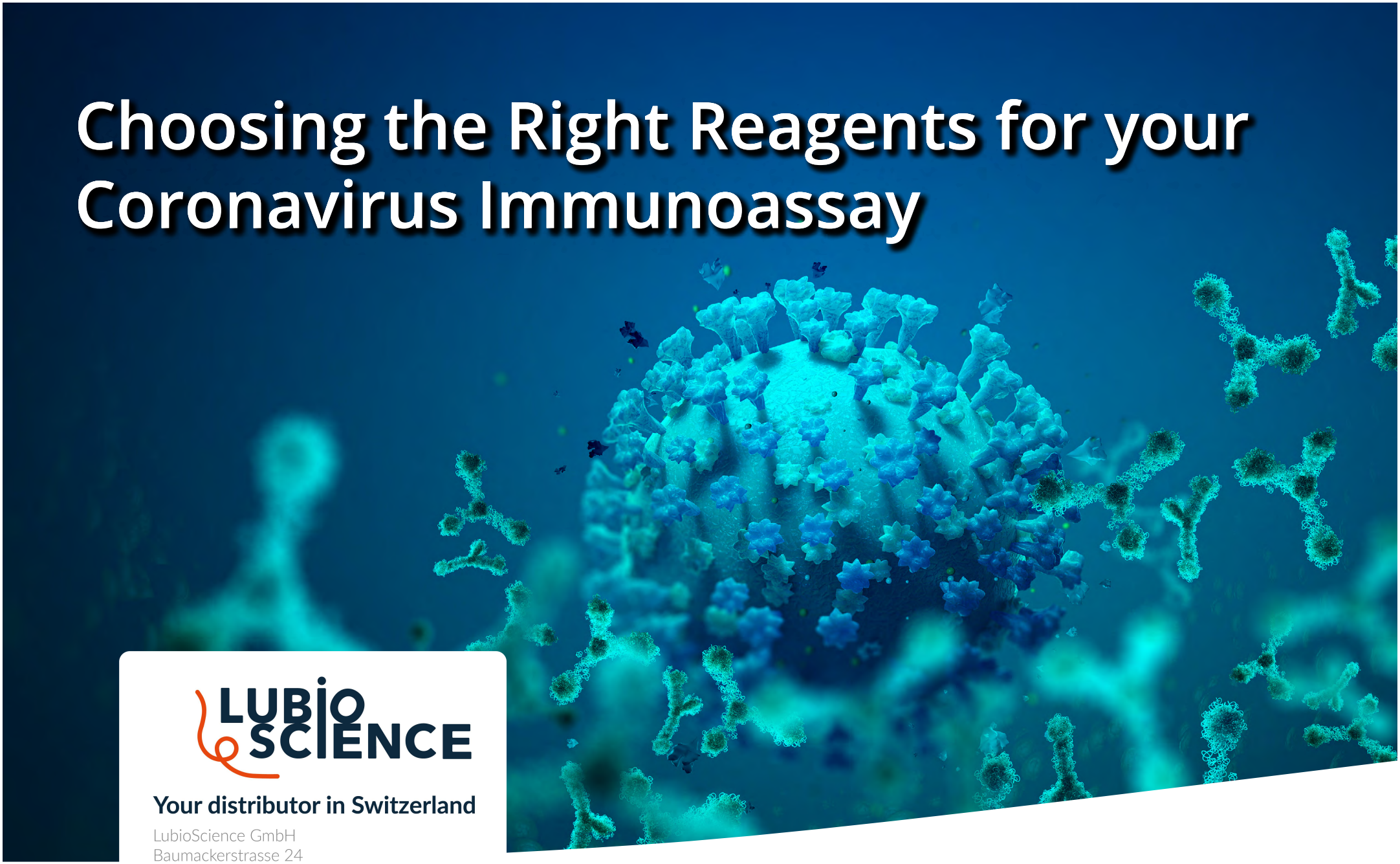
Choosing the Right Reagents for your Coronavirus Immunoassay



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THE NativeAntigen COMPANY

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The Role of *In Vitro* Diagnostics

The Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) is a positive-sense, single-stranded RNA virus of the *Coronaviridae* family and the causative agent of COVID-19. Since emerging in 2019, SARS-CoV-2 has infected tens of millions worldwide, resulting in an unprecedented global health and economic crisis.

In most cases, COVID-19 is not life threatening and manifests as a range of non-specific, flu-like symptoms, such as fever, cough and sore throat. However, up to 20% of individuals experience more severe forms of illness that can progress to acute respiratory distress syndrome (ARDS), viral sepsis, multi-organ dysfunction and death [1].

Currently, there are no specific treatments available for COVID-19 beyond a handful of investigational therapeutics that are limited to the severest cases. A small number of vaccines are now in early use, but their safety and efficacy is not yet certain. Given the lack of specific countermeasures, non-pharmaceutical interventions (NPIs), such as self-isolation, travel quarantines, social distancing and personal protective equipment continue to be the mainstay of disease control.

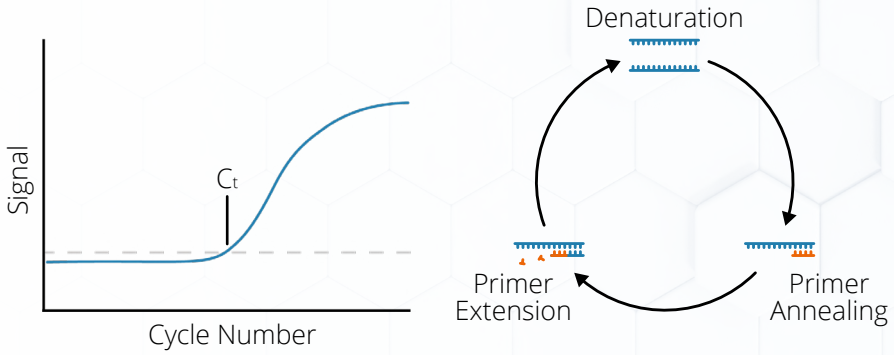
In spite of these efforts, the long incubation periods, overlapping symptoms and high prevalence of subclinical SARS-CoV-2 infection have continued to make disease control a significant challenge. *In vitro* diagnostics are now considered crucial in detecting SARS-CoV-2-positive individuals, in addition to a range of epidemiological and R&D applications:

- Disease status diagnosis
- Immune status diagnosis
- Providing epidemiological variables for modelling and public health policy
- Screening vaccine and therapeutic sera
- Understanding immune dynamics and defining correlates of protection

Challenges Associated with Diagnosis

RT-PCR

The reverse-transcriptase polymerase chain reaction (RT-PCR) is the preferred and most widely used method for the clinical diagnosis of COVID-19. After taking a nasal, oral or nasopharyngeal swab, cDNA is reverse-transcribed from a target viral RNA sequence and amplified by polymerase enzymes to produce a confirmatory signal. As a nucleic acid amplification technique (NAAT), RT-PCR requires only minute amounts of RNA and therefore benefits from inherently high sensitivity [2]. RT-PCR diagnosis of COVID-19 has also benefitted from widely available protocols and extensively validated operating procedures that have facilitated its rapid global adoption.

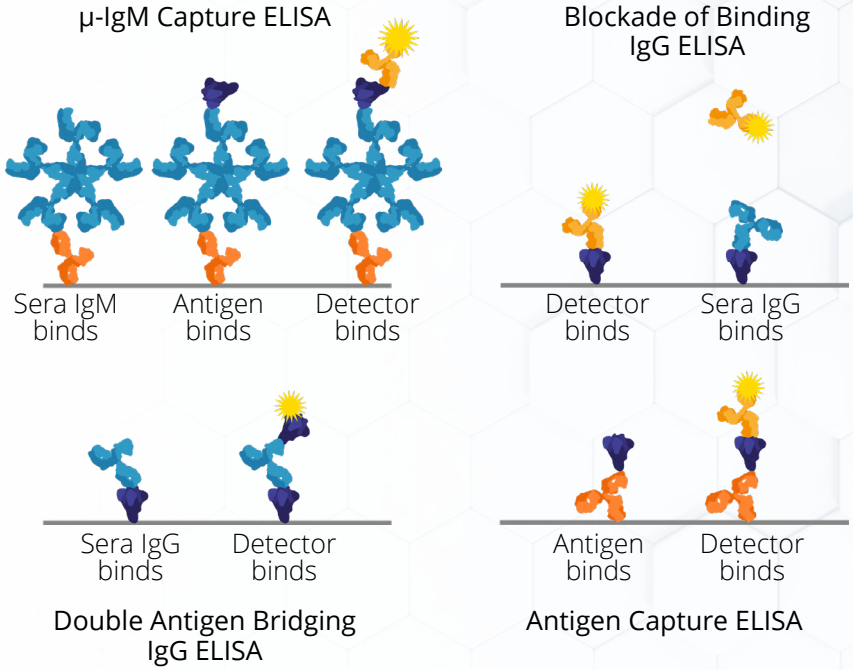


The diagnostic limitations of RT-PCR for COVID-19 diagnosis largely relate to the availibility of its analytes. Firstly, as the sites of viral replication change over the time-course, and according to the nature of infection, respiratory swabs may fail to capture viral RNA [3]. In such instances, lack of genomic material can lead to false-negative results that risk further exposure of surrounding individuals to those infected. Secondly, as viral load rapidly drops following the acute-phase, there is a limited time window for NAAT diagnosis during the first weeks of infection [4]. This temporal constraint precludes the use of RT-PCR in detecting historic infections and makes asymptomatic or sub-clinical infections especially difficult to detect.

Notwithstanding these issues, RT-PCR continues to be the workhorse of COVID-19 diagnosis and is currently the major contributor to case identification, isolation and contact tracing. However, to improve the reliability of patient diagnosis and develop effective countermeasures to SARS-CoV-2, alternative technologies are required.

Immunoassays

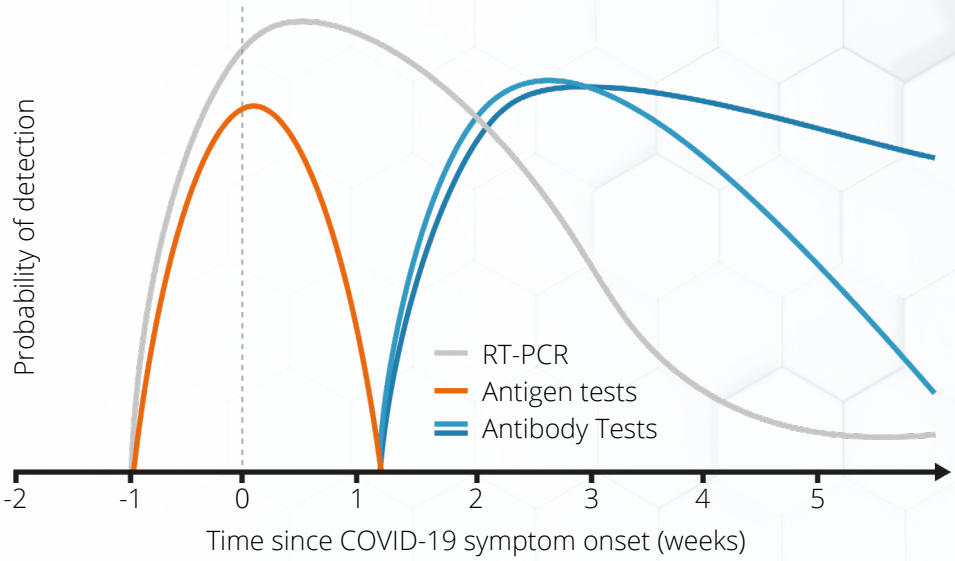
Unlike molecular methods, immunoassays harness the interactions of immune proteins to determine the presence of, or past exposure to a pathogen. While a range of immune proteins can be detected, antigens (direct detection) and antibodies (indirect detection) from either blood or sputum are the most informative. The design and detection methods of immuoassays differ, but all rely on the specific interactions of immune proteins: Antigens are detected using capture antibodies, which are bound by detectors to produce a positive signal, while antibodies are detected using capture antigens, which are likewise bound by detectors to produce a positive signal.



As antigen tests require the presence of whole virus or its protein products, diagnosis is limited to the acute-phase of infection when virus is present and actively replicating in the respiratory tract. However, because immunoassays do not include an analyte amplification step, antigen testing lacks the sensitivity of NAAT and is therefore not the preferred method of clinical diagnosis when RT-PCR is available [5].

For antibody testing, different antibody isotypes can be detected from either sputum (IgA) or blood (IgM and IgG). However, unlike antigens or RNA, antibodies are not present during the early stages of infection, with IgM/IgG antibodies to SARS-CoV-2 taking a median time of 11 days to be detected following the onset of symptoms [6]. Antibodies are also long-lasting and may persist in the bloodstream many years after SARS-CoV-2 infection. As such, anti-SARS-CoV-2 antibodies may be used to determine infection retrospectively, with various downstream applications.

On national scales, widespread and frequent serosurveillance is needed to understand the temporal and geographical dynamics of disease transmission to inform epidemiological models and support changes to public health policy. At the level of care, the nature and degree of patient antibody profiles could be used to infer the time since initial exposure and inform patient prognosis [7]. Antibody testing is also needed to support the research and development of therapeutic and prophylactic countermeasures to SARS-CoV-2. To develop convalescent patient sera, for example, the neutralising ability and potential cross- or auto-reactive activity of samples needs to be determined; To develop vaccines, it is necessary to determine levels of neutralising and non-neutralising antibody titres and the length of immune protection conferred by candidates. Pre-vaccination screening is also needed to determine previous exposure to SARS-CoV-2 and other human coronaviruses in clinical trials.



While the applications of antibody testing are clear, the effective implementation of these technologies is impeded by our current lack of understanding of SARS-CoV-2 immunity. In particular, the factors influencing disease severity, and the correlates and longevity of immune protection are not well characterised. This firstly makes the development of countermeasures to SARS-CoV-2 challenging, as relevant endpoints are hard to define for clinical trials, and the ambiguity surrounding the relevance of seropositivity means that clinical decision-making or so-called “immune passport” applications are not advised by public health bodies [8]. This significantly limits the utility of antibody testing, as seropositive individuals must continue to adhere to social distancing and workplace restrictions, with the associated economic consequences. Better characterisation of antibody-mediated immunity will therefore continue to be a major research priority [9].

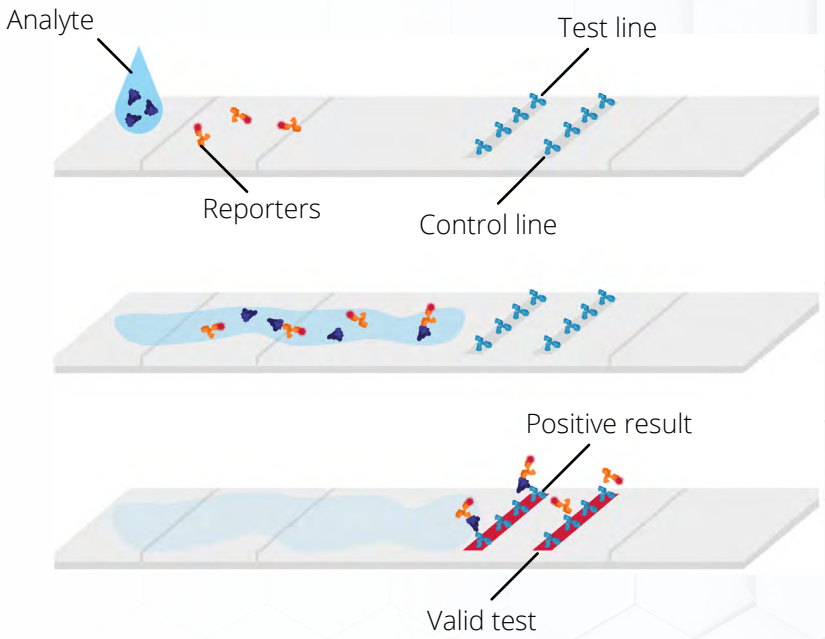
Point-of-Care Testing

Given the resource, expertise and biocontainment requirements of processing COVID-19 samples, nearly all testing — whether molecular or immunoassay — has been carried out in the laboratory environment to-date. However, sample transportation has required the development of extensive collection and distribution systems, and as transmission has continued to increase, supply chains have buckled under the pressure. In many countries, these effects have been further compounded by the lack of established diagnostic industries, leading to delays in sourcing testing materials and reagents. In combination, this has constrained testing capacity and led to sample-to-result turnaround times typically in excess of 24h [10].

Given the limitations of centralised testing, efforts are now underway to develop more rapid, simple and economical tests that can be distributed for use at the point-of-care (PoC). While there are a range of formats to choose from, one of the most practical, cost-effective and easy to manufacture is the lateral flow assay (LFA) — a portable, rapid immunoassay format that typically provides results within a matter of minutes [11]. Moreover, as an immunoassay, LFAs can detect both antigens and antibodies, allowing for a broad scope of applications.

Large scale use of antigen LFAs could improve detection of asymptomatic carriers, reduce the time to obtaining actionable results, and support the appropriate use of isolation resources. Rapid antigen testing would be especially useful in improving detection in resource-limited settings, such as international airports, and in developing countries [12]. The major drawback of antigen LFAs is their lower sensitivity in comparison to most NAATs, which is a concern in high-risk settings such as nursing homes or countries that are successfully controlling transmission. In spite of this, modelling studies suggest that frequent repeat antigen testing could be more effective in identifying cases than less frequent, but higher sensitivity RT-PCR [13].

Given our knowledge constraints, antibody LFAs have largely been used in epidemiology and basic reasearch applications to-date. However, once SARS-CoV-2 immunity is better understood, antibody LFAs could play in important role in clinical diagnosis, screening of patient sera in clinical trials, and to assign immune passports to those no longer deemed at-risk.



LFAs typically comprise a plastic cassette (not shown), containing a strip of absorbent material that transports and detects analyte. Top: Analyte is added to one end of the strip and absorbed, allowing analyte to migrate along it. Middle: Analyte encounters area of reporter antibodies, which specifically bind analyte. Bottom: Analyte:reporter continues to migrate to area of detection antibodies that are specific to analyte and bind to produce a visible line that indicates a positive result. Secondary control lines are used to detect migrated reporter antibodies and ensure that the test has worked correctly.

Currently, over 200 rapid antigen and antibody tests are in development or have already been commercialised for use [14]. However, due to the pace at which kits have been developed, many have not be adequately assessed for use in care settings or for at-home diagnosis [15]. While PoC diagnostic technologies offer the possibility of faster and more informative acute-phase and immune status testing [16], balancing the need for greater testing capacity and the risk of diagnostic error remains a significant challenge to public health. The use of improperly validated tests has the potential to threaten not only public trust in healthcare, but the safety of patients and communities. Further research, development and validation of tests is therefore required before LFAs for SARS-CoV-2 can be effectively deployed. In particular, more studies are needed in prospective cohorts for the intended use populations that include a range of ages and ethnicities, with transparent reporting of data.

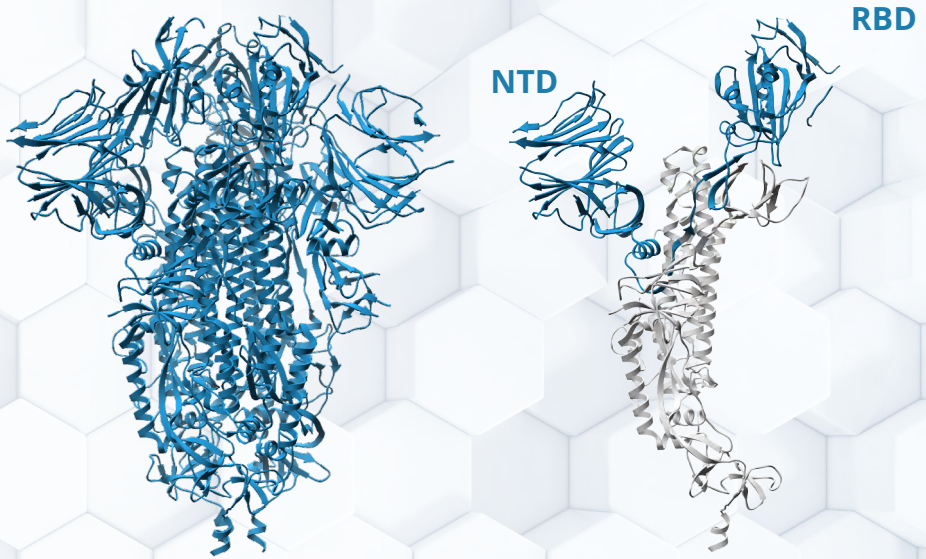
Central to the design of any high performance immunoassay is the development, selection and appropriate use of high quality reagents. Yet, selecting reagents is not always straightforward as there are multiple binding targets to choose from and a range of quality factors to consider.

Choosing Your Assay Target

Spike

The Spike protein is a large type I transmembrane protein trimer that projects from the surface of the SARS-CoV-2 virion. Each Spike monomer comprises three segments: A large ectodomain (comprising the S1 and S2 subunits), a transmembrane anchor, and a short intracellular tail [17]. The S1 subunit of the ectodomain mediates binding of the virion to the ACE-2 host cell-surface receptor through its receptor-binding domain (RBD), whereas the S2 subunit fuses with both host and viral membranes, by undergoing dramatic structural changes.

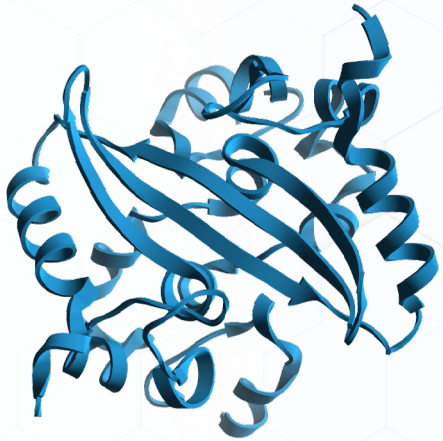
So-called 'Whole' Spike antigens include the full breadth of naturally-occuring Spike epitopes and can be used to maximise the sensitivity of assays. To further modulate assay performance characteristics, specific portions of Spike have also been investigated. The S1 and S2 subunits are popular choices as they are highly exposed to the virus's external environment and can readily induce neutralising antibody responses. Antibodies specific to S1 and its receptor-binding domain, in particular, can neutralise virus by precluding S1's interaction with ACE2. The N-terminal domain of S1 is also highly neutralising and exhibits the greatest sequence variation across the coronavirus family, making it an ideal choice for maximising the specificity of assays [18].



Above left: SARS-CoV-2 Spike ectodomain trimer in closed conformation. Above right: Spike ectodomain monomer with NTD (left) and RBD (right) labelled blue. Structure determined by Walls et al. [17] and modelled with UCSF CHIMERA.

Nucleoprotein

Nucleoprotein is found within the coronavirus virion, where it binds genomic RNA to modulate virion structure, replication and transcription. Each Nucleoprotein monomer contains structurally independent N-terminal and C-terminal dimerisation domains, which bind to RNA via phosphate groups and are separated by an intrinsically disordered linker [19]. The assembly of Nucleoprotein into higher-order ribonucleoprotein complexes is not well understood, but is thought to involve cooperative interactions between the dimerisation domain, other regions of the protein, and bound RNA.



Right: SARS-CoV-2 dimerisation (N2b) domain comprising C- and N-termini. Structure determined by Ye et al. [19] and modelled with UCSF CHIMERA.

While not as immunodominant as Spike, Nucleoprotein is still highly immunogenic, and is profusely over-expressed during the acute-phase of infection and elicits a slightly faster antibody response than Spike [20]. Moreover, as nearly all SARS-CoV-2 vaccines under development seek to elicit responses against the Spike protein, Nucleoprotein is a popular target for the development of diagnostics that can distinguish vaccine-induced immune responses from those that have occurred due to natural infection.

The challenge in using Nucleoprotein is the sequence similarity it exhibits between different coronaviruses, which can elicit broadly cross-reactive antibodies – especially between SARS-CoV-2 and the genetically distinct, 2002 SARS Coronavirus [21]. Thorough assay validation or the design of novel formats is therefore required to ensure that Nucleoprotein-based assays do not bind cross-reactive antibodies and generate false-positive results.

Further Considerations

The majority of antibody immunoassays currently under development are designed to capture both IgM and IgG, with some also capturing IgA [14]. There does not yet appear to be a distinct advantage in testing for single or multiple antibodies for diagnosis. However, broadening the pool of assay targets could improve sensitivity, while differentiation between the antibodies detected and their relative levels may help to define immune status and correlates of protection. A small number of multi-antigen assays employing AND/OR logic rules between different antigen readouts have recently been developed, showing improved performance in clinical samples [22].

In most populations, seropositivity and the prevalence of SARS-CoV-2 is relatively low. Therefore, high specificity is required to maximise the positive predictive value of tests and minimise false-positive results. To achieve this, there are various routes of investigation. When designing the assay itself, novel strategies can be used, such as so-called 'quenching antigens' that 'soak-up' excess cross-reacting antibodies from patient sera [23]. If inherently cross-reactive antibodies are being detected, such as those elicited by conserved antigen regions, cross-reactive epitopes can be ablated by introducing point mutations, while attempting to minimise structural changes to other regions.

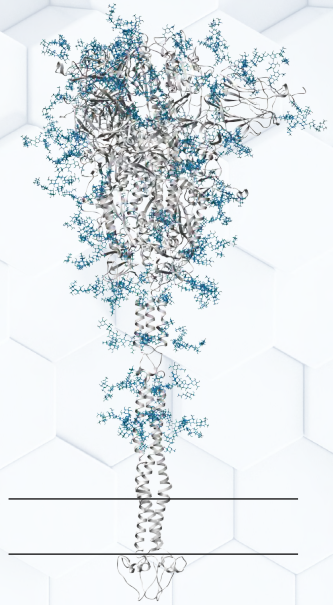
However, even tests that exceed 98% specificity are likely to incur false-positive results when used in large populations, risking the misuse of healthcare resources Additionally, as the northern hemisphere enters its flu season, there is a growing need to differentiate between SARS-CoV-2 and other respiratory viruses that commonly circulate in the winter months. One way to address these challenges is with orthogonal testing algorithms that employ multiple tests in sequence when the first test yields a positive result [24]. To satisfy these algorithms, distinct tests should be designed with select characteristics such as different antigen or antibody targets and a differing emphasis on sensitivity or sensitivity, accordingly. To design tests that can detect mulitple analytes simultaneously, multiplexing approaches can also be used.

Choosing Your Expression System

Developing accurate immunoassays for COVID-19 critically relies on the use of high quality viral antigens to capture or raise antibodies. Nearly all modern immunoassays are developed and manufactured with recombinant proteins expressed from cell culture, which offer the advantage of not requiring high biosafety facilities to handle and allow improved batch-to-batch consistency and standardisation [25]. However, this in turn can introduce new challenges as the degree to which these reagents can vary is significant, and structural fidelity is not always ensured.

The Spike protein — which most immoassays and vaccines are based on — is heavily post-translationally modified with up to 66 glycan sugars in its trimeric form [26]. During natural infection, this flexible layer of carbohydrates plays a crucial role in mediating the pathogenic function of Spike, including facilitating RBD-ACE2 interactions and blocking the access of proteolytic enzymes [27]. This highly dense coating of weakly immunogenic carbohydrates alos shields otherwise potent epitopes to evade immune recognition.

Therefore, the removal of specific Spike glycans has been investigated as a vaccine strategy to uncover key epitopes and increase the breadth and degree of protection. From the perspective of assay development, these glycans constitute many of the key surface epitopes that are recognised by host antibodies. As a result, developing antigen immunoassays or immunising hosts with unglycosylated Spike risks the binding/generation of non-specific cross-reactive antibodies.



Right: Full SARS-CoV-2 Spike protein in closed conformation, including ectodomain, transmembrane anchor and intracellular tail. Glycans labelled blue, polypeptide labelled grey, lipid bilayer shown as parallel lines. Structure determined by Walls et al. [17] and bilayer position modelled with CHARMM-GUI/UCSF CHIMERA.

To ensure that recombinant glycoproteins are produced with full glycosylation and proper conformational folding, assay developers must take care in selecting and optimising their expression systems. Simpler organisms like *E. coli*, for example, do not have the necessary machinery to glycosylate recombinant antigens, which becomes even more important when trying to retain the native conformation and epitopes of truncated antigens such as S1 and S2. More advanced systems, such as mammalian or insect are therefore required. However, scale-up production typically introduces new yield and batch-to-batch consistency challenges that require careful consideration.

To ensure full glycosylation and proper folding of our antigens, The Native Antigen Company produces glycoproteins in mammalian or insect cell-expression systems.

For the investigation of novel therapeutics and vaccines, The Native Antigen Company also offers custom services to ablate specific N-linked glycans via site-directed mutagenesis.

For more information get in touch with one of our scientists at:

contact@thenativeantigencompany.com

System	Bacterial	Insect	Mammalian
Advantages	Low cost Simple transformation Simple growth conditions	High yield Similar PTMs Baculovirus vectors	High yield in suspension Chaperones and cofactors Native-like PTMs and folding
Disadvantages	Protein insolubility Endotoxin contamination Lack of PTMs and chaperones	Cost Demanding growth conditions Time-consuming vector production	Cost Demanding growth conditions

High Quality Coronavirus Antigens

To support the development of high quality immunoassays, The Native Antigen Company offers an extensive range of SARS-CoV-2, SARS-CoV, MERS-CoV, HCoV-229E, HCoV-OC43, HCoV-NL63 and HCoV-HKU1 antigens from mammalian, insect and bacterial expression systems.

Our Spike antigens are available in whole, subunit, and fusion forms, with C- or N-terminal His-tags for ease of purification and immobilisation in assays. Expressed in our HEK293 and insect expression system, these antigens are fully glycosylated and exhibit proper folding. Our SARS-CoV-2, SARS-CoV, MERS-CoV, and endemic human coronavirus (HCoV) Nucleoprotein antigens can be used as controls in the development of highly specific immunoassays, including those used for screening vaccine candidates.

For native sources of antigen, we offer SARS-CoV-2, HCoV-NL63 and HCoV-229E viral lysates, purified from mammalian cells. These lysates have been highly purified using sucrose density gradient ultracentrifugation, followed by detergent- and heat-inactivation, validated in tissue culture infectivity assays. Our lysates are appropriate as controls for the development of highly specific immunoassays.

We also offer highly purified human angiotensin-converting enzyme 2 (ACE2) and CD147 protein, which are bound by the SARS-CoV-2 Spike protein to mediate cell entry. These proteins have been tested for functional RBD binding in ELISA and include C-terminal human Fc-tags for ease of purification and detection.

In addition to our range of antigens and receptors, we also offer various biologically active SARS-CoV-2 enzymes, which are under investigation as targets for the development of novel antivirals: RNA-dependent RNPolymerase (RdRp) catalyses the synthesis of viral RNA, and the papain-like protease (PLpro) and 3C-like protease (3CLpro) cleave polyproteins.

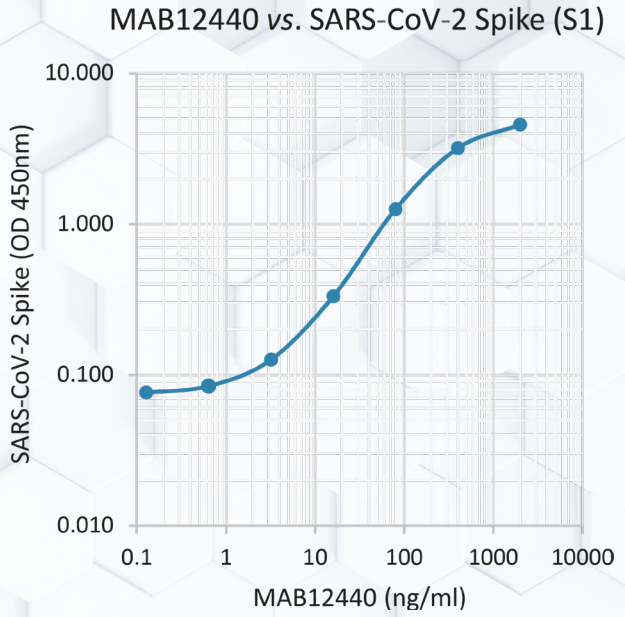
High Quality Coronavirus Antibodies

To complement our antigens, we offer an extensive range of both monoclonal and polyclonal IgG, IgM and IgA antibodies specific to SARS-CoV-2, SARS-CoV and MERS-CoV.

Our SARS-CoV-2 Spike monoclonals (MAB12440-MAB12449) have been raised against the company's own mammalian-expressed S1 and S2 subunit antigens. To determine their epitope-specificity, these antibodies have been assessed in ELISA, and screening has been carried out against the Company's other coronavirus Spike proteins from SARS, MERS, OC43, 229E, NL63 and HKU1 to demonstrate specificity to SARS-CoV-2.

Our CR3022 SARS-CoV-2 Spike monoclonals show high affinity for the RBD of Spike, and in IgM, IgG and IgA classes, with conjugate variants also avaiable. Polyclonal anti-SARS-CoV-2 Spike IgG antibodies are also available and show binding to various regions of Spike in ELISA and Western blot.

Our CR3009/CR3018 monoclonals recognise the Nucleoproteins of SARS-CoV and SARS-CoV-2. Competitive ELISA data suggests that these antibodies bind different Nucleoprotein epitopes, making them suitable in combination for virus capture assays. Our 3861 and 3851 Nucleoprotein antibodies are also suitable for use as matched pairs in capture assays.



Antigen-down ELISA showing binding of MAB12440 to immobilised SARS-CoV-2 Spike (S1) protein (REC31806).

*Product under development

Antigens	Product Code	Source	Format
SARS-CoV-2 Spike Glycoprotein (Whole)	REC31868	CHO Recombinant	Liquid
SARS-CoV-2 Spike Glycoprotein S1	REC31806	HEK293 Recombinant	Liquid
SARS-CoV-2 Spike Glycoprotein S1	REC31828	Insect Cell Recombinant	Liquid
SARS-CoV-2 Spike Glycoprotein S1 (D614G Mutant)	REC31883*	HEK293 Recombinant	Liquid
SARS-CoV-2 Spike Glycoprotein S1 RBD	REC31849	HEK293 Recombinant	Liquid
SARS-CoV-2 Spike Glycoprotein S1 RBD	REC31831 REC31843	CHO Recombinant	Liquid
SARS-CoV-2 Spike Glycoprotein S1 NTD	REC31835	HEK293 Recombinant	Liquid
SARS-CoV-2 Spike Glycoprotein S2	REC31807	HEK293 Recombinant	Liquid
SARS-CoV-2 Spike Glycoprotein S2	REC31830	Insect Cell Recombinant	Liquid
SARS-CoV-2 Spike Glycoprotein S2 (1000-1200)	REC31846	*E. coli* Recombinant	Liquid
SARS-CoV-2 Spike Glycoprotein S2 (800-1000)	REC31844	*E. coli* Recombinant	Liquid
SARS-CoV-2 Nucleoprotein	REC31812	*E. coli* Recombinant	Liquid
SARS-CoV-2 RBD-Nucleoprotein Chimera	REC31881	CHO Recombinant	Liquid
SARS-CoV-2 Spike-Envelope-Membrane Mosaic	REC31829	*E. coli* Recombinant	Liquid
SARS-CoV-2 Membrane-Envelope Fusion	REC31848	*E. coli* Recombinant	Liquid
SARS-CoV-2 3C-Like Proteinase (3CLpro), Active	REC31875	*E. coli* Recombinant	Liquid
SARS-CoV-2 Papain-Like Protease (PLpro), Active	REC31873	*E. coli* Recombinant	Liquid

Antigens	Product Code	Source	Format
SARS-CoV-2 RNA-Dependent Pol. (RdRp), Active	REC31874	*E. coli* Recombinant	Liquid
SARS-CoV-2 Purified Viral Lysate	NAT41605	VeroE6 Native	Liquid
SARS-CoV Spike Glycoprotein S1	REC31809	HEK293 Recombinant	Liquid
SARS-CoV Spike Glycoprotein S1 Mosaic	REC31842	*E. coli* Recombinant	Liquid
SARS-CoV Spike Glycoprotein S1 Mosaic (N-Term)	REC31840	*E. coli* Recombinant	Liquid
SARS-CoV Spike Glycoprotein S2 Mosaic (C-Term)	REC31841	*E. coli* Recombinant	Liquid
SARS-CoV Envelope Protein	REC31839	*E. coli* Recombinant	Liquid
SARS-CoV Nucleoprotein	REC31744	HEK293 Recombinant	Liquid
SARS-CoV Nucleoprotein (N-Term)	REC31836	*E. coli* Recombinant	Liquid
SARS-CoV Nucleoprotein (C-Term)	REC31837	*E. coli* Recombinant	Liquid
SARS-CoV Membrane Protein (Matrix)	REC31838	*E. coli* Recombinant	Liquid
MERS-CoV Spike Glycoprotein S1	REC31847	HEK293 Recombinant	Liquid
MERS-CoV Spike Glycoprotein S1	REC31760	*E. coli* Recombinant	Liquid
MERS-CoV Spike Glycoprotein S1	REC31855	Insect Cell Recombinant	Liquid
HCoV-229E Spike Glycoprotein S1	REC31895	HEK293 Recombinant	Liquid
HCoV-229E Nucleoprotein	REC31758	*E. coli* Recombinant	Liquid
HCoV-229E Purified Viral Lysate	NAT41608	HeLa Native	Liquid

Antigens	Product Code	Source	Format
HCoV-NL63 Spike Glycoprotein S1	REC31896	HEK293 Recombinant	Liquid
HCoV-NL63 Nucleoprotein	REC31759	*E. coli* Recombinant	Liquid
HCoV-NL63 Purified Viral Lysate	NAT41607	Vero Native	Liquid
HCoV-HKU1 Spike Glycoprotein S1	REC31897	HEK293 Recombinant	Liquid
HCoV-HKU1 Nucleoprotein	REC31856	*E. coli* Recombinant	Liquid

Receptors	Product Code	Source	Format
Human ACE2 (18-615)	REC31832	HEK293 Recombinant	Liquid
Human ACE2 (19-740)	REC31833	HEK293 Recombinant	Liquid
Human CD147 (22-205)	REC31872	HEK293 Recombinant	Liquid
Human CLEC4M	REC31686	HEK293 Recombinant	Liquid

Antibodies	Product Code	Source	Format
Mouse SARS-CoV2 Spike S1 RBD IgG (FG11)	MAB12445	Hybridoma	Liquid
Mouse SARS-CoV2 Spike S1 RBD IgG (DH6)	MAB12444	Hybridoma	Liquid
Mouse SARS-CoV2 Spike S1 RBD IgG (CE5)	MAB12443	Hybridoma	Liquid
Mouse SARS-CoV2 Spike S1 IgG (HH10)	MAB12442	Hybridoma	Liquid
Mouse SARS-CoV2 Spike S1 IgG (FH4)	MAB12441	Hybridoma	Liquid
Mouse SARS-CoV2 Spike S1 IgG (EB5)	MAB12440	Hybridoma	Liquid
Mouse SARS-CoV2 Spike S2 IgG (HA11)	MAB12448	Hybridoma	Liquid
Mouse SARS-CoV2 Spike S2 IgG (AD10)	MAB12446	Hybridoma	Liquid
Mouse SARS-CoV2 Spike S2 IgG (CH1)	MAB12447	Hybridoma	Liquid
Mouse SARS-CoV2 Spike S2 IgG (JC7)	MAB12449	Hybridoma	Liquid
Human SARS-CoV-2 Spike S1 IgG mAb (CR3022)	MAB12422	Hybridoma	Liquid
Human SARS-CoV-2 Spike S1 IgM mAb (CR3022)	MAB12423	Hybridoma	Liquid
Rabbit SARS-CoV-2 Spike S1 IgG mAb (CR3022)	MAB12424	Hybridoma	Liquid
Human SARS-CoV-2 Spike IgA mAb (A60H)	MAB12439	Hybridoma	Liquid
Rabbit SARS-CoV-2 Spike S1 pAb	PAB21471	Rabbit	Liquid
Rabbit SARS-CoV-2 Spike S2 pAb	PAB21472	Rabbit	Liquid
Human SARS-CoV-2 NP IgG mAb (CR3009)	MAB12433	Hybridoma	Liquid

Antibodies	Product Code	Source	Format
Human SARS-CoV-2 NP IgG mAb (CR3009)	MAB12434	Hybridoma	Liquid
Human SARS-CoV-2 NP IgM mAb (CR3009)	MAB12435	Hybridoma	Liquid
Rabbit SARS-CoV-2 NP IgG mAb (CR3018)	MAB12436	Hybridoma	Liquid
Human SARS-CoV-2 NP IgG mAb (CR3018)	MAB12437	Hybridoma	Liquid
Human SARS-CoV-2 NP IgM mAb (CR3018)	MAB12438	Hybridoma	Liquid
Rabbit SARS-CoV-2 Nucleoprotein pAb	PAB21474	Rabbit	Liquid
Mouse SARS-CoV Nucleoprotein IgG mAb (3851)	MAB12184	Hybridoma	Liquid
Mouse SARS-CoV Nucleoprotein IgG mAb (3861)	MAB12183	Hybridoma	Liquid
Mouse SARS-CoV Nucleoprotein IgG mAb (3862)	MAB12425	Hybridoma	Liquid
Mouse SARS-CoV Nucleoprotein IgG mAb (3863)	MAB12426	Hybridoma	Liquid
Mouse SARS-CoV Nucleoprotein IgG mAb (3864)	MAB12427	Hybridoma	Liquid
Rabbit SARS-CoV Nucleoprotein pAb	PAB21469	Rabbit	Liquid
Mouse MERS-CoV Spike S1 IgG mAb (3871)	MAB12395	Hybridoma	Liquid
Mouse MERS-CoV Spike S1 IgG mAb (3872)	MAB12396	Hybridoma	Liquid
Mouse MERS-CoV Spike S1 IgG mAb (3873)	MAB12397	Hybridoma	Liquid

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