickly to a pandemic. Cell culture, as opposed to chicken eggs, was seen as one way to secure a rapid response. Simply ordering and delivering the vast quantities of eggs needed for conventional vaccine manufacture would delay production by several months.

Cell culture in combination with filtration and chromatography, should also be the method of choice in efforts to produce a vaccine against the deadly H5N1 bird flu virus. The H5N1 virus is endemic in poultry in parts of Asia, and experts fear that it could mutate into a human strain.

**Generic production strategy based on ReadyToProcess**
Like all viruses, human influenza virus particles are much larger than proteins and peptides. This feature can be used to advantage to separate viruses from the fermentation broth and then purify them.

A generic cell culture-filtration-chromatography production approach that features ReadyToProcess single-use components is outlined opposite. Note also that biosensor-based Biacore™ systems play a key analytical role in vaccine development and production, for example, hemagglutinin [HA] quantitation.





## Influenza process

Cell culture

MDCK cells grown Cytodex™ microcarriers

Clarification

ULTA™ Prime GF

Ultrafiltration/
Diafiltration

Cross-flow filtration

Nonbinding
anion exchange
chromatography

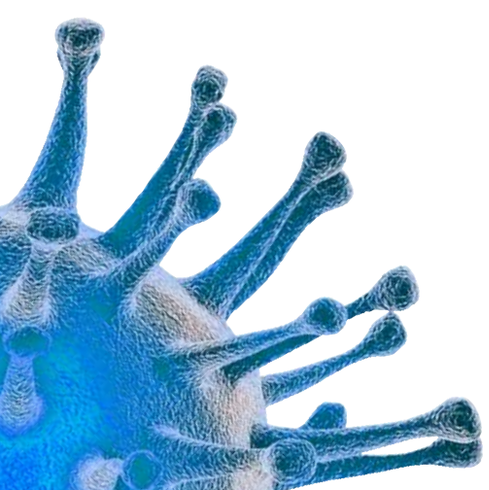
Capto ViralQ

Ultrafiltration/
Diafiltration

Cross-flow filtration

Sterile filtration

ULTA Pure SG

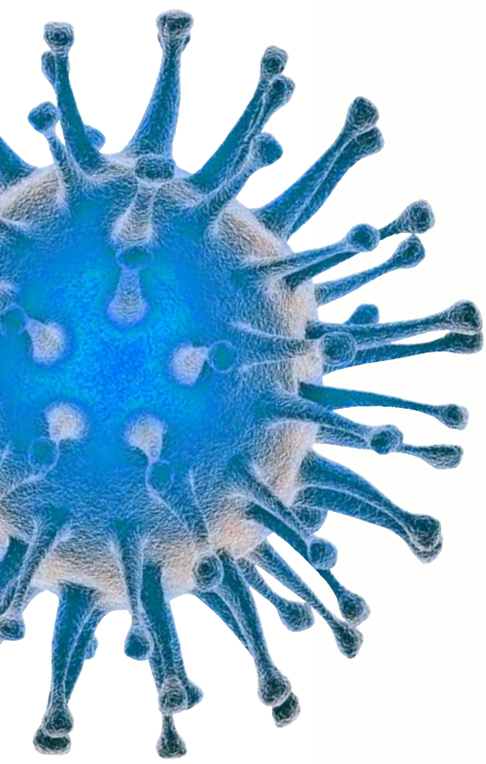


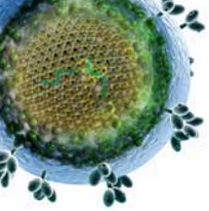
# Biacore systems speed-up analytical steps in vaccine manufacture

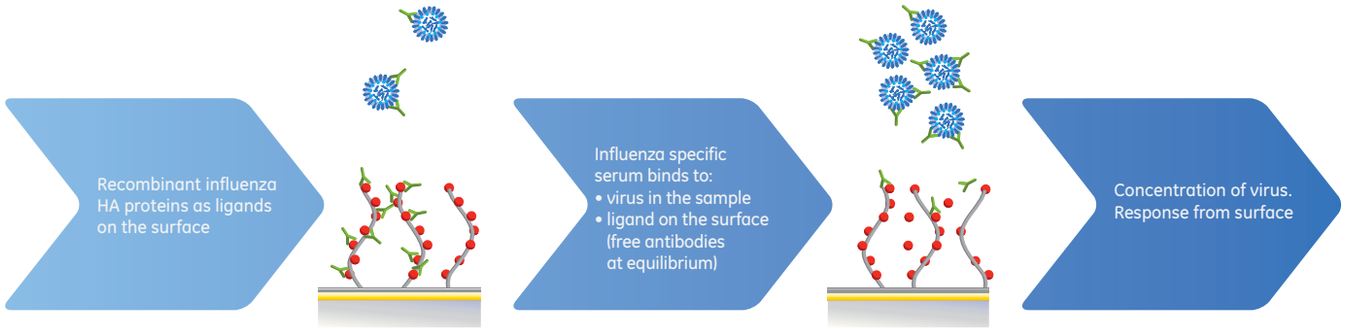
*Authorities and producers aware of the need to improve analytical methods*

Shorter development cycles have had a major impact on the speed with which vaccine products enter manufacture, but many of the analytical tools that are essential for process development and final release have not kept pace.

In vaccine production, quantitating virus HA concentration and host cell protein (HCP) impurities is critical for the vaccine process and final batch release. Yet one of the most common HA quantitation methods used is based on a vaccine dispersion diffusing through an antibody-containing gel. This is slow, labor-intensive, and prone to variance. In contrast, modern biosensor assays, offer faster and more precise methods.








**Biosensor-analysis reduces hand-on time, increases sensitivity, and improves precision**

The slow and uncertain HA assay method, known as single radial immunodiffusion (SRID), is typical of the analytical challenges faced by vaccine manufacturers during development and production. Today, hundreds of tests are often performed that take from a few minutes to hours or even days to complete. And when the results do arrive, the precision is often low.

Surface Plasmon Resonance (SPR) biosensors monitor molecular interaction on the surface of a chip, in real-time, and without the need for labels.

The SPR biosensor technology used in GE Healthcare's Biacore systems determines concentrations with higher sensitivity, with less hands-on time, and with higher precision than SRID and other commonly used methods such as ELISA.

**Quantitative and qualitative determination of vaccine recovery, yield, and purity**

Biacore T200 is a highly automated system operating with 96- or 384-well microplates, offering outstanding sensitivity, accuracy, and reproducibility in label-free interaction analysis. The system provides vaccine developers and producers with vital data that can help formulate a safe and effective final product. In the following examples, a Biacore label-free interaction analysis system and Sensor Chip CM5 were used for all analyses.

**Quantitation of influenza virus**

One example of how Biacore assays speed up and improve vaccine-manufacturing processes is the quantitation of influenza virus and HCP, which is a critical step in formulating the final vaccine preparation.

In the influenza assay setup, the antiserum and the virus sample are mixed prior to analysis. Free antibodies at equilibrium bind to the surface ligand (a recombinant HA protein specific for the three strains, A/H1N1, A/H3N2, and B) and are detected by the SPR biosensor. The reference serum and antigen are the same as used in the SRID assay recommended by the European Pharmacopoeia and WHO but the Biacore assay offers several advantages.

The Biacore assay decreases hands-on time from 6 to 8 h to 1 to 2 h, gives a higher sensitivity with a limit of quantitation (LOQ) of 1 µg/ml compared with the SRID 10 µg/ml, has lower variation (CV 1 to 5%) than SRID, and is much more precise.

The practical advantages of the Biacore method are realized in batch release tests for trivalent vaccines. As the seasonal influenza vaccine consists of three viral strains (A/H1N1, A/H3N2, and B), batch release with SRID requires lengthy analysis on three different immunodiffusion gels. In contrast, the Biacore assay quickly determines trivalent samples in a single experiment, which allows earlier batch release.

**High-sensitivity HCP assay**

Similarly, samples from the various steps of a vaccine purification process were quantitated with both a traditional Bradford protein assay, which detects total protein content, and a Biacore biosensor HCP assay. The Biacore assay showed over 100-fold higher sensitivity than the Bradford (0.3 µg/ml compared with 60 µg/ml), allowing quantitation of a much wider range of samples in the purification process.

# Plasmid DNA vaccines

*Platform purification paves the way for clinical application*

The therapeutic potential of DNA vaccines is an exciting prospect. We know that plasmid DNA immunization offers many advantages over traditional forms of vaccination. However, verifying that it evokes a response sufficiently strong enough to protect against disease requires a number of clinical trials, and sufficient quantities of material with which to conduct them.

If vaccination with plasmid DNA is to be used commercially in both human and veterinary applications, the industrial-scale purification method employed must be flexible, easily scalable, robust, and economical.

**Many purification challenges**

For vaccine applications, plasmid DNA should be in a supercoiled form and essentially free from bacterial chromosomal DNA, RNA, proteins, and endotoxins. As the most common host for plasmid DNA production is *E. coli*, removing other nucleic acids (including a highly complex mixture of RNA varieties), endotoxins, and trace contaminants represents a real purification challenge.

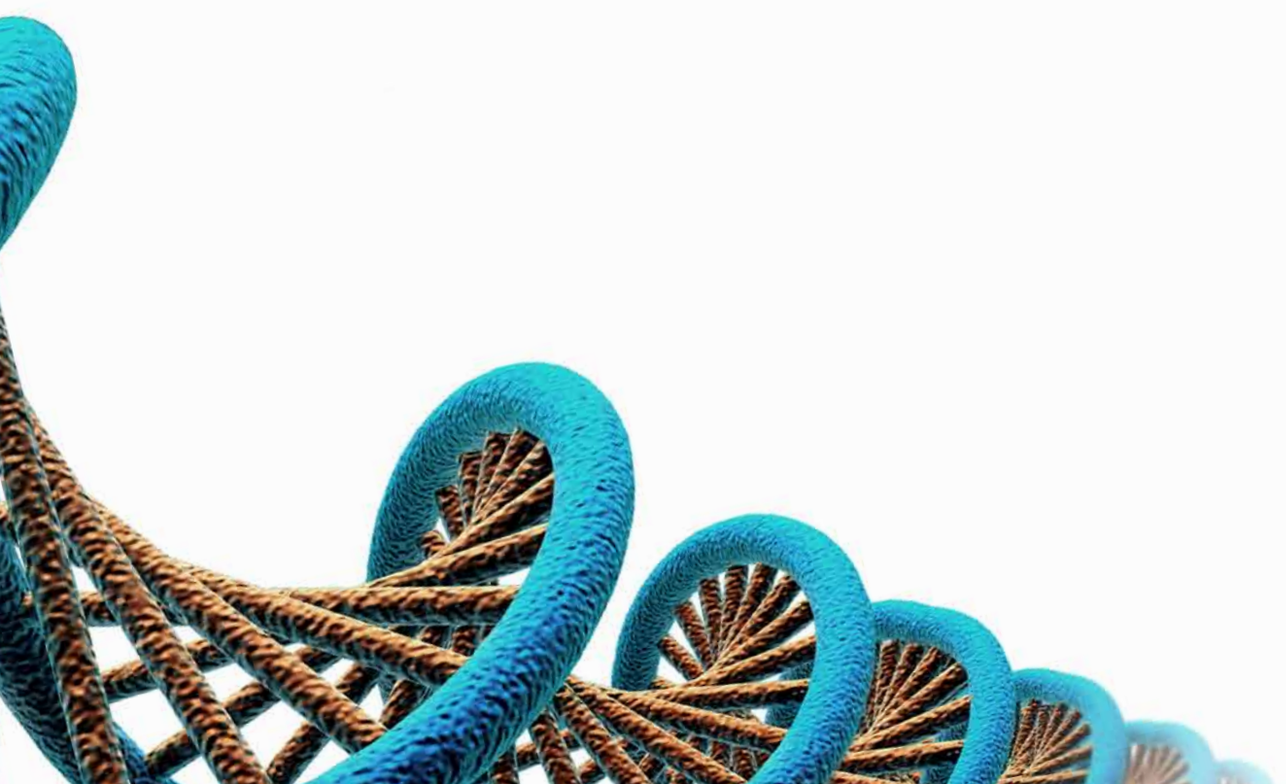
**Platform process built around PlasmidSelect Xtra**

The need for effective purification plus smooth, trouble-free scale-up is met by the workflow built around the PlasmidSelect Xtra process, shown opposite. This is a true plasmid DNA platform comprising simple, yet highly efficient concentration and purification steps based on filtration and chromatography.

Starting material, an *E. coli* cell lysate containing a high-copy number plasmid, is harvested prior to alkaline lysis, clarified, and concentrated on a hollow-fiber ultrafiltration cartridge.

Chromatography using Sepharose™ 6 Fast Flow performs RNA removal and buffer exchange before capture of the plasmid DNA on PlasmidSelect Xtra, yielding a high-quality supercoiled, covalently closed circular product. Polishing on SOURCE™ 30Q then removes endotoxins and trace contaminants prior to formulation and final hollow-fiber ultrafiltration.

Systems from the ÄKTA range such as ÄKTAcrossflow™, ÄKTApilot™, and ÄKTAprocess, ensure smooth scale-up plus highly convenient operation. Electrophoresis purity data for a pilot-scale run confirm that the PlasmidSelect Xtra process achieves high purities and yields, and meets regulatory requirements for cGMP production of plasmids for vaccine use.



## PlasmidSelect Xtra process

Alkaline lysis

Clarification — Dead-end filtration: ULTA GF

Ultrafiltration — Sample concentration: Hollow-fiber

Group separation — RNA removal: Sepharose 6 Fast Flow

PlasmidSelect Xtra — Supercoiled pDNA capture: PlasmidSelect Xtra

Ion exchange — Supercoiled pDNA polishing: SOURCE 30Q

Ultrafiltration/ Diafiltration — Formulation: Hollow-fiber

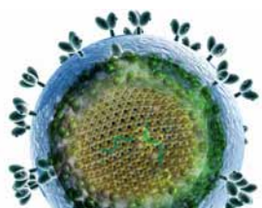
Sterile filtration — Filtration: ULTA SG

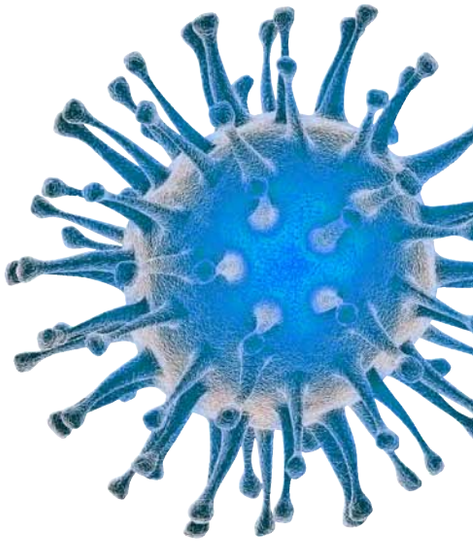
# Efficient cell-based production strategies save on capital expenditure

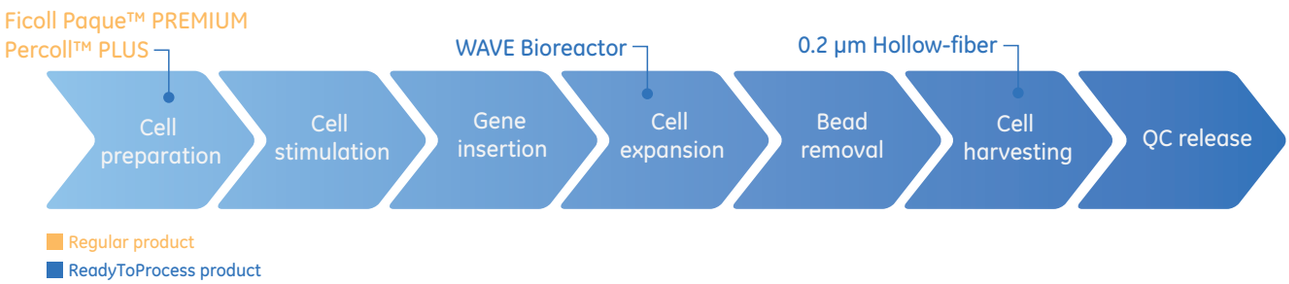
*Cost-effective, time-saving, and easily expandable upstream processing*

No one doubts that the vaccine manufacturing industry needs a better upstream alternative to the labor-intensive and time-consuming egg-based production methods that are the traditional base of influenza vaccine production. Egg-based technology is simply not fast enough to react to a pandemic.

Viruses (influenza and others) can instead be propagated in cultured cell lines. Vero cells grown on Cytodex™ 3 microcarriers have been used to manufacture licensed human vaccines for polio and rabies for over twenty years.








Workflow 2: Cell isolation

Cell-based technology using Cytodex to inoculate industrial bioreactors offers an easily manageable environment plus optimal, high-density growth. Most importantly, cell-based vaccine manufacture is easy to scale up and expand. Stockpiling batches of frozen cells is straightforward and capacity can be increased simply by adding multiple bioreactors.

Cell culture on Cytodex promotes the rapid, high-yield industrial production of inter-pandemic virus and the ability to respond to emerging variant pandemic virus strains within a short time frame. Furthermore, WAVE Bioreactor system, with its presterile, disposable Cellbag™ bioreactor, offers rapid inoculation and safe propagation.

### Cytodex microcarriers

Microcarriers make large-scale cell culture for viral vaccine production practical and economical. Cytodex 1 and Cytodex 3 are especially useful as all cells in the culture can be infected simultaneously.

Cytodex 1, formed by substituting a cross-linked dextran matrix with positively charged DEAE groups, is a general purpose microcarrier suitable for most established, anchorage-dependent cell lines.

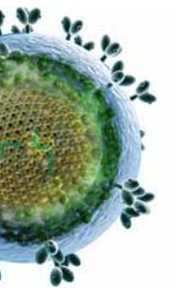
Cytodex 3, formed by chemically coupling a thin layer of denatured pig skin collagen type I to the cross-linked dextran matrix, is specifically designed for cells difficult to cultivate *in vitro*, particularly cells with an epithelial-type morphology.

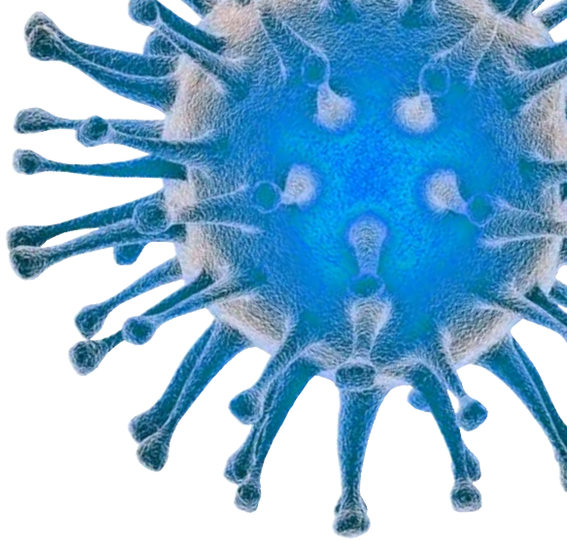
### WAVE Bioreactor

WAVE Bioreactor is a closed-system for cell culture that is suitable for virus production. Culture medium and cells contact only a presterilized, disposable bioreactor (Cellbag) placed on a special rocking platform, which induces waves in the culture fluid. These waves promote mixing and oxygen transfer, resulting in an optimal environment for cell growth. In a gene therapy application, for example, human 293 cells were grown in suspension and then infected with recombinant adenovirus. Cells grew to $4 \times 10^6$ cells/ml and virus production was $1 \times 10^5$ virus particles/cell.

A range of bioreactor sizes is available. Extensive application work on the WAVE Bioreactor 2/10 and 20/50 systems has established SOPs for the culture of MDCK and Vero cells. Work on both Cytodex 1 and Cytodex 3 has also demonstrated that various strains of influenza can be produced in these two cell lines.

The large-scale WAVE Bioreactor 500/1000 system has also been used to grow anchorage-dependent cells on Cytodex 3 for the production of a recombinant protein.





# High productivity and throughput reduce downstream processing costs

*Robust purification strategies keep cost of goods low*

In contrast to early vaccines, which largely comprised inactivated or weakened bacteria and viruses, today's equivalents are increasingly complex structures with specific targeted efficacy. Consequently, the purification strategies for these more complex molecules must be equally advanced. Once again, quick, efficient, and robust processing is essential to meet the challenge of delivering large batches of safe and cost-effective vaccine in the shortest possible time. Well-established filtration and chromatographic separations provide the answer.

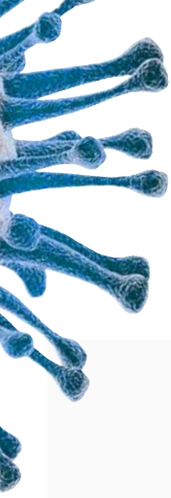
As the majority of the approved vaccines are based on bacteria, viruses, or polysaccharides/conjugated polysaccharides, size-based separations play a prominent role in processing. Filter separations offer a number of key benefits, for example normal flow/depth filtration is generally the first membrane technique applied, used for clarification and/or bioburden reduction. This is usually followed by cross-flow filtration using hollow-fiber cartridges for concentrating and washing feed streams. Sterile filtration at the end of the process assures final vaccine safety. In addition, depth filters are often used between chromatography steps to protect columns.

**Filtration devices**

Hollow-fiber cross-flow cartridges for ultrafiltration and diafiltration play a key role in vaccine processing. They are typically used to increase titer and for buffer adjustments to achieve the final formulation. Recently, there has been an increasing use of cross-flow filtration with the adoption of clarification and partial purification processes. GE Healthcare's hollow-fiber cartridges are well suited to vaccine processes due to their ease of validation—they use the same materials of construction for both micro- and ultrafiltration ratings in scalable flow paths; to their open flow path—providing gentle flow to protect fragile viruses and molecules; to their suitability for aseptic processing—lab cartridges are autoclavable while process-scale offer Steaming-in-Place capability; to their favorable economics—low cost/$m^2$, long service lifetimes, and self-containment. Our hollow-fiber cartridges are an integral part of the ReadyToProcess portfolio and can be used as "stand-alone" components or integrated in the ReadyCircuit bag assemblies with up to 3.1 $m^2$ of filtration area.

The ULTA range of normal flow filters includes ULTA Pure SG, ULTA Pure HC and ULTA Prime cartridges. They offer proven performance and high-processing efficiency from early-phase vaccine development through to full-scale manufacture.

Filtration systems include ÄKTAcrossflow and UniFlux™.




**Chromatography**

Chromatography offers several techniques for highly efficient purification of viruses. Size-exclusion chromatography using Sepharose and Sephacryl™ gel filtration media for group separation has long been widely used in vaccine processing. Today other chromatographic techniques such as affinity and ion exchange play an increasing role. GE Healthcare offers a number of media for vaccine purification, several based on the high-flow agarose base matrix.

The Capto media platform is based on highly-rigid agarose with improved pressure flow properties that increases speed and throughput. The media combine high capacity with high flow velocity and low back-pressure to reduce process cycle times and increase productivity.

Capto Q is a strong anion exchanger and can be used for nonviral binding in vaccine processes. Capto ViralQ is identical to Capto Q but is intended for viral binding and is thus sold with a license for virus purification.

Capto DeVirs, with a dextran-sulphate ligand, shows affinity-like behaviour, which makes it suitable for capture and purification of many viruses, but in particular for influenza virus.

AVB Sepharose High Performance is suitable for affinity purification of adeno-associated viruses. These viruses are of increasing interest as potential vectors for gene therapy where robust, processing with high yields, high purity, and low leakage of ligand is required.

Plasmidselect Xtra is a thiophilic aromatic adsorption chromatography medium, based on agarose, with a multimodal ligand. It has a selectivity that allows supercoiled covalently closed circular forms of plasmid DNA to be separated from open circular forms for gene therapy and DNA vaccination applications. PlasmidSelect Xtra forms the basis of a generic process for purifying plasmid DNA, see page 14.

Chromatography systems include ÄKTApilot and ÄKTAprocess, with columns from the AxiChrom platform.

# Flexible manufacturing solutions drive production economics & speed of response

*Plug and play solutions reduce both up-front investment and waste*

At present, it takes nearly nine months to produce currently licensed influenza vaccines. Even this prolonged schedule leaves little room for manufacturing error and no potential to scale up if demand suddenly increases. Time-lines have to be shortened if we are to meet the need for a faster and more flexible response. Flexibility must also be improved to allow quick increases in batch volumes for cell culture and purification.

Single-use components, for example disposable flow paths and culture bags that replace tanks, and plastic tubing instead of steel piping, are not only practical in use, they also withstand tough economic comparisons with the traditional alternatives. In addition, they help eliminate time-consuming practices.

We call our platform of ready to use, plug and play products ReadyToProcess. This platform includes preconditioned filtration cartridges, prepacked, prequalified chromatography columns, as well as a range of fluid management components. All are presanitized and ready to use with no need for cleaning or cleaning validation.

The ReadyToProcess platform paves the way for a new era of vaccine production. Instead of manufacturing facilities that take years to build, ready to use facilities can quickly be brought on line and even transported to bring them closer to the site of epidemics. It adds up to fast, flexible, and cost-effective vaccine manufacture – whenever and wherever the need arises.

**ReadyToProcess for vaccine manufacture**

Many vaccines are not manufactured on the same large scale as some high-demand recombinant proteins and monoclonal antibodies currently in routine production. They can, on the other hand, be needed much quicker, but for a more limited length of time.

The solution to this challenge is ReadyToProcess – faster manufacturing with less investment/capital cost and the potential to dispose of the equipment post-production. ReadyToProcess components also eliminate the need to inactivate and clean all production equipment. As some vaccine components are disease-causing agents, this step is often otherwise required. And as the need to clean equipment is avoided, so is the time-consuming task of cleaning validation.

ReadyToProcess solutions include WAVE Bioreactor systems and WAVE Mixer™, as well as ReadyCircuit assemblies that form self-contained bioprocessing modules with disposable sensors for cross-flow or normal-flow filtration. Assemblies can be secured using the flexible mobile processing station ReadyKart. ReadyMate Disposable Aseptic Connectors facilitate dry-to-dry aseptic connections between assembly parts in non-aseptic environments and maintain an aseptic path. The disposability of the entire circuit after processing reduces downtime between finishing one batch and starting the next.

Packed and prequalified ReadyToProcess chromatography columns are available in bed volumes up to 20 l packed with Capto and Sepharose Fast Flow media. ÄKTA ready is a fully-automated chromatography system suitable for vaccine scale-up and production. The system operates with ready to use, disposable flow paths including sensors and detection flow cells.

# Integrated support and service

*GE Healthcare provides comprehensive support for vaccine processes*

**BioProcess™ Media**
Media such as Capto and MabSelect™ are specifically designed to meet the demands of today's industrial biomanufacturing. BioProcess Media are produced according to validated methods and tested under strict quality control to fulfill key process performance specifications. Regulatory Support Files are available.

**ÄKTA systems**
The ÄKTA system platform offers a range of purification systems for the lab bench to full-scale production, all controlled by UNICORN™ software, which allows for easy transfer and scale-up of methods.

**Filtration products**
Our filtration portfolio includes products for cross-flow and normal-flow filtration applications. ÄKTAcrossflow and UniFlux systems, together with a range of membrane devices, provide integrated applications at every scale, from the lab bench to full-scale production.

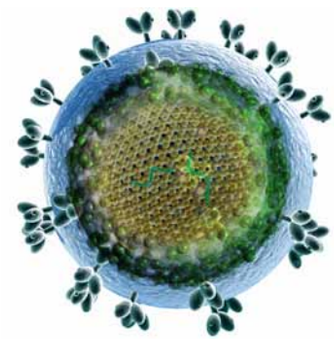
**Analysis systems**
Label-free analysis using Biacore and MicroCal systems provides comprehensive characterization of biomolecular interactions and biomolecule stability. These assays are used to design vaccines with desired properties, speed up optimization of process parameters and formulation, and to perform batch release tests with great accuracy and precision.

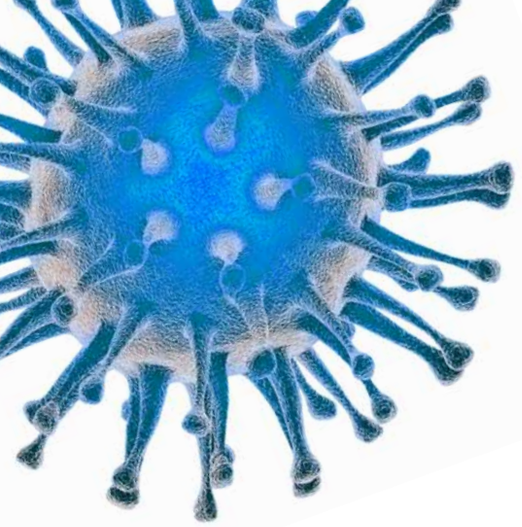
**ReadyToProcess products**
This platform comprises ready to use WAVE Bioreactor technology, ReadyToProcess columns, filters, systems, and fluid management components for faster and simpler bioprocessing operations.

**Security of supply**
Our large production capacity, clear ordering and delivery routines, and contracts for Media Safety Stock assure secure supplies of critical BioProcess Media. For systems and columns, there are Spare Parts Locker and other service contracts to secure maximum processing uptime.

**Fast Trak Services**
Fast Trak Services provide a range of courses and process development consulting. Practical support and advice from Fast Trak can help you plan, implement, and document upstream and downstream processes from startup to routine production, as well as train your personnel.

**GE Services**
Executing Installation and Operational Qualification (IQ/OQ) and Change Control Protocols (CCP) requires knowledge of both the techniques and regulatory requirements involved. Our specially trained and certified engineers perform onsite IQ/OQs and CCPs in accordance with cGMP, as well as providing on-site training for your personnel.





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