The dual function monoclonal antibodies VIR-7831 and VIR-7832 demonstrate potent in vitro and in vivo activity against SARS-CoV-2

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ABSTRACT

VIR-7831 and VIR-7832 are dual action monoclonal antibodies (mAbs) targeting the spike glycoprotein of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). VIR-7831 and VIR-7832 were derived from a parent antibody (S309) isolated from memory B cells of a 2003 severe acute respiratory syndrome coronavirus (SARS-CoV) survivor. Both mAbs contain an "LS" mutation in the Fc region to prolong serum half-life and potentially enhance distribution to the respiratory mucosa. In addition, VIR-7832 encodes an Fc GAALIE mutation that has been shown previously to evoke CD8+ T-cells in the context of an in vivo viral respiratory infection. VIR-7831 and VIR-7832 potently neutralize wild-type and variant authentic virus in vitro as well as variant pseudotyped viruses. In addition, they retain activity against monoclonal antibody resistance mutations conferring reduced susceptibility to currently authorized mAbs. The VIR-7831/VIR-7832 epitope does not overlap with mutational sites in current variants of concern and continues to be highly conserved among circulating sequences consistent with the high barrier to resistance observed in vitro. Furthermore, both mAbs can recruit effector mechanisms in vitro that may contribute to clinical efficacy via elimination of infected host cells. In vitro studies with these mAbs demonstrated no enhancement of infection. In a Syrian Golden hamster proof-of concept wildtype SARS-CoV-2 infection model, animals treated with VIR-7831 had less weight loss, and significantly decreased total viral load and infectious virus levels in the lung compared to a control mAb. Taken together, these data indicate that VIR-7831 and VIR-7832 are promising new agents in the fight against COVID-19.

INTRODUCTION

The coronavirus disease (COVID-19) pandemic caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has resulted in more than 191 million confirmed cases and over 4 million deaths

47 worldwide[1]. SARS-CoV-2 infection results in a broad range of disease severity[2]. Infection fatality rates
48 increase significantly with age, with 28.3% of COVID-19 patients over the age of 85 succumbing to
49 disease[2]. However, even in mild-to-moderate COVID-19 patients, significant post-infection sequelae can
50 affect overall health and cause long-term disability[3]. While multiple SARS-CoV-2 vaccines are now
51 authorized for use, issues of supply, vaccine hesitancy and emergence of variants may prevent rapid
52 attainment of herd immunity[4–9]. In addition, there may be individuals who remain at risk despite
53 vaccination due to disease or underlying immunodeficiency. Thus, additional interventions and potential
54 prophylactic agents are needed to reduce morbidity and mortality due to COVID-19.

55 Several monoclonal antibodies (mAbs) targeting the SARS-CoV-2 spike protein have recently been
56 authorized for use in early treatment of COVID-19 patients[10–13] and clinical data have been reported to
57 show promising results in treatment and prophylactic studies[12–15]. However, rapidly spreading variants
58 exhibit reduced susceptibility in vitro to some currently authorized antibodies that target the receptor
59 binding motif (RBM) of the viral spike (S) glycoprotein [10,11,16,17]. Therefore, mAbs targeting unique S
60 epitopes are needed for use alone or in combination with current agents for the treatment and prevention
61 of COVID-19. Furthermore, in addition to viral neutralization, antibodies possessing potent effector
62 function to aid in the killing of virally infected cells and the elicitation of T cell immunity could
63 significantly assist in halting disease progression[18–20].

64 VIR-7831 and VIR-7832 are dual action mAbs derived from the parent antibody S309 identified from a
65 2003 SARS-CoV survivor[21]. These mAbs target an epitope containing a glycan (at position N343) that is
66 highly conserved within the Sarbecovirus subgenus in a region of the S receptor binding domain (RBD)
67 that does not compete with angiotensin converting enzyme 2 (ACE2) binding[22]. This epitope does not
68 overlap with mutations observed in current variants of concern[10,11,16,17]. The variable region of VIR-7831
69 and VIR-7832 have been engineered for enhanced developability. In addition, both antibodies possess an
70 Fc "LS" mutation that confers extended half-life by binding to the neonatal Fc receptor and potentially
71 enhances distribution to the respiratory mucosa [23–25]. VIR-7832 is identical to VIR-7831 with the

72 exception of the addition of a 3 amino acid GAALIE (G236A, A330L, I332E) modification to the Fc
73 domain[26]. The GAALIE modification has previously been shown in vitro to enhance binding to FcγIIa
74 and FcγIIIa receptors, decrease affinity for FcγIIb compared to typical IgG1 and evoke protective CD8+
75 T-cells in the context of viral respiratory infection in vivo [27,28].

76 Here we characterize the antiviral potential of VIR-7831 and VIR-7832. These mAbs effectively
77 neutralize SARS-CoV-2 live virus in vitro as well as in pseudotyped virus assays against emerging
78 variants of concern and variants that confer resistance to currently authorized mAbs[29]. In addition to the
79 neutralizing capacity, both antibodies demonstrate potent effector function and mediate antibody
80 dependent cellular cytotoxicity (ADCC) and antibody dependent cellular phagocytosis (ADCP) in vitro.
81 Furthermore, resistance selection experiments and epitope conservation analyses indicate the potential for
82 a high barrier to resistance. Data derived from the Syrian golden hamster model demonstrates efficacy in
83 a proof-of-concept in vivo model. Taken together, these data indicate that VIR-7831 and VIR-7832 are
84 promising key components of the arsenal in the fight against COVID-19.

85 **RESULTS**

86 **VIR-7831 and VIR-7832 bind SARS-CoV-2 spike and effectively neutralize live virus in vitro.**
87 Previously published work showed that S309 bound SARS-CoV-2 recombinant and cell surface-
88 associated S and neutralized live virus in vitro[21]. We initiated these studies by repeating and extending
89 these earlier results. To determine the binding activity of VIR-7831 and VIR-7832 to the SARS-CoV-2 S,
90 enzyme-linked immunosorbent assay (ELISA), surface plasmon resonance (SPR) and flow cytometry
91 assays were utilized. VIR-7831 and VIR-7832 bound to recombinant S RBD (amino acids 331-541) with
92 EC_{50} values of 20.40 ng/mL and 14.9 ng/mL, respectively, by ELISA (**Figure 1a**). Using SPR, both
93 antibodies demonstrated potent binding to recombinant S RBD with an equilibrium constant (Kd) of 0.21
94 nM (**Figure 1b**). As antibody recognition of cell surface-bound S could mediate killing of virally infected
95 cells, flow cytometry-based studies using cells transiently transfected with a S-encoding plasmid were

96 used to examine antibody binding to cell surface-expressed S trimer. By this method, both VIR-7831 and
97 VIR-7832 bound efficiently to surface-expressed S (**Figure 1c**).

98 To examine neutralization capacity, VIR-7831 and VIR-7832 were tested in a VeroE6 cell-based live
99 SARS-CoV-2 virus system against the Washington 2019 (wild-type) virus as well as against the Alpha
100 (B.1.1.7), Beta (B.1.351) and Gamma (P.1) variants. Concentration-dependent viral neutralization of the
101 Washington 2019 strain was observed for both antibodies, with geometric mean $IC_{50/90}$ values of
102 100.1/186.3 ng/mL and 78.3/253.1 ng/mL, respectively (**Figure 1d**). $IC_{50/90}$ values observed for VIR-7831
103 and VIR-7832 against the Beta and Gamma variant viruses were similar to those against the wild-type
104 strain. A slight shift in the VIR-7831/VIR-7832 $IC_{50/90}$ compared to wild-type was observed for the Alpha
105 variant. VIR-7831 showed a 3-fold and 4.1-fold shift in IC_{50} and IC_{90}, respectively, against the Alpha
106 variant compared to wild-type while VIR-7832 had a 3.1-fold shift in IC_{50} and 3.7-fold shift in IC_{90} versus
107 wild-type (**Figure 1d, Table 1)**. As variant evolution is a natural part of SARS-CoV-2 biology and
108 emerging live virus variants are not always readily accessible for testing, a vesicular stomatitis virus
109 (VSV)-based pseudotyped virus system targeting Vero E6 cells was used to examine VIR-7831 and VIR-
110 7832 neutralization against emergent variants (**Table 2**). Fold-changes in VIR-7831 and VIR-7832 IC_{50}
111 values compared to wild-type against pseudotyped virus expressing spike from the Alpha, Beta or
112 Gamma variant were similar to those observed in the authentic virus system. VIR-7831 was tested against
113 an extended panel of pseudotyped viruses incorporating emerging variants as well as all variants deemed
114 as Variants of Concern (VOC) or Variants of Interest (VOI) by the World Health Organization (WHO).
115 VIR-7831 retained activity in vitro against all variants tested including all WHO VOCs and VOIs with
116 fold changes in IC_{50}s ranging from 0.4- to 2.3-fold (**Table 2**).

117 **VIR-7831 and VIR-7831 exhibit potent effector function in vitro.** Although direct antiviral
118 mechanisms are crucial to provide protection, Fc-dependent mechanisms mediated by interaction with Fc
119 gamma receptors (FcγRs) on immune cells or with complement, can contribute to overall potency in vivo.
120 The potential for VIR-7831 and VIR-7832 to mediate effector functions were assessed in vitro by

121 measuring binding to FcγRs and C1q and in assays designed to demonstrate antibody-dependent cellular
122 cytotoxicity (ADCC) or antibody-dependent cellular phagocytosis (ADCP)[31–34].

123 Antibody binding to the human activating FcγRIIa (low-affinity R131 and high affinity H131 alleles),
124 FcγRIIIa (low-affinity F158 and high-affinity V158 alleles), and to the inhibitory FcγRIIb were examined
125 using SPR (**Supplemental figure 1a**). VIR-7831 similarly bound both the H131 and R131 alleles of
126 FcγRIIa and binds FcγRIIb. VIR-7831 bound both FcγRIIIa alleles, with reduced binding to the F158
127 allele compared to V158, as is characteristic for human IgG1[35]. Binding of VIR-7831 to C1q was similar
128 to the parental antibody (S309-LS) (**Supplemental figure 1b**). As previously reported for antibodies
129 encoding the GAALIE mutation[26,36], VIR-7832 bound with comparatively higher affinity to activating
130 FcγRIIa and FcγRIIIa than VIR-7831 (**Supplemental figure 1a**). Conversely, VIR-7832 showed reduced
131 affinity for FcγIIb and abrogation of binding to C1q (**Supplemental figure 1b**).

132 The antibodies were also assessed for the ability to activate human FcγRIIa, FcγRIIb or FcγRIIIa, using a
133 Jurkat cell reporter assay[37] (**Figure 2a-d**). S309-GRLR, which contains the effector function-abrogating
134 G236R, L328R mutations was used as a negative control. Cells stably transfected with the SARS-CoV-2
135 spike protein (CHO-CoV-2-Spike) served as target cells. Both VIR-7831 and the parental S309-LS
136 activated signaling of the higher-affinity allele FcγRIIa (H131) but did so less efficiently than the
137 GAALIE-containing antibody VIR-7832 (**Figure 1a**) while VIR-7831, VIR-7832 and S309-LS induced
138 similar low-level activation of the inhibitory receptor FcγRIIb (**Figure 1b**). VIR-7831 demonstrated
139 substantially lower activation of FcγRIIIa F158 versus V158 as expected while VIR-7832 showed
140 increased activation of both alleles of FcγRIIIa (F158 and V158) (**Figures c,d**).

141 To further elucidate the effector function potential of the antibodies, ADCC and ADCP assays were
142 performed using donor PBMCs or NK cells as effector cells and CHO cells stably expressing S (CHO-
143 CoV-2-Spike) as target cells (**Figure 2e-g**). The ability of antibodies to activate NK cell-mediated killing
144 was measured in vitro using two genotyped donors expressing homozygous low-affinity (F/F158) or high-
145 affinity (V/V158) (**Figure 2e-f**). Compared to the parental mAb S309-LS, VIR-7831 had slightly

146 increased capacity to induce NK cell-mediated ADCC when using cells from either F/F158 or V/V158
147 donors. As expected, VIR-7832 induced NK cell-mediated ADCC in cells from donors expressing the
148 low-affinity F/F158 allele of FcγIIIa more efficiently than VIR-7831. These results were confirmed with
149 NK cells from a heterozygous donor (F/V 158).

150 The ability of VIR-7831 and VIR-7832 to facilitate ADCP by primary $CD14^+$ monocytes was measured in
151 vitro by exposing freshly isolated human PBMCs to CHO-CoV-2-Spike cells that were pre-incubated
152 with antibody (**Figure 2g**). VIR-7831, VIR-7832 and S309-LS induced similar levels of ADCP by $CD14^+$
153 monocytes. These results indicate that VIR-7831 and VIR-7832 have the potential to trigger ADCC and
154 ADCP of cells displaying SARS CoV-2 S protein.

155 **Subneutralizing levels of VIR-7831 and VIR-7832 do not enhance virus uptake, replication or**
156 **cytokine production in vitro.** One potential concern with any antibody therapeutic targeting a viral agent
157 is the possibility of antibody-dependent enhancement (ADE). ADE is an in vivo phenomenon in which
158 the presence of an antibody worsens disease. There are several in vitro assays that may provide plausible
159 correlates for ADE in vivo, though none of these have been proven relevant to COVID-19 as to date ADE
160 has not been observed in trials of monoclonal antibodies or plasma[13,15,38,39]. ADE can occur by several
161 potential mechanisms[40]. Poorly neutralizing antibodies or subneutralizing levels of antibody could
162 theoretically facilitate enhanced virus entry and infection through Fc receptor interactions. A second
163 theoretical mechanism involves antibody-antigen complex formation leading to enhanced cytokine
164 production. A third mechanism of ADE has been observed in a porcine model of influenza where the
165 kinetics of viral fusion to the target cell was enhanced in a Fab-dependent manner by fusion-enhancing
166 non-neutralizing antibodies[41,42].

167 To explore whether VIR-7831 and VIR-7832 exhibit in vitro activities that might be related to ADE in
168 vivo, we evaluated SARS-CoV-2 replication in human cells that express FcγRs: monocyte-derived
169 dendritic cells (moDCs), peripheral blood mononuclear cells (PBMCs) and the human U937 macrophage
170 cell line (**Supplemental Figure 2a-b**). Subneutralizing concentrations of VIR-7831 and VIR-7832 were

171 precomplexed with SARS-CoV-2 (MOI =0.01) and added to target cells. Using immunostaining methods,
172 at 24 hours post-infection no productive entry of SARS-CoV-2 into moDCs, PBMCs, or U937 cells was
173 observed in the presence or absence of either mAb, while VeroE6 control cells demonstrated
174 internalization in all conditions evaluated. Reduced internalization of SARS-CoV-2 in VeroE6 cells was
175 observed at the highest concentration of VIR-7831 and VIR-7832 (p-value <0.05), indicating effective
176 virus neutralization prevented virus entry. Using a focus forming assay, virus replication and secretion of
177 infectious virus were detectable by 48 hours post-infection in VeroE6 cells, with comparable levels of
178 replication in the presence or absence of VIR-7831 or VIR-7832. However, no replication of SARS-CoV-
179 2 was detected in moDCs, PBMCs or U937 cells regardless of antibody treatment, indicating lack of
180 productive SARS-CoV-2 infection of these cells, consistent with previously published data[43].

181 To evaluate the potential for VIR-7831 and VIR-7832 to enhance cytokine release upon SARS-CoV-2
182 infection in FcγR-expressing cells, cytokines and chemokines were measured in the supernatants from
183 cells infected with SARS-CoV-2-in the presence of VIR-7831 or VIR-7832 (**Supplemental figure 2c**).
184 Levels of IFN-γ, IL-10, IL-6, IL 8, IP-10, MCP-1, and TNF-α in the supernatant were quantified by MSD
185 at 24- and 48-hours post-infection. For all cell types evaluated, cytokine/chemokine production was
186 similar between all antibody concentrations tested and the no antibody control at both 24- and 48-hours
187 post-infection. Taken together, these in vitro data indicate that neither VIR-7831 nor VIR-7832 exhibit in
188 vitro activities that have been proposed to possibly correlate with ADE in vivo.

189 **VIR-7831 and VIR-7832 have a high barrier to resistance in vitro and do not display cross-**
190 **resistance with other SARS-CoV-2 mAbs.** We next determined whether resistant variants could be
191 elicited by serial passage of SARS-CoV-2 in the presence of VIR-7832. As VIR-7831 and VIR-7832
192 differ only in the Fc region of the antibody, resistance selection experiments were conducted with VIR-
193 7832 as a proxy for both antibodies. SARS-CoV-2 was subjected to 10 passages in the presence of VIR-
194 7832 at fixed concentrations of ~10x, 20x, 50x or 100x IC_{50} (1, 2, 5, or 10 µg/mL) in VeroE6 cells. No
195 CPE was detected in wells passaged with antibody through 10 passages, while CPE was observed in the

196 no antibody control in all passages. Similarly, no virus was detected by focus forming assay at any
197 concentration of VIR-7832 through all 10 passages even at the lowest concentration tested.

198 As no viral breakthrough was observed in the fixed concentration resistance selection, a second method
199 was employed wherein SARS-CoV-2 virus was passaged in sub-IC_{50} concentrations of antibody followed
200 by subsequent passaging in the presence of increasing concentrations of mAb in an attempt to force
201 resistance emergence (**Supplemental Figure 3**). Passaging was performed in duplicate wells to account
202 for founder effects, and concentration increases for each well were based on CPE observations. Five
203 sequential passages were conducted using increasing concentrations of VIR-7832 at 0.5, 1, 2, 5 and ~10x
204 IC_{50} (0.05, 0.1, 0.2, 0.5, 1 µg/mL; **Supplemental Figure 3a**), though no CPE was observed by passages 4
205 and 5 (0.5 and 1 µg/mL, respectively) indicating that variants originally selected at the lower
206 concentrations were either unfit or susceptible to the higher concentrations of antibody. To further assess
207 whether resistance mutations could be generated, selection was restarted using passage 3 virus generated
208 with ~2x IC_{50} (0.2 µg/mL) of VIR-7832 in duplicate wells at ~2x and ~5x IC_{50} (0.2, 0.5 µg/mL),
209 generating two passage lineages (**Supplemental Figure 3b-c**).

210 Supernatants were evaluated for detectable virus at each passage by focus forming assay and cell
211 supernatants from viral passages containing detectable virus were tested in SARS-CoV-2 neutralization
212 assays to evaluate IC_{50} shifts as a marker of reduced susceptibility (**Supplemental Table 1**). With the
213 exception of passage 8, modest fold changes were observed, with shifts in IC_{50} values ranging from 5.4-
214 to 6.5-fold compared to the wild-type SARS-CoV-2 stock virus. In lineage 1, the passage 8 virus
215 displayed a >10-fold shift in IC_{50} (greater than highest concentration tested). Sequence analysis detected
216 an identical 4 amino acid insertion in the N-terminal domain (215-216insKLRS) and 5 amino acid
217 deletion in correspondence of the furin cleavage site (675-679del) in both lineages at all passages
218 sequenced, as well as the amino acid substitution E340A in lineage 1, and R682W, and V1128F in
219 lineage 2. The deletion at amino acids 675-679 has been previously described during passaging of SARS-
220 CoV-2 in tissue culture suggesting enrichment to be a result of cell culture adaptation[44] while the 215-

221 216insKLRS was detected in the input virus. Neither 215-216insKLRS nor R682W variants were highly
222 enriched with passaging (**Supplemental Table 1**) and enrichment of 675-679del and V1128F did not
223 profoundly alter the VIR-7832 IC_{50}. However, appearance of the E340A variant at 98.7% did correlate
224 with a >10-fold shift in IC_{50} suggesting this variant may confer resistance.

225 To evaluate whether amino acid variants identified in the resistance selection conferred reduced
226 susceptibility to VIR-7831 and VIR-7832, neutralization of pseudotyped viruses encoding the S variants
227 was assessed (**Supplemental Table 2**). VIR-7831 and VIR-7832 neutralized R682W and V1128F SARS-
228 CoV-2 pseudotyped virus spike variants with IC_{50} values similar to wild type (< 2-fold change in IC_{50})
229 indicating that these variants do not alter susceptibility. In contrast, E340A conferred reduced
230 susceptibility to VIR-7831 and VIR-7832 (> 100-fold change in IC_{50}) indicating that E340A is a VIR-
231 7831/VIR-7832 monoclonal antibody resistance mutation (MARM).

232 As VIR-7831/VIR-7832 demonstrated a unique in vitro resistance profile, we investigated the potential
233 for cross-resistance to MARMs that confer reduced susceptibility to the authorized monoclonal antibodies
234 bamlanivimab, imdevimab and casirivimab [10,11,45–47] using pseudotyped virus. Notably, some of these
235 mutations are found in highly prevalent variants of concern[17,30,48]. VIR-7831 effectively neutralized
236 pseudotyped viruses expressing spike MARMs that alter bamlanivimab, casirivimab and/or imdevimab
237 activity (**Table 3**). Fold changes in IC_{50} values compared to wild-type were <3-fold for 18/19 variants
238 tested. A modest 3.4-fold shift in the VIR-7831 IC_{50} was observed for the V445A variant that confers
239 reduced susceptibility to imdevimab. These data indicate that VIR-7831/VIR-7832 does not display cross-
240 resistance with currently authorized mAbs and supports the potential combination use of VIR-7831/VIR-
241 7832 with other mAb therapeutics.

242 **The VIR-7831/VIR-7832 epitope is highly conserved among SARS-CoV-2 sequences.** The parental
243 antibody of VIR-7831 and VIR-7832 (S309) binds to a highly conserved sarbecovirus epitope that is
244 potentially intolerant of variation. To investigate the current state of epitope conservation, >1,700,000
245 spike sequences from SARS-CoV-2 deposited in the GISAID database as of June 4, 2021 were examined

246 for epitope variation. More than 99.8% conservation is seen for those amino acids comprising the epitope
247 among currently available sequences for all positions including 16/23 amino acid positions that were
248 ≥99.99 conserved (**Table 4**).

249 VIR-7831 activity against viral mutants carrying single substitutions in the epitope was assessed in
250 pseudotyped virus assays. VIR-7831 effectively neutralized epitope variants at most amino acid positions
251 tested (**Table 5**). A moderate shift in activity was observed for the K356T variant (5.9-fold shift in IC_{50}).
252 Variants at two positions, E340 and P337, resulted in significant IC_{50} shifts indicating reduced
253 susceptibility to VIR-7831. Moderate shifts in potency were observed for P337H and P337T variants
254 (7.50- and 5.38-fold, respective) while more significant shifts in potency were observed for P337L/R and
255 E340A/K/G (27-fold to >276-fold). Notably, these variants are detected in a low number of sequences
256 and do not have a pattern that suggest emergence in the GISAID database (93 and 95 variant counts out of
257 >1,700,000 sequences for P337 and E340, respectively). This observation is consistent with the
258 possibility that variations at these positions come with a fitness cost to the virus.

259 **VIR-7831 reduces weight loss, total viral load and infectious virus levels in a hamster model of**
260 **SARS-CoV-2 infection.** To evaluate the efficacy of VIR-7831 in vivo, the hamster model was utilized.
261 As it was unknown what effect the LS mutation would have in the hamster, a non-LS version of VIR-
262 7831 (SGHmAb-no-LS) was used for these experiments. Hamsters were administered SGHmAb-no-LS
263 intraperitoneally at Day -1 (30, 5, 0.5 or 0.05 mg/kg) or Day -2 (15, 5, 0.5 or 0.05 mg/kg) prior to
264 intranasal SARS-CoV-2 inoculation (**Figure 3a**). Using body weight as a marker of degree of clinical
265 disease, doses of ≥5mg/kg resulted in significantly reduced weight loss at Day 4 compared to controls.
266 (**Figure 3b-e**). Significant decreases in lung viral load were also observed at ≥5mg/kg as measured by
267 RT-qPCR (**Figures f-g**). Day 4 $TCID_{50}$ measurements indicated that antibody administered at ≥0.5 mg/kg
268 resulted in significantly lower levels of infectious virus in lung tissue compared to controls (**Figure 3h-i**).
269 Notably, across these experiments, no enhancement of disease was observed in animals receiving
270 SGHmAb-no-LS based on changes in weight, viral RNA in the lungs, or $TCID_{50}$ infectious virus levels.

271 Collectively, these data indicate that VIR-7831 prevented in a dose-dependent fashion virus replication
272 and morbidity in SARS-CoV-2 challenged hamsters without signs of ADE at any dose tested.

273 **DISCUSSION**

274 Here we show the in vitro and in vivo preclinical characterization of VIR-7831 and VIR-7832, two
275 monoclonal antibodies being advanced into clinical studies[49–51]. Both antibodies demonstrate high-affinity
276 binding to S in vitro, including on the surface of cells, and effectively neutralize wildtype SARS-CoV-2
277 in a live virus assay. VIR-7831 and VIR-7832 retain activity against the Alpha (B.1.1.7), Beta (B.1.351)
278 and Gamma (P.1) variants in an authentic virus system, consistent with data using pseudotyped viruses.
279 VIR-7831 bind C1q, activate FcγRs and demonstrate ADCC and ADCP in vitro. Experiments in the
280 hamster model of SARS-CoV-2 infection show proof-of-concept efficacy in vivo. Notably, in vitro and in
281 vivo data did not provide any supporting evidence that these antibodies would demonstrate ADE in a
282 clinical setting.

283 That VIR-7831 and VIR-7832 retain activity against spike variants in authentic virus and pseudotyped
284 virus assays is a key finding at this stage of the pandemic. With the increased transmissibility and
285 potential for more severe disease observed with these viruses, the availability of therapeutic or
286 prophylactic mAbs that remains active against variants is essential. In addition to retaining activity
287 against all current WHO VOCs and VOIs, in pseudotyped virus experiments VIR-7831 showed no
288 significant cross-resistance with variants that reduce the activity of authorized mAbs. These data
289 additionally demonstrate the uniqueness of VIR-7831 and VIR-7832 and further highlight the utility VIR-
290 7831 and VIR-7832 could have, alone or in combination, as clinical agents.

291 Notably, even at this stage of the pandemic, the VIR-7831/VIR-7832 epitope remains highly conserved
292 among available sequences of circulating virus with ≥99.8% conservation of epitope amino acids. This is
293 consistent with the value of the strategy used for isolation of monoclonal antibodies that neutralize both
294 SARS-CoV and SARS-CoV-2 based on the idea that these two virulent human viruses are

295 phylogenetically divergent within the sarbecovirus subgenus. Furthermore, MARMs identified at
296 positions P337 and E340 are present at very low levels among current sequences. That amino acids P337
297 and E340 remain ≥99.99% conserved at this stage of the pandemic indicates that variants at these
298 positions may confer disadvantageous effects on the virus, consistent with the conservation of this epitope
299 across the sarbecovirus family[21].

300 Viral variants of concern for RBM-targeting mAbs are quickly spreading[53]. The vaccines presently being
301 deployed around the world generate high-titer neutralizing antibodies that target the S protein RBM.
302 Importantly, the RBM is highly immunodominant for responses to natural infection[54]. Vaccine-induced
303 and convalescent immunity may therefore potentially put further mutational pressure on the RBM
304 sequence to evade such antibody responses. In contrast, antibody responses overlapping with the VIR-
305 7831/VIR-7832 epitope are limited after infection [54], possibly because of the shielding effect of the highly
306 conserved N343 glycan. In this regard the epitope may face less vaccine- or infection-generated immune
307 pressure, potentially preserving this conserved epitope long-term.

308 Recent data have indicated that the cells used to generate live virus stocks and overexpression of
309 ACE2/TMPRSS2 in target cells used for assays can affect mAb activity in vitro[29,55]. The VIR-7831/VIR-
310 7832 parental antibody S309 seems particularly sensitive to in vitro methods using ACE2 overexpressing
311 cells[55]. It is therefore notable that VIR-7831 displays significant efficacy in an in vivo proof-of-concept
312 SARS-CoV-2 infection experiment using hamsters despite the fact that patterns of engagement of hamster
313 FcRs by human IgG1 antibodies may not reflect patterns of human IgG1 antibodies with their cognate
314 human FcRs. These findings argue that in vitro data derived from such ACE2 and/or TMPRSS2
315 overexpression cell lines do not accurately reflect the in vivo antiviral capacity of tested mAbs.
316 Furthermore, that the significant in vivo effects of VIR-7831 in the hamster model likely occurred in the
317 absence of full effector functions due to species-specific interactions between antibodies and FcRs, argues
318 that effects in COVID-19 patients incorporating both the neutralization capacity of the antibody plus the
319 ability to harness the strength of the immune system could lead to positive clinical outcomes.

320 The clinical potential of VIR-7832, with the inclusion of the GAALIE Fc mutation, is of special interest
321 in the context of SARS-CoV-2 infection. Previously published data by the Ravetch laboratory comparing
322 the in vivo efficacy of a hemagglutinin-targeting mAb with and without inclusion of the GAALIE
323 mutation in a transgenic humanized FcγR mouse model of influenza infection demonstrated superior
324 efficacy of the GAALIE-containing antibody in both therapeutic and prophylactic experiments[26]. These
325 effects were mediated by protective $CD8^+$ T cell responses elicited by the GAALIE antibody. Clinical
326 data examining the contribution of the adaptive immune response in SARS-CoV-2 infection indicate that
327 poor T cell induction correlates with severe disease (reviewed in [56]). Thus, the potential for VIR-7832 to
328 augment the T cell response to SARS-CoV-2 infection could conceivably play a crucial role in limiting
329 progression to severe COVID-19 disease or in treatment of severe established disease. This latter
330 possibility is supported by recent publications showing that monoclonal antibodies with effector functions
331 are especially effective in the therapeutic setting via recruitment of tissue-protective monocyte functions
332 [19], and that potency of antibodies in the pre-clinical mouse model does not correlate with in vitro
333 neutralizing activity of antibodies[18].

334 Taken together, these data indicate that VIR-7831 and VIR-7832 could play a powerful role in the fight
335 against COVID-19 through the dual action of broadly neutralizing activity paired with engagement of the
336 immune system through effector function capabilities.

337

338 **METHODS**

339 **Cells.** Vero E6 cells (ATCC) and Lenti-X 293T cells (Takara) were cultured in Dulbecco's Modified
340 Eagle's medium (DMEM), 10% FBS, 1x Penicillin-Streptomycin at 37°C, 5% CO_2.

341 **Monoclonal Antibodies.** VIR-7831 and VIR-7832 were produced at WuXi Biologics (China). SGHmAb-
342 no-LS, S309-LS, and S309-GRLR were produced at Humabs Biomed SA, a subsidiary of Vir

343 Biotechnology (Bellinzona, Switzerland) in expiCHO cells transiently co-transfected with plasmids
344 expressing the heavy and light chain, as previously described [57].

345 **Virus. S**ARS-CoV-2 isolates USA-WA1/2020, UK/VUI/3/2020, hCoV-19/South Africa/KRISP-
346 K005325/2020 and hCoV-19/Japan/TY7-503/2021 were obtained from BEI Resources. To propagate
347 SARS-CoV-2, VeroE6 or VeroE6-TMPRSS2 cells were seeded at $10X10^6$ cells in T175 flasks in growth
348 media and infected the next day at a MOI of 0.001 in virus propagation media. Virus was adsorbed for 1
349 hour at 37°C. Virus inoculum was removed, flasks were washed once with PBS, 25 mL of infection
350 media was added to the cells and flasks were incubated at 37°C. Supernatants were collected at 48 hours
351 post-infection once cytopathic effect was visible, centrifuged at 500 x g for 5 minutes, followed by a
352 second centrifugation at 1000 x g for 5 minutes. Clarified supernatants were then aliquoted and stored at -
353 80°C. Virus titers were determined using a plaque assay on VeroE6 cells, using standard methods.
354 Briefly, 10-fold dilutions of virus stock were incubated in 6 well plates with 2.4% colloidal cellulose
355 overlay for 24 hours. Cells were fixed with 4% PFA for 30 minutes at room temperature (RT),
356 permeabilized with 0.125% Triton X-100, stained with anti-SARS-CoV-2 nucleocapsid antibody at
357 1:5000 and goat anti-rabbit IgG HRP at 1:5000. Plaque forming units (PFU) were visualized with
358 TrueBlue reagent.

359 **In vitro binding ELISA.** For the ELISA assay, 96-well plates were coated with 100 µl/well recombinant
360 SARS-CoV2 RBD diluted in assay diluent (1% BSA/PBS) at a final concentration of 2 µg/mL and
361 incubated overnight at 4°C. Plates were washed three times with 300 µl/well wash buffer using an
362 automated washer. Assay diluent (100 µl/well) was added to block the plates and incubated for 1 hour at
363 room temperature (RT) with shaking. Assay diluent was removed, and plates washed three times with
364 wash buffer. Serial 1:3 dilutions of mAb (concentration range from 6 µg/mL to 0.33 ng/mL) in assay
365 diluent were dispensed at 100 µl/well and incubated 1 hour at RT with shaking, then washed three times
366 with wash buffer. The HRP-conjugated secondary antibody reagent (1:5,000 dilution in assay diluent)
367 was added to each well (100 µl/well) and incubated for 1 hour at RT with shaking. After three washes

368 with wash buffer, 100 µl/well of 2-component TMB peroxidase substrate solution was dispensed in each
369 well and developed for 5 minutes at RT. The reaction was stopped with 100 µL/well 1M H_2SO_4 and the
370 OD was read immediately at 450 nm on a SpectraMax M5 Microplate reader. EC_{50} values were calculated
371 using non-linear regression of log (agonist) versus response in Graph Pad Prism.

372 **Spike binding affinity quantification by SPR.** Antibody was diluted to 2 µg/mL (1 mL) in HBS-EP+
373 buffer and injected at 10 µL/min for 30 seconds across one flow cell of a CM5 sensor chip immobilized
374 with anti-human Fc antibody docked in a Biacore T200. SARS-CoV2-RBD diluted in HBS-EP+ buffer
375 was then injected at a single concentration, 1:3 dilutions from 100 nM to 3.7 nM, across both the flow cell
376 containing captured the antibody as well as a reference flow cell containing only anti-human Fc antibody.
377 Binding was measured with a flow rate of 30 µL/min and an injection time of 600 seconds; dissociation
378 was monitored for 1800 seconds after injection. Data were collected at 10 Hz. After each binding
379 measurement, regeneration reagent was injected to prepare the surface for a new cycle. Experiments were
380 performed at 25°C, with the samples held at 15 °C in the instrument prior to injection.

381 **Measurement of Binding to Human Fcγ Receptors by SPR.** Binding of VIR-7831 and VIR-7832 to
382 human recombinant FcγRs was measured by surface plasmon resonance (SPR) on a Biacore T200.
383 Briefly, Biotin CAPture Reagent (modified streptavidin) was injected across all flow cells of a CAP
384 sensor chip docked in a Biacore T200. Biotinylated Fc receptors at 1 µg/mL were injected across a single
385 flow cell at 10 µL/min for 60 seconds (one receptor per flow cell), with one flow cell reserved as a
386 reference surface. VIR 7831 or VIR-7832 at 100 µg/mL (diluted in HBS-EP+) were injected across all
387 flow cells for 200 seconds using a flow rate of 30 µL/min and association was monitored. Dissociation
388 was monitored for another 200 seconds after injection. Data was collected at 10 Hz. After each binding
389 measurement, CAP Regeneration reagent was injected to prepare the surface for a new cycle.
390 Experiments were performed at 25°C, with the samples held at 15°C in the instrument prior to injection.

391 **Measurement of Binding to Human Complement Protein C1q.** Binding of VIR-7831 and VIR-7832 to
392 human complement was measured by biolayer interferometry (BLI) using an Octet Red96 instrument

393 (FortéBio). Briefly, anti-human Fab (CH1-specific) sensors were used to capture VIR-7831 and VIR-
394 7832 at 10 µg/ml for 10 minutes. The IgG-loaded sensors were then exposed to kinetics buffer containing
395 3 µg/ml of purified human C1q for 4 minutes, followed by a dissociation step in the same buffer for
396 additional 4 minutes. Association and dissociation profiles were measured in real time as changes in the
397 interference pattern.

398 **Binding to Cell Surface Expressed SARS-CoV-2 Spike Protein.** The SARS-CoV-2 spike protein
399 coding sequence (YP_009724390.1, Wuhan-Hu-1 strain) was cloned into a cell expression plasmid under
400 the control of the human CMV promoter (phCMV1) to generate phCMV1 WT spike. ExpiCHO-S cells
401 were seeded the day before transfection at 3 x 10^6 cells/mL in ExpiCHO Expression Medium.
402 Immediately before transfection, the cells were seeded at 6 x 10^6 cells cells/mL in a volume of 15 mL in
403 125 mL shake flasks. Six µg of phCMV1 WT spike plasmid or vector control were diluted in 1.2 mL of
404 iced OptiPRO SFM., followed by addition of 48 µL of ExpiFectamine CHO Reagent and complexing for
405 1 minute at RT. The transfection mixture was added dropwise to cells with gentle swirling. Cells were
406 then incubated at 37°C, 8% CO2 with shaking for 42 hours. At 42 hours post-transfection, ExpiCHO-S
407 cells were harvested, washed twice with FACS buffer and resuspended at a concentration of 1.0 x 10^6
408 cell/mL in PBS. Cells (5 x 10^4 cells in 50 µl/wells) were dispensed into a 96-well V-bottom plate.
409 Antibody was serially diluted (1:4, 10 points) starting at a concentration of 10 µg/mL. Cells were pelleted
410 at 300 x g for 5 minutes and resuspended in 50 µL/well of antibody serial dilutions and plates were
411 incubated for 45 mins on ice. Cells were washed twice in FACS buffer. Alexa Fluor 647-labelled Goat
412 Anti-Human IgG secondary Ab was diluted 1:750 in FACS buffer and 50 µL was added to the cell pellet
413 for 15 min on ice. Cells were washed twice with FACS buffer, resuspended in 1% PFA. Data was
414 acquired by flow cytometry (CytoFlex LX).

415 **Pseudotyped virus production.** Lenti-X™ 293T cells were seeded in 10-cm dishes for 80% next day
416 confluency. The next day, cells were transfected with the plasmid pcDNA3.1(+)-spike-D19 (encoding the
417 SARS-CoV-2 spike protein) or pcDNA3.1(+)-spike-D19 variants using the transfection reagent TransIT-

418 Lenti according to the manufacturer's instructions. One day post-transfection, cells were infected with
419 VSV-luc (rVSVΔG; Kerafast) at an MOI of 3. The cell supernatant containing SARS-CoV-2 pseudotyped
420 virus was collected at day 2 post-transfection, centrifuged at 1000 x g for 5 minutes to remove cellular
421 debris, aliquoted and frozen at -80°C.

422 **In Vitro Neutralization of SARS-CoV-2 Pseudotyped Virus.** VeroE6 cells were seeded into flat
423 bottom tissue culture 96-well plates at 20,000 cells/well and cultured overnight at 37°C. Twenty-four
424 hours later, 9-point 1:4 serial dilutions of VIR-7831 were prepared in infection medium and each dilution
425 was tested in triplicate per plate (range: 20,000 to 0.3 ng/mL final concentration). SARS-CoV-2 virus
426 stock was diluted in infection media for a final concentration of 2000 plaque forming units per well (MOI
427 0.1). Antibody dilutions were added to virus and incubated for 30 minutes at 37°C. Media was removed
428 from the VeroE6 cells, mAb-virus complexes were added, and cells were incubated at 37°C. At 6 hours
429 post-infection, cells were fixed with 250 µL 4% PFA, incubated for 30 minutes at RT, then washed 3
430 times with PBS to remove residual PFA. The cells were permeabilized with 50 µL of 0.125% Triton X-
431 100 in PBS for 30 minutes at RT. The blocking buffer was removed, 50 µL of SARS-CoV-2 nucleocapsid
432 antibody at 1:2,000 in blocking buffer was added, and plate was incubated for 1 hour at RT. Plates were
433 washed three times with PBS and then incubated for 1 hour at RT with 50 µL/well of goat anti-rabbit-
434 Alexa647 secondary antibody at a final dilution of 1:1,000 mixed with 2 ug/mL Hoechst dye in blocking
435 buffer. After washing 5 times with PBS, 100 µL of fresh PBS was added for imaging. Plates were imaged
436 on a Cytation5 plate reader. Whole well images were acquired (12 images at 4X magnification per well)
437 and nucleocapsid-positive cells were counted using the manufacturer's software.

438 **Live virus neutralization.** VeroE6 cells were seeded into flat bottom tissue culture 96-well plates at
439 20,000 cells/well and cultured overnight at 37°C. Twenty-four hours later, 9-point 1:4 serial dilutions of
440 VIR-7831 were prepared in infection medium and each dilution was tested in triplicate per plate (range:
441 20,000 to 0.3 ng/mL final concentration). SARS-CoV-2 virus stock was diluted in infection media for a
442 final concentration of 2000 plaque forming units per well (MOI 0.1). Antibody dilutions were added to

443 virus and incubated for 30 minutes at 37°C. Media was removed from the VeroE6 cells, mAb-virus
444 complexes were added, and cells were incubated at 37°C. At 6 hours post-infection, cells were fixed with
445 250 µL 4% PFA, incubated for 30 minutes at RT, then washed 3 times with PBS to remove residual PFA.
446 The cells were permeabilized with 50 µL of 0.125% Triton X-100 in PBS for 30 minutes at RT. The
447 blocking buffer was removed, 50 µL of SARS-CoV-2 nucleocapsid antibody at 1:2,000 in blocking buffer
448 was added, and plate was incubated for 1 hour at RT. Plates were washed three times with PBS and then
449 incubated for 1 hour at RT with 50 µL/well of goat anti-rabbit-Alexa647 secondary antibody at a final
450 dilution of 1:1,000 mixed with 2 ug/mL Hoechst dye in blocking buffer. After washing 5 times with PBS,
451 100 µL of fresh PBS was added for imaging. Plates were imaged on a Cytation5 plate reader. Whole well
452 images were acquired (12 images at 4X magnification per well) and nucleocapsid-positive cells were
453 counted using the manufacturer's software..

454 **Determination of Viral Titer by Focus-Forming Assay.** One day prior to infection, $1.2X10^4$ VeroE6
455 cells were plated in black-walled, clear bottomed 96-well plates. Virus samples were diluted 1:5 in
456 infection media and adsorbed onto VeroE6 cells for one hour at 37°C. The cells were washed once and
457 overlaid with 1% methylcellulose/serum-containing media. At 24 hours post-infection, the
458 methylcellulose overlay was removed, and cells were washed with PBS. Cells were fixed with 4% PFA,
459 incubated for 30 minutes at RT, then washed with PBS to remove residual PFA. The cells were
460 permeabilized with 50 µL of 0.25% Triton X-100 in PBS for 30 minutes at RT. The Triton X-100 was
461 removed, cells were washed twice with PBS, and incubated with 50 µL of SARS-CoV-2 nucleocapsid
462 antibody at 1:2,000 in blocking buffer for one hour at RT. Plates were washed three times with PBS and
463 then incubated for one hour at RT with 50 µL/well of goat anti-rabbit-Alexa647 secondary antibody at
464 1:1,000 in blocking buffer. After washing three times with PBS, 50 µL of Hoechst dye at 1:1,000 in PBS
465 was added for imaging. Plates were imaged on a Cytation5 plate reader. Whole well images were
466 acquired (12 images at 4X magnification per well) and nucleocapsid-positive foci were counted using the
467 manufacturer's software and used to determine focus-forming units/mL supernatant (FFU/mL).

468 **Determination of mAb-Dependent Activation of Human FcγRIIa, FcγRIIIa or FcγRIIb.** VIR-7831,
469 VIR-7832, S309-LS, and a control mAb with abrogated FcγR binding, S309-GRLR, were serially diluted
470 6-fold in assay buffer from 10,000 ng/ml to 0.006 ng/ml. Nine-point serial dilutions of mAbs were
471 incubated with 12,500 (for FcγRIIIa and FcγRIIb) or 10,000 (for FcγRIIa) CHO-CoV-2-Spike cells per
472 96-plate well in a white, flat-bottom plate for 15 minutes at room temperature. Jurkat effector cells
473 expressing indicated FcγRs and stably transfected with an NFAT-driven luciferase gene were thawed,
474 diluted in assay buffer, and added to the plate at an effector to target cell ratio of 6:1 for FcRγIIIa and
475 FcγRIIb or 5:1 for FcγIIa. Control wells were also included that were used to measure antibody-
476 independent activation (containing target cells and effector cells but no antibody) and background
477 luminescence of the plate (wells containing assay buffer only). Plates were incubated for 18 hours at 37°C
478 with 5% CO2. Activation of human FcγRs in this bioassay results in the NFAT-mediated expression of
479 the luciferase reporter gene. Luminescence was measured with a luminometer after adding the Bio
480 GloTM Luciferase Assay Reagent according to the manufacturer's instructions. To control for
481 background, the mean of the relative luminescence units (RLU) values in wells containing only Assay
482 Buffer was calculated and subtracted from all data points. Data were expressed as the average of RLUs
483 over the background

484 **Determination of NK-Cell Mediated Antibody-Dependent Cellular Cytotoxicity.** Primary NK cell
485 activation was tested using freshly isolated cells from two previously genotyped donors expressing
486 homozygous low affinity (F158) or high affinity (V158) FcγRIIIa. Serial dilutions of mAbs (serially
487 diluted 10-fold in AIM-V Medium from 40,000 ng/ml to 0.075 ng/ml) were incubated with 7,500 CHO-
488 CoV-2 Spike cells per well of a 96 well round-bottom plate for 10 minutes. Target cell and antibody
489 mixtures were then incubated with primary human NK cells as effectors at an effector-to-target ratio of
490 10:1. ADCC was measured using lactate dehydrogenase (LDH) release as a readout according to the
491 manufacturer's instructions (Cytotoxicity Detection Kit (LDH), Roche) after 4 hours of incubation at
492 37°C. In brief, plates were centrifuged for 4 minutes at 400 x g, and 35 µl of supernatant was transferred

493 to a flat 384 well plate. LDH reagent was prepared and 35 µl were added to each well. Using a kinetic
494 protocol, the absorbance at 490 nm and 650 nm was measured once every 2 minutes for 8 minutes, and
495 the slope of the kinetics curve was used as result. The percent specific lysis was determined by applying
496 the following formula: (specific release – spontaneous release) / (maximum release - spontaneous release)
497 x 100.

498 **Determination of Monocyte-Mediated Antibody-Dependent Cellular Phagocytosis.** ADCP assays
499 were performed using human PBMCs freshly isolated from whole blood. CHO CoV-2-Spike cells were
500 used as target cells and were fluorescently labeled with PKH67 Fluorescent Cell Linker Kit (Sigma
501 Aldrich) prior to incubation with mAbs, according to manufacturer's instructions. Serial dilutions of
502 mAbs (serially diluted 5-fold from 5,000 ng/ml to 0.32 ng/ml in RPMI-1640 + L-glutamine supplemented
503 with 10% Hyclone FBS + 2x anti-anti (antibiotic-antimycotic)) were incubated with 10,000 CHO-CoV-2-
504 Spike cells per well of a 96 well polypropylene plate for 10 minutes. Primary PBMCs were fluorescently
505 labeled with Cell Trace Violet according to the manufacturer's instructions. Target cell and antibody
506 mixtures were then incubated with labeled PBMCs at an effector-to-target ratio of 16:1. After an
507 overnight incubation at 37°C, monocytes were stained with anti-human CD14-APC antibody (BD
508 Pharmingen). Antibody-mediated phagocytosis was determined by flow cytometry, gating on CD14+
509 cells that were double positive for cell trace violet and PKH67. Raw data were exported from the flow
510 cytometer into the flow cytometry analysis software FlowJo v10 (Becton Dickinson) for gating and
511 determination of the percentage of $CD14^+$ cells that were also double positive for cell trace violet and
512 PKH67. Cells expressing only cell trace violet or only PKH67 were used to set the positive staining gates.

513 **In vitro resistance selection.** The selection of variants in the presence of increasing concentrations of
514 VIR-7832 was conducted in VeroE6 cells. The day before infection, 6 x 10^4 VeroE6 cells were seeded in
515 24 well plates and incubated overnight at 37°C. The next day, 600 focus forming units (FFU) of SARS-
516 CoV-2 virus (MOI = 0.01) was incubated with 0.5X IC_{50} of VIR-7832 (0.05 µg/mL) at 37°C for one hour
517 in infection media. The mAb-virus complexes were adsorbed on VeroE6 cells for one hour at 37°C in

518 duplicate wells. After adsorption, cells were washed with DMEM and overlaid with infection media
519 containing 0.05 µg/mL VIR-7832. Control wells infected without antibody were included with each
520 passage. Infected cells were monitored visually for CPE daily. In general, when infected cells exhibited ≥
521 50% CPE, the culture supernatants were harvested, diluted 1:200, and added to fresh VeroE6 cells in 24-
522 well plates with equivalent or increasing concentrations of VIR-7832. At each passage, supernatant was
523 aliquoted and frozen at -80°C for titer and neutralization analyses.

524 **In vitro assessment of potential for ADE.** VeroE6 cells were plated at $1.25X10^4$ cells/well one day prior
525 to infection. For each independent experiment, moDCs and PBMCs from five unique moDC donors and
526 six unique PBMC donors were used, with three unique donors used for each independent experiment.
527 Cryopreserved monocytes from unique donors were differentiated into moDCs for six days using human
528 moDC differentiation media according to the manufacturer's protocol. Cryopreserved PBMCs from
529 unique donors are thawed in the presence 0.3 mg/mL DNase and cultured in media for one day prior to
530 infection. On the day of infection, moDCs, PBMCs, and U937 cells were counted and plated at $7.5X10^4$
531 cells/well.

532 To examine viral entry, 24 hours post-infection, cells were fixed with 4% PFA, incubated for 30 minutes
533 at RT, then washed with PBS to remove residual PFA. The cells were permeabilized with 50 µL of 0.25%
534 Triton X-100 in PBS for 30 minutes at RT. The Triton X-100 was removed, cells were washed twice with
535 PBS, and incubated with 50 µL of SARS-CoV-2 nucleocapsid antibody at 1:2,000 in blocking buffer for
536 one hour at RT. Plates were washed three times with PBS and then incubated for one hour at RT with 50
537 µL/well of goat anti-rabbit-Alexa647 secondary antibody at 1:1,000 in blocking buffer. After washing
538 three times with PBS, 50 µL of Hoechst dye at 1:1,000 in PBS was added for imaging. Plates were
539 imaged on a Cytation5 plate reader. Whole well images were acquired (12 images at 4X magnification
540 per well) and nucleocapsid-positive cells were counted using the manufacturer's software. The percent of
541 nucleocapsid+ cells was quantified using the Gen5 Imager software (Biotek, Vermont) as number of

542 Cy5+ cells, [(nucleocapsid+ cells)/number of Hoechst+ cells (total cells)]x100. Data was analyzed using
543 Prism v8.00 (GraphPad Software, La Jolla California USA, www.graphpad.com).

544 In order to quantify chemokines and cytokines from supernatants in a BSL2 laboratory, supernatants were
545 inactivated by 10 minutes exposure to UVC light at 5,000 µJ/cm2. Supernatants were diluted 1:5 in
546 infection media and levels of cytokines/chemokines were quantified using the U-plex 96-well assay
547 according to the manufacturer's protocol (Meso Scale Diagnostics, Rockville, MD). Quantification of
548 cytokines and chemokines were determined based on an 8-point standard curve in duplicate, provided by
549 the manufacturer. Cytokine data was analyzed using the Discovery Workbench v4.0.13 software (Meso
550 Scale Diagnostics). Data was graphed and statistical analyses were conducted using Prism software.

551 **Sequencing of SARS-CoV-2 Spike Gene.** To isolate nucleic acid from the supernatant of viral passages,
552 120 µL of cell supernatant was added to 360 µL of Trizol and stored at -80°C for further analysis. Trizol
553 collected samples from viral passages where a shift in neutralization > 2-fold relative to wild type was
554 detected were subjected to RNA isolation using PureLink RNA Mini Kit with the incorporation of on-
555 column PureLink DNase Treatment, following manufacturer's instructions. Reverse transcription
556 reactions were performed with 6 µL of purified RNA and oligoT primers using the NEB ProtoScript II
557 First Strand cDNA Synthesis kit, according to manufacturer's instructions. The resulting cDNA was used
558 as a template for PCR amplification of the spike gene using the KapaBiosystems polymerase (KAPA HiFi
559 HotStart ReadyMix) with primers 5' aattatcttggcaaaccacg-3' and 5' tgaggcttgtatcggtatcg-3'.
560 Amplification conditions included an initial 3 minutes at 95°C, followed by 28 cycles with 20 seconds at
561 98°C, 15 seconds at 62°C and 72°C for 2 minutes, with a final 4 minutes at 72°C. PCR products were
562 purified using AMPure XP beads following manufacturer's instructions. The size of the amplicon was
563 confirmed by analyzing 2 µL of PCR products using the Agilent D5000 ScreenTape System. Products
564 were quantified by analyzing 1 µL with the Quant-iT dsDNA High-Sensitivity Assay Kit. Twenty ng of
565 purified PCR product was used as input for library construction using the NEBNext Ultra II FS DNA
566 Library Prep kit following manufacturer's instructions. DNA fragmentation was performed for 13

567 minutes. NEBNext Multiplex Oligos for Illumina Dual Index Primer Set 1 was used for library
568 construction, with a total of 6 PCR cycles. Libraries size was determined using the Agilent D1000
569 ScreenTape System and quantified with the Quant iT dsDNA High-Sensitivity Assay Kit. Equal amounts
570 of each library were pooled together for multiplexing and 'Protocol A: Standard Normalization Method'
571 of the Illumina library preparation guide was used to prepare 8 pM final multiplexed libraries with 1%
572 PhiX spike-in for sequencing. The MiSeq Reagent Kit v3 (600-cycle) was used for sequencing the
573 libraries on the Illumina MiSeq platform, with 300 cycles for Read 1, 300 cycles for Read 2, 8 cycles for
574 Index 1, and 8 cycles for Index 2.

575 **Bioinformatics Analysis of Conservation.** Available genome sequences for SARS-CoV-2 were
576 downloaded from Global Initiative on Sharing All Influenza Data (GISAID; https://www.gisaid.org/) on
577 June 4, 2021. Bat and pangolin sequences were removed to yield human-only sequences. The spike open
578 reading frame was localized by aligning the reference protein sequence (NCBI reference sequence:
579 YP_009724390.1) to the genomic sequence of isolates with Exonerate v.2.4.0. Coding nucleotide
580 sequences were translated in silico using seqkit v.0.12.0. Multiple sequence alignment was performed
581 using MAFFT v.7.455. Variants were determined by comparison of aligned sequences to the reference
582 sequence using the R v3.6.3/Bioconductor v.3.10 package Biostrings v.2.54.0.

583 **In vivo studies.** Syrian golden hamster studies were conducted at Lovelace Biomedical (Albuquerque,
584 NM). Twelve- to sixteen-week-old male hamsters were interperitoneally administered a non-LS version
585 of VIR-7831 (SGHmAb-no-LS), control antibody or diluent Day -1 or Day -2 prior to virus challenge.
586 Animals were inoculated intranasally at Day 0 with $7.4x10^4$ $TCID_{50}$ with SARS-CoV-2 (isolate USA-
587 WA1/2020). Animals were also weighed once daily in the morning beginning on study Day -10 and
588 continuing until the end of the study. Following euthanasia, RT-qPCR was performed on lung
589 homogenates using quantitative real-time PCR methods targeting the SARS-CoV-2 N gene and the
590 median tissue culture infections dose ($TCID_{50}$) was determined per Lovelace internal methodology.

591 **Author Contributions**

592 Conceived studies: A.L.C, C.H-D., F.A.P, D.M., M.S., L.S., A.T., L.A.P., S.H., G.S., H.W.V., D.C., C.M.H.
593 Designed studies and experiments: A.L.C, C.H.D., F.A.P, D.M., M.S., M.L.A., E. D., B.G., J.D., L.R.,A.C., A.S.,
594 R.S., J.W., N.C., E.C., S.L., C.C., D.P., C.S., J.N., A.P., A.W., L.S., A.T., L.A.P., S.H., G.S., H.W.V., D.C., C.M.H.
595 Performed experiments: D.M., M.S., M.L.A., B.G., J.D., E.D., A.S., L.R., H.T., J.D., S.S., D.P., C.S., J.N., B.S.,
596 S.B., J.W., J.Z., H.K., A.C., M.M-R., A.P., A.W., N.C., E.C. Analyzed and interpreted data: A.L.C., C.H-D., F.A.L.,
597 D.M., M.S., M.L.A., B.G., J.D., D.P., C.S., J.N., E.L., A.S., R.S., L.R., H.T., B.S., S.B., J.W., J.Z., H.K., A.C., M. M-
598 R., N.C., E.C., S.L., A.W., C.C., L.S., A.T., S.H., G.S., H.W.G, D.C., C.M.H. Prepared the manuscript with input
599 from all authors: A.L.C., G.S., A.T., L.P., D.C., H.W.G., C.M.H.

600 **Competing interests**

601 Some authors are current or former employees of Vir Biotechnology or Humabs BioMed SA (a fully-
602 owned subsidiary of Vir Biotechnology) and may hold shares in Vir Biotechnology. H.W.V. is a founder of
603 PierianDx and Casma Therapeutics.

604

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745

746 **FIGURE LEGENDS**

747 **Figure 1.** VIR-7831 and VIR-7831 bind S and neutralize SARS-CoV-2 virus and S variants of concern in
748 vitro. a) Binding of VIR-7831 (black circles) and VIR-7832 (blue squares) to SARS-CoV-2 RBD was
749 tested by ELISA. Shown is the average of four replicates and SD derived from three independent
750 experiments. b) Association and dissociation profiles of VIR-7831 to SARS-CoV-2-RBD were measured
751 using SPR. The double reference subtracted curves (shown for single replicates) are plotted together with
752 the curve fit in black (obscured by close overlay with the data). Values are from two independent
753 experiments. c) Binding of VIR-7831 (black circles) and VIR-7832 (blue squares) to cell-surface S
754 protein was determined by flow cytometry. Data are expressed as the percentage of the positive cells.
755 Results shown are from one experiment and representative of three independent experiments performed.
756 d) In vitro neutralization of live SARS-CoV-2 by different concentrations of VIR-7831 (left) and VIR-
757 7832 (right) measured by nucleocapsid staining 6-hours post-infection. Results shown are from one
758 experiment and representative of at least three independent experiments performed.

759 **Figure 2.** VIR-7831 and VIR-7832 demonstrate effector function in vitro. In vitro effector function (a-e)
760 activation profiles of human FcγRIIa (a), FcγRIIb (b), FcγRIIIa low-affinity (F158) (c) or FcγRIIIa high-
761 affinity binding allele (V158) (d) using bioreporter assays using S-expressing CHO cells as the target

762 antigen. Data points show means± SD of duplicates. NK-cell mediated killing (ADCC) of S-expressing
763 CHO cells using freshly isolated cells from two donors previously genotyped for homozygous expression
764 of low-affinity (F/F158) (e) or high-affinity (V/V158) FcγRIIIa (f). Data points are means of
765 quadruplicates ± SD. g) Antibody-dependent cellular phagocytosis (ADCP) using S-expressing CHO cells
766 and freshly isolated PBMCs. Data represent the means of duplicates ± SD.

767 **Figure 3.** VIR-7831 shows in vivo efficacy in a hamster SARS-CoV-2 model of infection. a) Overview
768 of hamster in vivo study design. b) and c) Animal weight over time as a percent of starting weight in
769 animals dosed a Day -1 (b) or Day -2 (c). Medians of at least N=6 animals and interquartile range are
770 shown. d) and e) Day 4 terminal weights expressed as a percentage of starting weight for animals dosed at
771 Day -1 (d) or Day -2 (e). Bar denotes median values. f) and g) Day 4 lung viral load in Day -1 (f) or Day -
772 2 (g) treated animals as assessed by RT-qPCR. Bar denotes median values. h) and i) infectious virus in
773 lung at Day 4 for Day -1 (h) or Day -2 (i) dosed animals. Bar denotes median values. ns=not significant,
774 ** = $p<0.05$, and *** = <0.005 as assessed by the Mann-Whitney U-test.

775 **Table 1.** VIR-7831 and VIR-7832 retain activity against S variants of concern in an authentic virus
776 system**.** Average fold change in VIR-7831 and VIR-7832 IC_{50} compared to relative wild-type controls for
777 S variants tested in an authentic virus system. Data shown are averages of at least two independent
778 experiments.

779 **Table 2.** VIR-7831 and VIR-7832 retain activity against S variants of concern in a pseudotyped virus
780 system**.** Average fold change in VIR-7831 and VIR-7832 IC_{50} compared to relative wild-type controls for
781 S variants tested in a VSV/VeroE6 pseudotyped virus system. Data shown are averages of at least two
782 independent experiments.

783 **Table 3.** VIR-7831 and VIR-7832 retain activity against variants that confer resistance to authorized
784 mAbs. Activity of VIR-7831 against variants conferring reduced susceptibility to bamlanivimab,
785 imdevimab or casirivimab in a VSV/VeroE6 pseudotyped virus system. The geometric mean of IC_{50}s and

786 average fold-change versus the relative wild-type control from at least two independent experiments are
787 shown.

788 **Table 4.** The VIR-7831/VIR-7832 epitope is highly conserved. Conservation data comprising >1,700,000
789 sequences from the GISAID database and variants at each position are shown. Variants in bold were
790 tested in a pseudotyped virus assay.

791 **Table 5.** Activity of VIR-7831 against epitope variants. VIR-7831/VIR-7832 epitope variants detected in
792 sequences from the GISAID database were tested in a VSV/VeroE6 pseudotyped virus system. The
793 geometric mean of IC_{50}s and average fold-change versus the relative wild-type control from at least two
794 independent experiments are shown. Variants marked with "a" indicates that the data shown are from the
795 parental antibody S309.

796 **Supplemental Figure 1.** Binding of VIR-7831 and VIR-7832 to human FcγRs and C1q as measured by
797 SPR. Binding of VIR-7831 and VIR-7832 to a) human FcγRIIa (H131 and R131 alleles), FcγRIIIa (F158
798 and V158 alleles) and FcγRIIb were measured using SPR. Biotinylated purified FcγRs were captured on
799 the sensor chip surface prior to injection of VIR-7831 or VIR-7832. Association and dissociation profiles
800 (separated by the vertical dotted line) were measured in real time as change in the SPR signal. b) Binding
801 of VIR-7831 and VIR-7832 to complement component C1q was measured using BLI on an Octet Red96
802 instrument. Association and dissociation profiles (separated by the vertical dotted line) were measured in
803 real time as change in the interference pattern.

804 **Supplemental Figure 2.** Sub-neutralizing concentrations of VIR-7831 and VIR-7832 do not enhance
805 viral entry, viral replication or cytokine production in vitro. Internalization (a) and replication (b) of
806 SARS-CoV-2 was evaluated in VeroE6, moDCs or PBMCs at various timepoints. Two independent
807 experiments with human moDCs and PBMCs from three individual donors were analyzed (5 unique
808 moDC donors, 6 unique PBMC donors total between two experiments). VeroE6 cells were run in
809 duplicate for both independent experiments. Data from each replicate well from two independent

810 experiments are plotted as individual points, with horizontal lines representing the median. Mann-
811 Whitney U-test comparison to no antibody group, *$p<0.05$. c) Supernatant cytokine and chemokine levels
812 as measured by MSD at the indicated time post infection. Data from two independent experiments (three
813 replicates each, five unique donors) are plotted as the mean and SD.

814 **Supplemental Figure 3.** Overview of VIR-7832 resistance selection method. All passaging was
815 conducted in duplicate wells. (a) VIR-7832 concentration was increased during each passage. P3 X
816 indicates passage 3 virus, after which virus was lost with subsequent increases in concentration. In (b) and
817 (c), p3X denotes where passage 3 virus from (a) was used to initiate (b) viral lineage 1 and (c) viral
818 lineage 2. Arrows indicate passages that were subjected to sequence analysis, and * indicate the passages
819 in lineage 1 with no detectable virus or CPE. Selection continued for a total of eight passages.

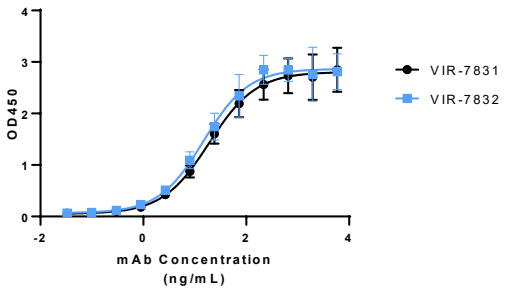
820 **Supplemental Table 1.** Amino acid substitutions identified in the SARS-CoV-2 S upon in vitro selection
821 with VIR-7832. Spike gene sequences were compared to a SARS-CoV-2 reference sequence (NCBI:
822 NC_045512.2) to identify variants. Fold-changes in IC_{50} were determined compared to the SARS-CoV-2
823 virus stock.

824 **Supplemental Table 2.** VIR-7831 and VIR-7832 activity against selected S variants. VIR-7831/VIR-
825 7832 epitope variants observed by in vitro resistance selection were individually tested in a VSV/VeroE6
826 pseudotyped virus system. The geometric mean of IC_{50}s and average fold-change versus the relative wild-
827 type control from at least two independent experiments are shown.

828

Figure 1

a)



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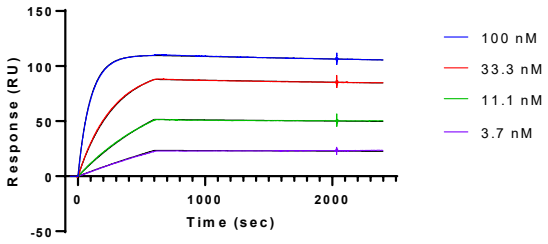

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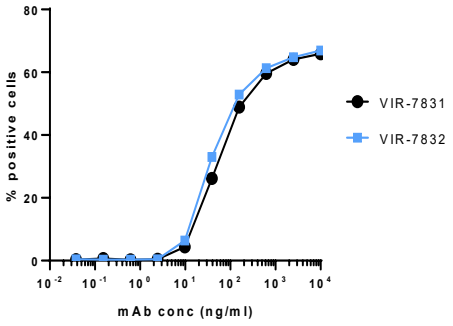

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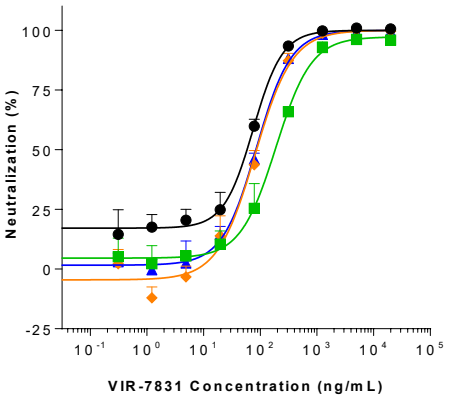


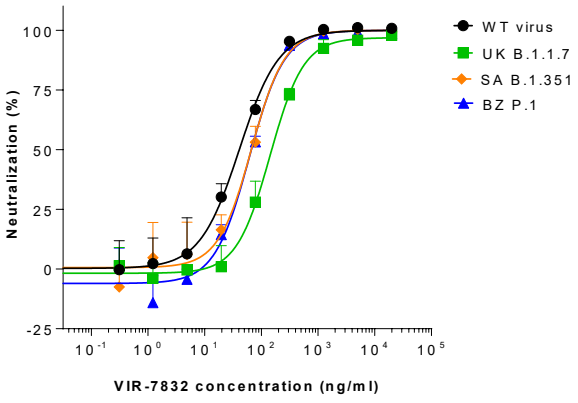


Figure 2

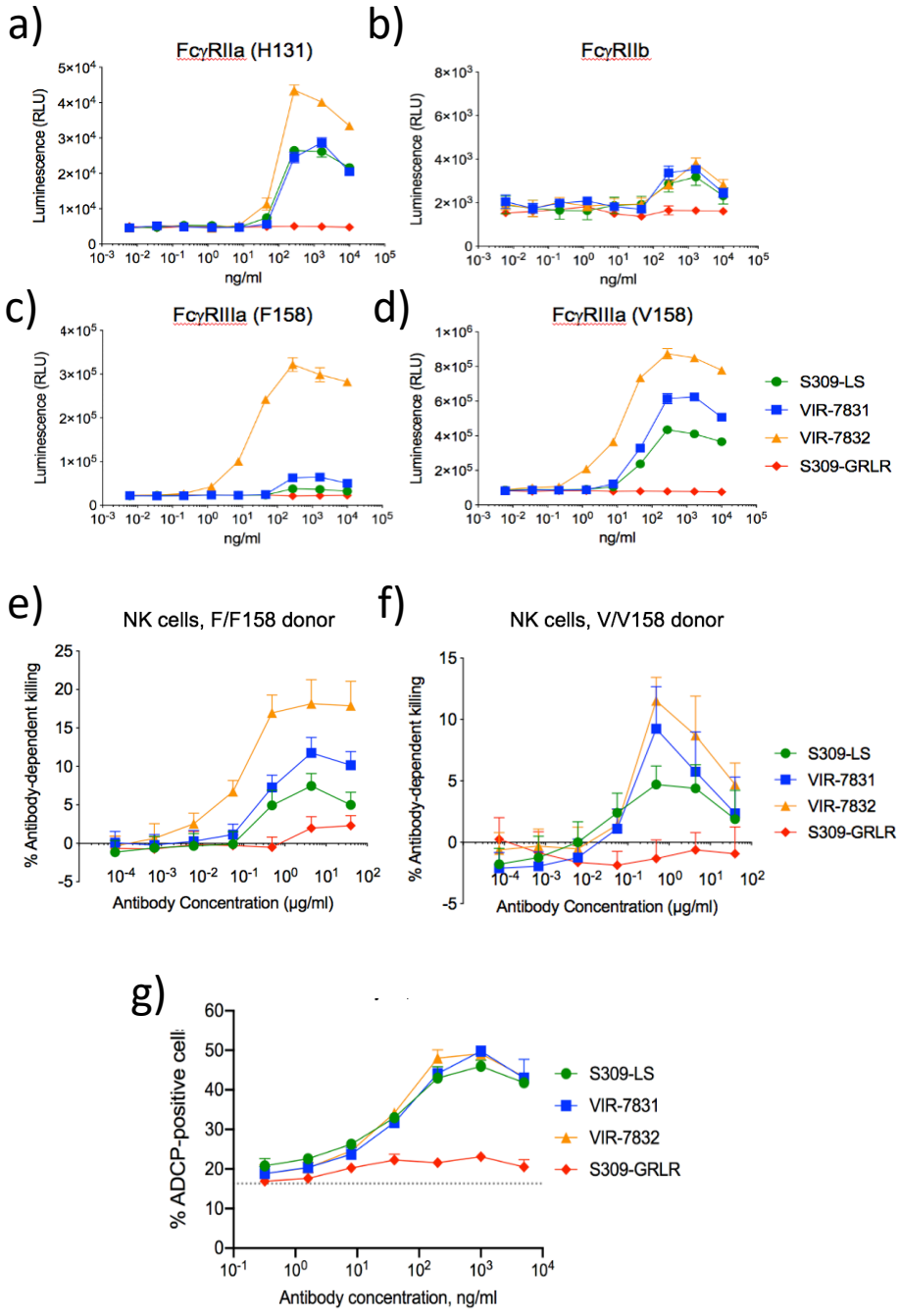
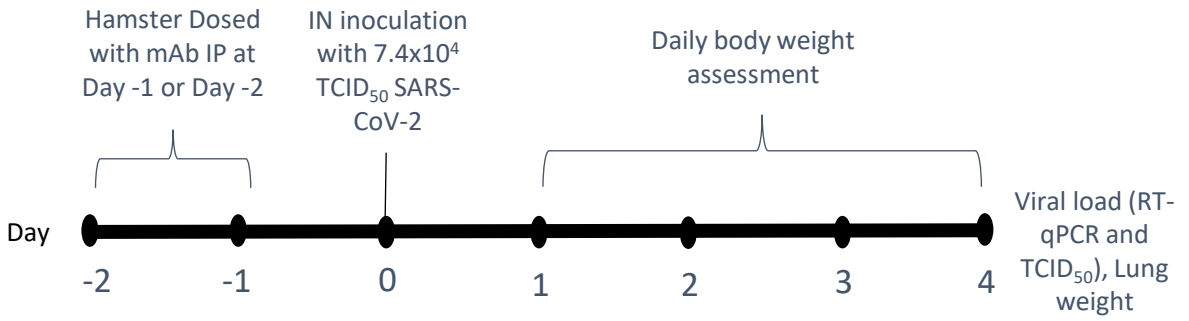

a)
FcγRIIa (H131)
Luminescence (RLU)
ng/ml
b)
FcγRIIb
Luminescence (RLU)
ng/ml
c)
FcγRIIIa (F158)
Luminescence (RLU)
ng/ml
d)
FcγRIIIa (V158)
Luminescence (RLU)
ng/ml
S309-LS
VIR-7831
VIR-7832
S309-GRLR
e)
NK cells, F/F158 donor
% Antibody-dependent killing
Antibody Concentration (μg/ml)
f)
NK cells, V/V158 donor
% Antibody-dependent killing
Antibody Concentration (μg/ml)
S309-LS
VIR-7831
VIR-7832
S309-GRLR
g)
% ADCP-positive cell
Antibody concentration, ng/ml
S309-LS
VIR-7831
VIR-7832
S309-GRLR

Figure 3

a)



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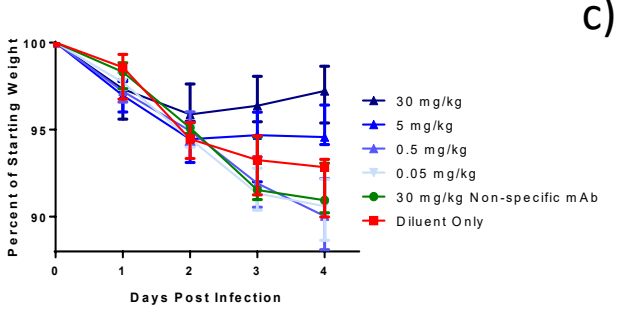

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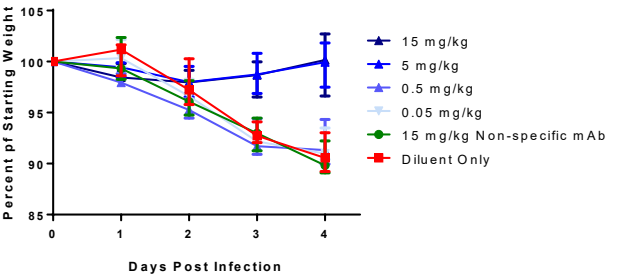

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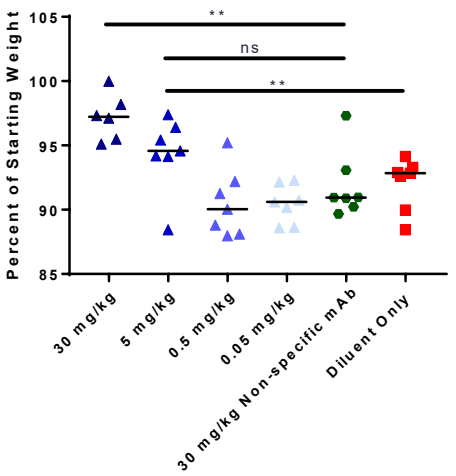

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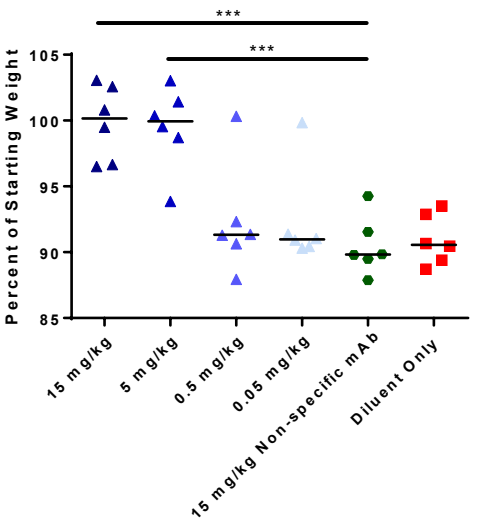

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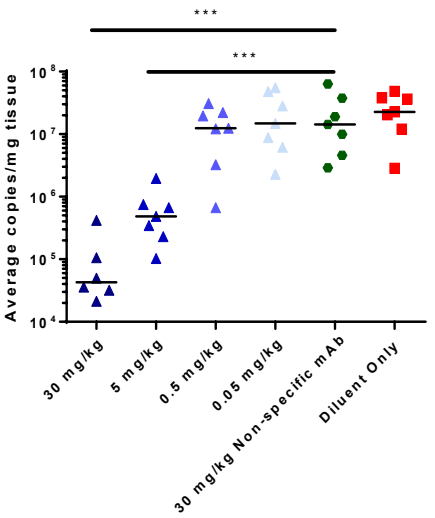

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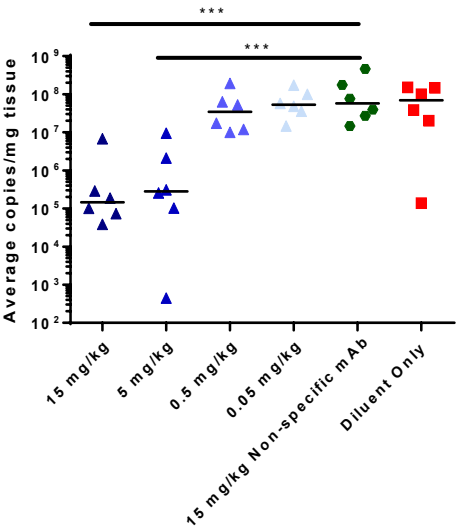

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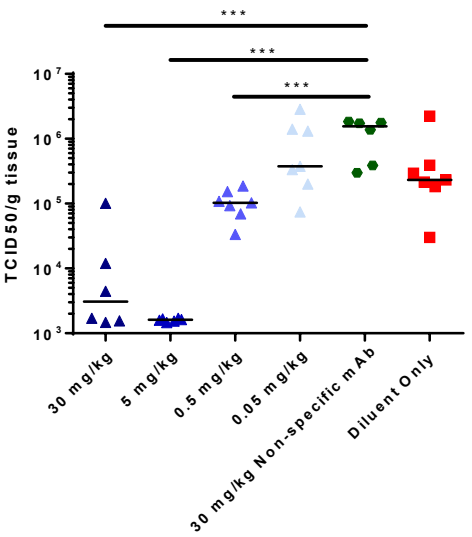


i)

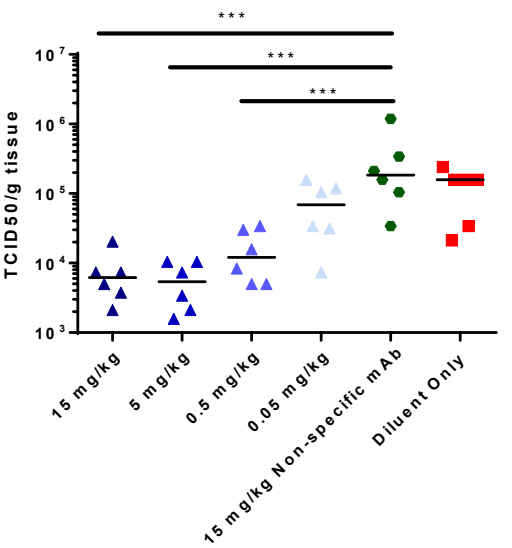


Table 1

SARS-CoV-2 Variant	**Geometric Mean VIR-7831 IC_{50} (ng/ml) (Average Fold Change IC_{50} vs. Wild-Type)**	**Geometric Mean VIR-7831 IC_{90} (ng/ml) (Average Fold Change IC_{90} vs. Wild-Type)**	**Geometric Mean VIR-7832 IC_{50} (ng/ml) (Average Fold Change IC_{50} vs. Wild-Type)**	**Geometric Mean VIR-7832 IC_{90} (ng/ml) (Average Fold Change IC_{90} vs. Wild-Type)**
UK (B.1.1.7)	187.15 (3.0)	1246.86 (4.1)	181.12 (3.1)	1222.95 (3.7)
South Africa (B.1.351)	71.89 (1.2)	385.01 (1.3)	59.67 (1.1)	309.84 (0.9)
Brazil (P.1)	73.11 (1.6)	335.79 (1.4)	48.94 (1.2)	217.02 (0.9)

Table 2

Variant	Spike Mutations	Fold-Change in VIR-7831 IC_{50} vs. Wild-type	Fold-Change in VIR-7832 IC_{50} vs. Wild-type
Alpha (B.1.1.7)	H69-, V70-, Y144-, N501Y, A570D, D614G, P681H, T716I, S982A, D1118H	2.3	2.5
Beta (B.1.351)	L18F, D80A, D215G, R246I, K417N, E484K, N501Y, D614G, A701V	0.6	0.7
Gamma (P.1)	D138Y, D614G, E484K, H655Y, K417T, L18F, N501Y, P26S, R190S, T1027I, T20N, V1176F	0.4	0.4
Delta (B.1.617.2)	T19R, G142D, E156G, F157-, R158-, L452R, T478K, D614G, P681R, D950N	1	NT
Epsilon (B.1.427/B.1.429)	S13I, W152C, L452R, D614G	0.7	NT
Eta (B.1.525; Eta)	Q52R, A67V, H69-, V70-, Y144-, E484K, D614G, Q677H, F888L	0.9	NT
Iota (B.1.526)	L5F, T95I, D253G, E484K, D614G, A701V	0.6	NT
Kappa (B.1.617.1)	T95I, G142D, E154K, L452R, E484Q, D614G, P681R, Q1071H	0.7	NT
Lambda (C.37)	G75V, T76I, del246-252, L452Q, F490S, T859N	1.5	NT
Mexico/Swiss (B.1.1.519)	T478K, D614G, P681H, T732A	0.8	NT
Scotland (B.1.258)	H69-, V70-, N439K, D614G	0.9	NT
US (R.2)	E484K, D614G, Q677H, T732S, E1202Q	0.8	NT
Liverpool (A.23.1)	R102I, F157L, V367F, E484K, Q613H, P681R	1.1	NT
Cameroon (B.1.619)	I210T, N440K, E484K, D614G, D936N, S939F, T1027I	1.3	NT
Bristol (B.1.1.7+E484K)	H69-, V70-, Y144-, E484K, N501Y, A570D, D614G, P681H, T716I, S982A, D1118H	1.7	NT

Table 3

Amino Acid position	Substitution / Deletion	mAb with Reduced Susceptibility	Variants in Tested Spike Sequence	VIR-7831 EC_{50} (ng/ml)	Average Fold Change in EC_{50} Compared to Relative Wild-Type
E406	W	casirivimab+ imdevimab	E406W	53.66	0.74
K417	E	casirivimab	K417E	67.71	0.89
N439	K	imdevimab	N439K, D614G	17.05	0.86
N440	D	imdevimab	N440D	80.47	1.29
N440	K	imdevimab	N440K, D614G	19.99	0.48
K444	Q	imdevimab	K444Q	79.68	1.11
V445	A	imdevimab	V445A	41.74	3.38
G446	V/I	imdevimab	G446V, D614G	18.41	1.50
Y453	F	casirivimab	G261D, Y453F	27.28	2.19
L455	F	casirivimab	L455F, D614G	21.65	0.56
G476	S	casirivimab	G476S	36.97	2.94
E484	K	bamlanivimab	E484K, D614G	12.91	0.33
F486	V/I	casirivimab	F486V	82.24	1.10
Y489	H	casirivimab	Y489H	92.29	1.48
F490	S	bamlanivimab	F490S	33.10	0.85
Q493	K	casirivimab, bamlanivimab	Q483K	69.79	0.98
S494	P	casirivimab, bamlanivimab	S494P, D614G	29.10	2.50

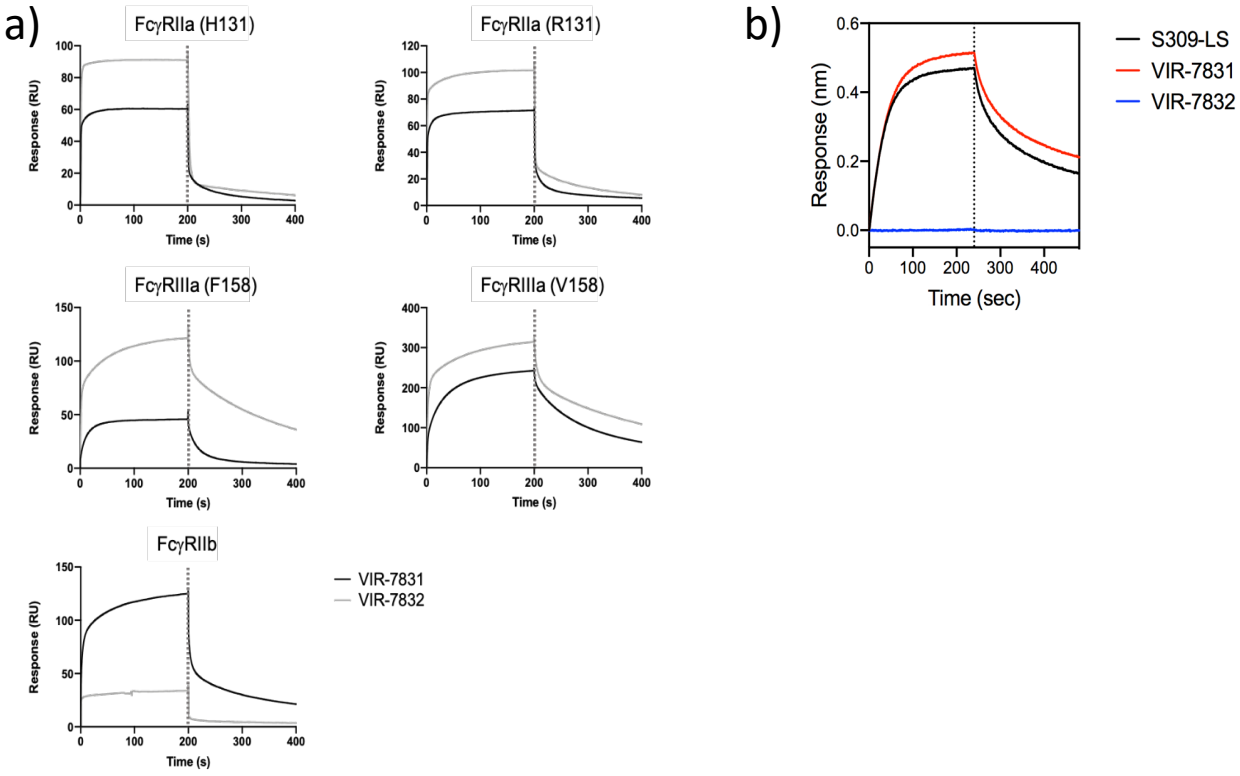
Table 4

Amino Acid Position	Reference Amino Acid[a]	Variants Identified in order of Prevalence[b]	Percent Reference AA Conservation
332	I	**V, T**	>99.99
333	T	**I**, K, A	>99.99
334	N	**Y**, **K, H**, S, D, T	>99.99
335	L	**F**, **S**, V, M	99.99
336	C	S	>99.99
337	P	**S**, **T**, **L**, **H**, **R**, K	>99.99
339	G	**D**, **S, V**, **C**, F, N	99.98
340	E	D, **K, G**, **A, Q**	>99.99
341	V	**I**, A, F, P, S	>99.99
343	N	Y, K, **S**	>99.99
344	A	**S**, **V**, **T**, D, F, P	99.98
345	T	**S**, I, **N**	>99.99
346	R	**S**, **K**, **I**, **T**, **G**, F	99.89
354	N	**K**, **D**, **S**, **H**, **I**, T, Y, G	99.96
356	K	**R, M**, **N**, **T**, E, G, Q, W, Y, I	99.99
357	R	**K, I**, G, T, C, L	99.93
358	I	**V**, T, **F**, **L**, A, E	>99.99
359	S	**T**, **N**, **G**, **R**, C, F, I	99.98
360	N	**Y**, S, F, A, L, T	>99.99
361	C	T, G, F, R, N, S	>99.99
440	N	**K**, **S**, **Y**, **T**, **D**, I, H, F, R	99.83
441	L	**R**, **F**, **I**, **V**, Y, H, M, S, E, N	>99.99
509	R	K, T, I, S	>99.99

Table 5

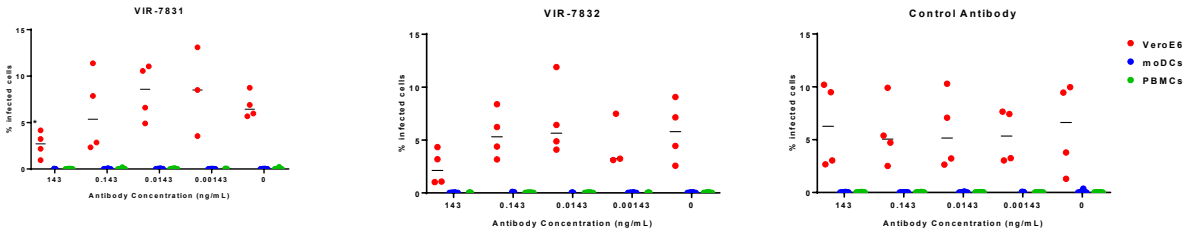
Epitope Reference Amino Acid	Amino Acid Changes in Spike protein	Geomean Neutralization EC_{50} (ng/mL)	Average Fold-Change EC_{50} Relative to Wild-Type
I332	I332V, D614G	53.43	1.48
	I332T, D614G	66.74	1.61
N334	N334H, D614G	30.74	0.87
	N334Y, D614G	32.89	0.96
L335	L335S, D614G	29.80	0.85
P337	P337L, D614G	>10000	>192
	P337H, D614G	185.29	5.13
	P337T, D614G	383.27	10.62
	P337R, D614G	>10000	>192
G339	G339V, D614G	78.32	1.26
E340	E340Q, D614G	>2500	>50
	E340G, D614G	640.07	18.21
N343	N343S, D614G	16.87	0.48
A344	A344V, D614G	53.87	1.14
T345	T345S, D614G	42.92	0.69
	T345N, D614G	20.29	0.57
R346	R346G, D614G	43.73	0.85
N354	N354I, D614G	37.09	1.05
K356	K356M, D614G	64.09	1.03
	K356T, D614G	281.13	5.90
I358	I358F, D614G	42.69	1.19
S359	S359T, D614G	39.98	0.84
N360	N360S, D614G	34.08	0.72
	N360Y, D614G	29.67	0.61
N440	N440T, D614G	50.81	0.82
L441	L441R, D614G	42.30	0.87
	L441V, D614G	48.24	0.98

Supplemental Figure 1

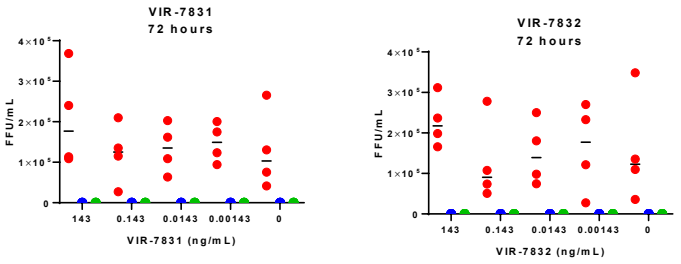


Supplemental Figure 2

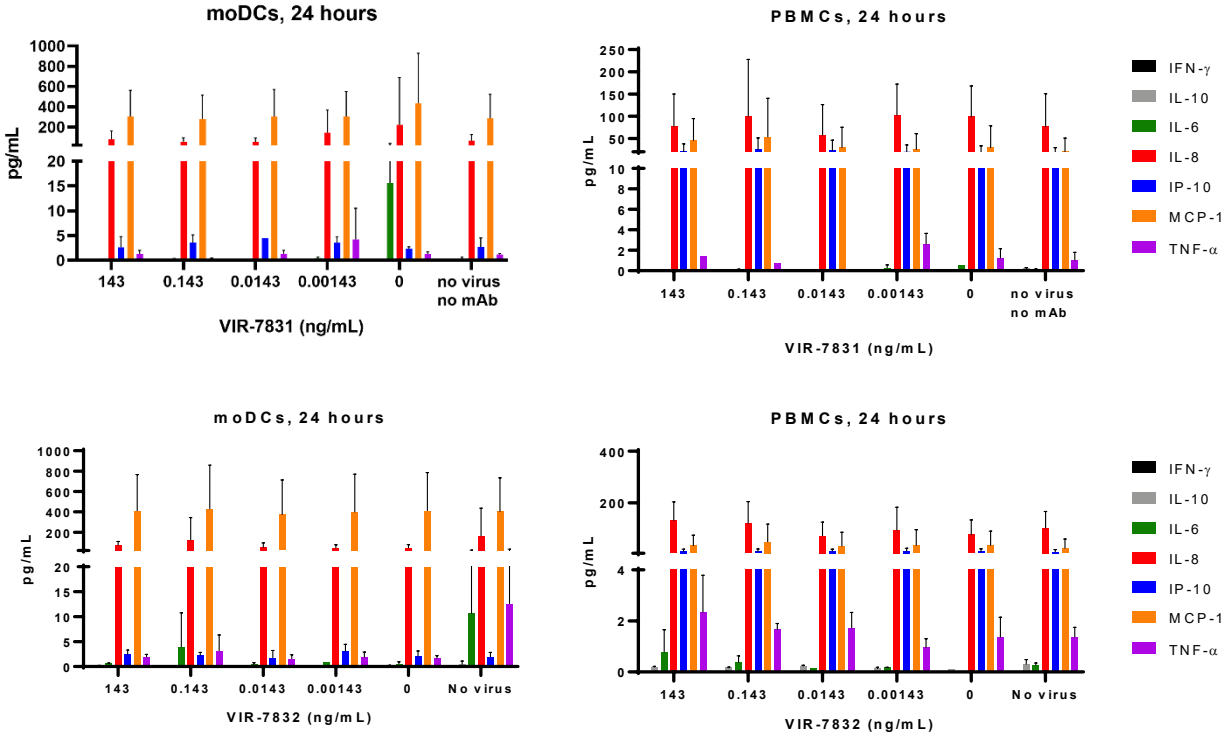
a)



b)

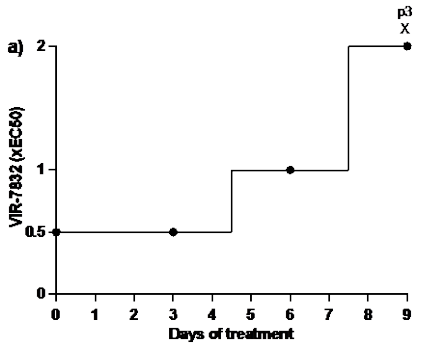


c)



Supplemental Figure 3

a)



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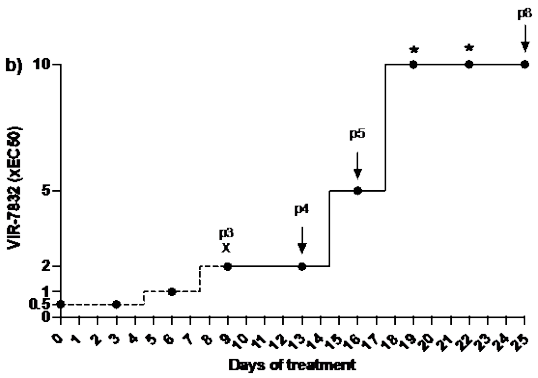
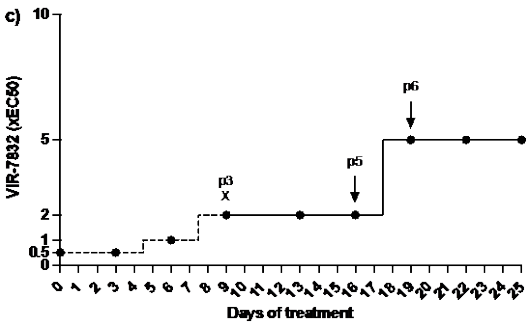


c)



Supplemental Table 1

Passage	**Spike Gene Amino Acid Substitution (Freq)** [a,b]	**EC_{50} (µg/mL)**	**Fold Change in EC_{50} to WT**[c]
SARS-CoV-2 virus stock[c]	H66R (5.7%) N74K (12.6%) T76I (5.6%) 215-216insKLRS (60.9%) H655Y (3.1%)	0.06	NA
VIR-7832 Lineage 1, passage 4	215-216insKLRS (74.5%) 675-679 del (20.6%)	0.34	5.64
VIR-7832 Lineage 1, passage 5	215-216insKLRS (74.6%) 675-679del (66.0%)	0.35	5.93
VIR-7832 Lineage 1, passage 8	215-216insKLRS (74.7%) E340A (98.7%) 675-679del (84.5%)	ND	>10
VIR-7832 Lineage 2, passage 5	215-216insKLRS (73.9%) 675-679del (47.3%) R682W (4.9%) V1128F (3.5%)	0.32	5.40
VIR-7832 Lineage 2, passage 6	215-216insKLRS (75.3%) 675-679del (74.2%) R682W (4.9%) V1128F (30.9%)	0.39	6.54

Supplemental Table 2

Amino Acid Changes in Spike protein	VIR-7831		VIR-7832	
	Geomean Neutralization EC_{50} (ng/mL)	Fold Change Relative to Wild-Type	Geomean Neutralization EC_{50} (ng/mL)	Fold Change Relative to Wild-Type
Wild Type[a]	104.46	NA	100.75	NA
E340A	> 10,000	>100	> 10,000	> 107
R682W	53.96	0.52	47.78	0.49
V1128F	50.65	0.53	49.69	0.60