Class 19

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Background

Pertussis (a.k.a Whooping Cough) is a highly infectious lung infection caused by the bacteia *B. pertussis*.

The CDC tracks case numbers in the US and makes this data available online:

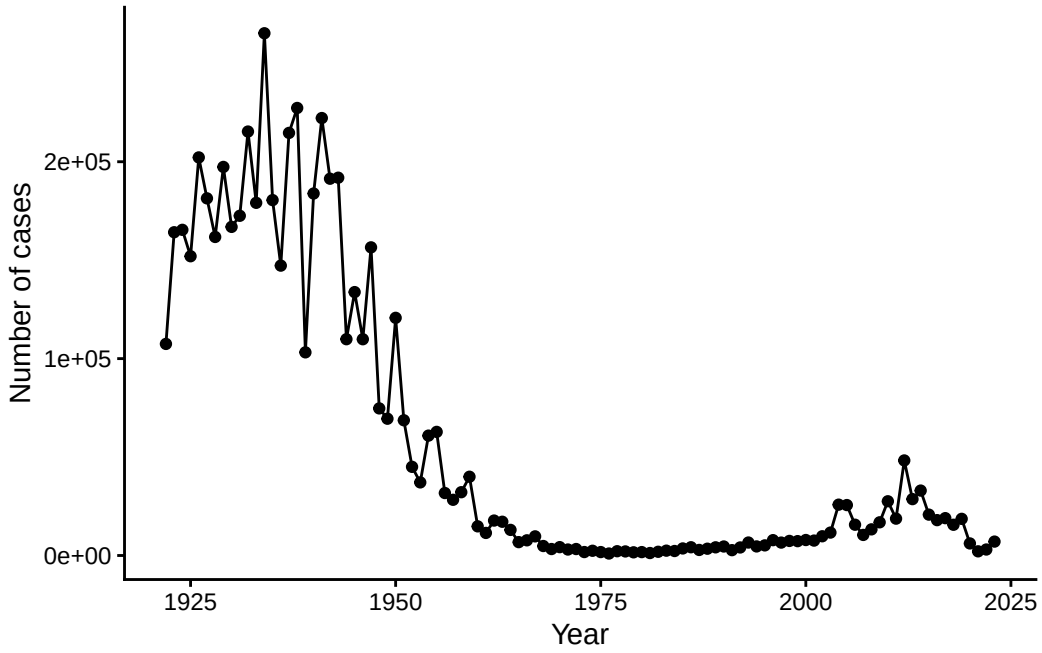
> Q1. With the help of the R "addin" package datapasta assign the CDC pertussis case number data to a data frame called cdc and use ggplot to make a plot of cases numbers over time.

```
library(ggplot2)
```

```
Warning: package 'ggplot2' was built under R version 4.5.2
```

```
cdcgraph <- ggplot(cdc) +
  aes(year, cases) +
  geom_point() +
  geom_line() +
  labs(x="Year",y="Number of cases") +
  theme_classic()

cdcgraph
```

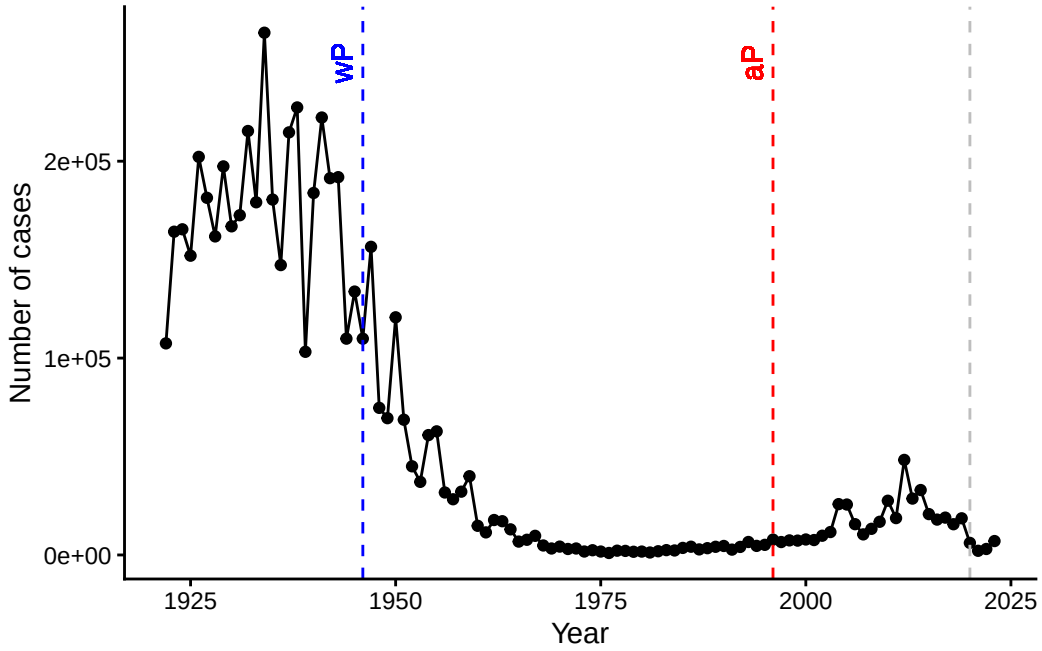


Q2. Using the ggplot `geom_vline()` function add lines to your previous plot for the 1946 introduction of the wP vaccine and the 1996 switch to aP vaccine (see example in the hint below). What do you notice?

```
cdcgraph +
  geom_vline(xintercept = 1946, linetype="dashed", color = "blue") +
  geom_vline(xintercept = 1996, linetype="dashed", color = "red") +
  geom_vline(xintercept = 2020, linetype="dashed", color = "grey") +
  geom_text(aes(x=1946, y=250000, label="wP"),
            angle=90, vjust = -0.5, color="blue") +
  geom_text(aes(x=1996, y=250000, label="aP"),
            angle=90, vjust = -0.5, color="red")
```

```
Warning in geom_text(aes(x = 1946, y = 250000, label = "wP"), angle = 90, : All aesthetics ha
i Please consider using `annotate()` or provide this layer with data containing
  a single row.

Warning in geom_text(aes(x = 1996, y = 250000, label = "aP"), angle = 90, : All aesthetics ha
i Please consider using `annotate()` or provide this layer with data containing
  a single row.
```



Q3. Describe what happened after the introduction of the aP vaccine? Do you have a possible explanation for the observed trend?

Maybe the vaccine wasn't as effective as hoped, or there were changes in vaccination rates, pathogen evolution, or reporting practices. Further investigation would be needed to determine the exact cause.

The CMI-PB Project

The CMI-PB project is a collaboration between researchers at UCSD and the Scripps Institution of Oceanography to study the microbial communities in the coastal waters of Southern California. The project involves collecting water samples from various locations along the coast and analyzing the microbial DNA using high-throughput sequencing techniques.

They make their data aavailable via a JSON format running API. E=We can read JSON format with the `read_json` function from the jsonlite R package..

```
library(jsonlite)
subject <- read_json("https://www.cmi-pb.org/api/subject", simplifyVector = TRUE)
head(subject, 3)
```

```
  subject_id infancy_vac biological_sex              ethnicity  race
1          1          wP         Female Not Hispanic or Latino White
2          2          wP         Female Not Hispanic or Latino White
3          3          wP         Female                 Unknown White
  year_of_birth date_of_boost      dataset
1    1986-01-01    2016-09-12 2020_dataset
2    1968-01-01    2019-01-28 2020_dataset
3    1983-01-01    2016-10-10 2020_dataset
```

Q4. How many aP and wP infancy vaccinated subjects are in the dataset?

```
table(subject$infancy_vac)
```

```
aP wP
87 85
```

```
subject$infancy_vac
```

```
  [1] "wP" "wP" "wP" "wP" "wP" "wP" "wP" "wP" "aP" "wP" "wP" "wP" "aP" "wP" "wP"
 [16] "wP" "wP" "aP" "wP" "wP" "wP" "wP" "wP" "wP" "wP" "wP" "aP" "wP" "aP" "wP"
 [31] "wP" "aP" "wP" "wP" "wP" "aP" "aP" "aP" "wP" "wP" "wP" "aP" "aP" "aP" "aP"
 [46] "aP" "aP" "aP" "aP" "aP" "aP" "aP" "aP" "aP" "aP" "aP" "aP" "aP" "aP" "aP"
 [61] "wP" "wP" "wP" "wP" "wP" "wP" "wP" "wP" "wP" "aP" "aP" "wP" "wP" "wP" "aP"
 [76] "aP" "wP" "wP" "wP" "wP" "wP" "aP" "aP" "aP" "aP" "aP" "aP" "aP" "aP" "aP"
 [91] "aP" "aP" "aP" "aP" "aP" "aP" "wP" "wP" "aP" "aP" "aP" "aP" "wP" "wP" "wP"
[106] "aP" "aP" "wP" "wP" "aP" "wP" "aP" "aP" "wP" "aP" "aP" "aP" "aP" "aP" "wP"
[121] "aP" "aP" "wP" "aP" "wP" "wP" "aP" "wP" "wP" "wP" "aP" "wP" "aP" "wP" "wP"
[136] "wP" "aP" "aP" "wP" "aP" "wP" "aP" "aP" "aP" "aP" "wP" "aP" "wP" "wP" "wP"
[151] "wP" "wP" "aP" "aP" "aP" "aP" "aP" "aP" "wP" "aP" "aP" "aP" "wP" "wP" "wP"
[166] "aP" "aP" "wP" "aP" "wP" "wP" "wP"
```

Q5. How many Male and Female subjects/patients are in the dataset?

```
table(subject$biological_sex)
```

```
Female   Male
   112     60
```

> Q6. What is the breakdown of race and biological sex (e.g. number of Asian females, White males etc…)?

```
table(subject$race, subject$biological_sex)
```

```
                                        Female Male
  American Indian/Alaska Native              0    1
  Asian                                     32   12
  Black or African American                  2    3
  More Than One Race                        15    4
  Native Hawaiian or Other Pacific Islander  1    1
  Unknown or Not Reported                   14    7
  White                                     48   32
```

Let's read more tables

```
library(jsonlite)
specimen <- read_json("https://www.cmi-pb.org/api/v5_1/specimen", simplifyVector = TRUE)
ab_titer <- read_json("https://www.cmi-pb.org/api/v5_1/plasma_ab_titer",simplifyVector = TRU
```

Working with Dates

> Q7. Using this approach determine (i) the average age of wP individuals, (ii) the average age of aP individuals; and (iii) are they significantly different?

```
library(lubridate)
```

```
Warning: package 'lubridate' was built under R version 4.5.2
```

```
Attaching package: 'lubridate'
```

```
The following objects are masked from 'package:base':

    date, intersect, setdiff, union
```

```
library(dplyr)
```

```

Attaching package: 'dplyr'

The following objects are masked from 'package:stats':

    filter, lag

The following objects are masked from 'package:base':

    intersect, setdiff, setequal, union
```

```
subject$age <- today() - ymd(subject$year_of_birth)

# (i)
ap <- subject %>% filter(infancy_vac == "aP")
round(summary(time_length(ap$age, "years" )))
```

```
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max. 
     23      27      28      28      29      35 
```

```
 # (ii)
wp <- subject %>% filter(infancy_vac == "wP")
round(summary(time_length(wp$age, "years")))
```

```
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max. 
     23      33      35      37      40      58 
```

```
# (iii)
t.test(ap$age,wp$age)
```

```
    Welch Two Sample t-test

data:  ap$age and wp$age
t = -12.918 days, df = 104.03, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -3686.855 days -2705.535 days
sample estimates:
Time differences in days
mean of x mean of y
 10165.28  13361.47
```

i) 28
ii) 37
iii) yes, significantly different (p 2.2e-16)

Q8. Determine the age of all individuals at time of boost?

```
subject$boost_age <- ymd(subject$date_of_boost) - ymd(subject$year_of_birth)
round(head(time_length(subject$boost_age,"years")))
```

```
[1] 31 51 34 29 26 29
```

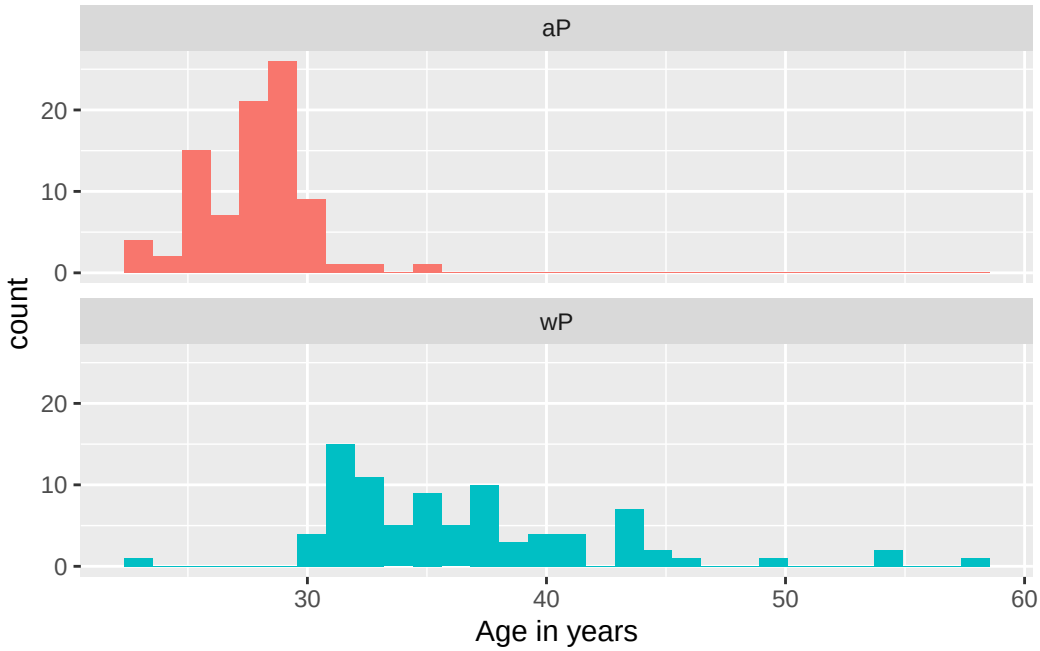
```
round(summary(time_length(subject$boost_age,"years")))
```

```
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
     19      21      26      26      30      51
```

Q9a. With the help of a faceted boxplot or histogram, do you think these two groups are significantly different?

```
ggplot(subject) +
  aes(time_length(age, "year"),
      fill=as.factor(infancy_vac)) +
  geom_histogram(show.legend=FALSE) +
  facet_wrap(vars(infancy_vac), nrow=2) +
  xlab("Age in years")
```

```
`stat_bin()` using `bins = 30`. Pick better value `binwidth`.
```



I think they are significantly different!

Join (or link, or merge) using the

> Q9b. Complete the code to join specimen and subject tables to make a new merged data frame containing all specimen records along with their associated subject details: Q10. Now using the same procedure join meta with titer data so we can further analyze this data in terms of time of visit aP/wP, male/female etc.

```
library(dplyr)

meta <- inner_join(subject, specimen)
```

```
Joining with `by = join_by(subject_id)`
```

```
head(meta)
```

```
  subject_id infancy_vac biological_sex              ethnicity  race
1          1          wP         Female Not Hispanic or Latino White
2          1          wP         Female Not Hispanic or Latino White
3          1          wP         Female Not Hispanic or Latino White
4          1          wP         Female Not Hispanic or Latino White
5          1          wP         Female Not Hispanic or Latino White
```

```
6          1          wP         Female Not Hispanic or Latino White
  year_of_birth date_of_boost      dataset        age  boost_age specimen_id
1    1986-01-01    2016-09-12 2020_dataset 14586 days 11212 days           1
2    1986-01-01    2016-09-12 2020_dataset 14586 days 11212 days           2
3    1986-01-01    2016-09-12 2020_dataset 14586 days 11212 days           3
4    1986-01-01    2016-09-12 2020_dataset 14586 days 11212 days           4
5    1986-01-01    2016-09-12 2020_dataset 14586 days 11212 days           5
6    1986-01-01    2016-09-12 2020_dataset 14586 days 11212 days           6
  actual_day_relative_to_boost planned_day_relative_to_boost specimen_type
1                           -3                             0         Blood
2                            1                             1         Blood
3                            3                             3         Blood
4                            7                             7         Blood
5                           11                            14         Blood
6                           32                            30         Blood
  visit
1     1
2     2
3     3
4     4
5     5
6     6
```

```
ab_data <- inner_join(meta,ab_titer)
```

```
Joining with `by = join_by(specimen_id)`
```

```
head(ab_data)
```

```
  subject_id infancy_vac biological_sex              ethnicity  race
1          1          wP         Female Not Hispanic or Latino White
2          1          wP         Female Not Hispanic or Latino White
3          1          wP         Female Not Hispanic or Latino White
4          1          wP         Female Not Hispanic or Latino White
5          1          wP         Female Not Hispanic or Latino White
6          1          wP         Female Not Hispanic or Latino White
  year_of_birth date_of_boost      dataset        age  boost_age specimen_id
1    1986-01-01    2016-09-12 2020_dataset 14586 days 11212 days           1
2    1986-01-01    2016-09-12 2020_dataset 14586 days 11212 days           1
3    1986-01-01    2016-09-12 2020_dataset 14586 days 11212 days           1
4    1986-01-01    2016-09-12 2020_dataset 14586 days 11212 days           1
```

```
5    1986-01-01    2016-09-12 2020_dataset 14586 days 11212 days           1
6    1986-01-01    2016-09-12 2020_dataset 14586 days 11212 days           1
  actual_day_relative_to_boost planned_day_relative_to_boost specimen_type
1                           -3                             0         Blood
2                           -3                             0         Blood
3                           -3                             0         Blood
4                           -3                             0         Blood
5                           -3                             0         Blood
6                           -3                             0         Blood
  visit isotype is_antigen_specific antigen        MFI MFI_normalised  unit
1     1     IgE              FALSE   Total 1110.21154       2.493425 UG/ML
2     1     IgE              FALSE   Total 2708.91616       2.493425 IU/ML
3     1     IgG               TRUE      PT   68.56614       3.736992 IU/ML
4     1     IgG               TRUE     PRN  332.12718       2.602350 IU/ML
5     1     IgG               TRUE     FHA 1887.12263      34.050956 IU/ML
6     1     IgE               TRUE     ACT    0.10000       1.000000 IU/ML
  lower_limit_of_detection
1                 2.096133
2                29.170000
3                 0.530000
4                 6.205949
5                 4.679535
6                 2.816431
```

Q11. How many specimens (i.e. entries in abdata) do we have for each isotype?

```
head(ab_data$isotype)
```

```
[1] "IgE" "IgE" "IgG" "IgG" "IgG" "IgE"
```

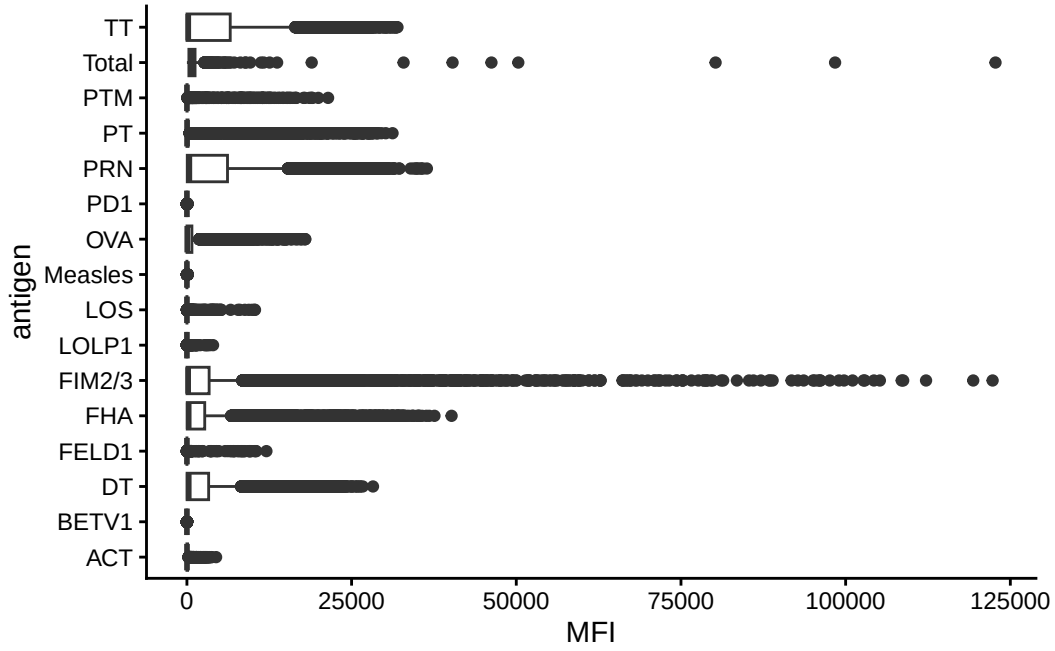
How many different antigens are there in the dataset?

```
unique(ab_data$antigen)
```

```
 [1] "Total"   "PT"      "PRN"     "FHA"     "ACT"     "LOS"     "FELD1"
 [8] "BETV1"   "LOLP1"   "Measles" "PTM"     "FIM2/3"  "TT"      "DT"
[15] "OVA"     "PD1"
```

```
ggplot(ab_data) +
  aes(MFI,antigen) +
  geom_boxplot() +
  theme_classic()
```

```
Warning: Removed 1 row containing non-finite outside the scale range
(`stat_boxplot()`).
```



Q12. What are the different $dataset values in abdata and what do you notice about the number of rows for the most "recent" dataset?

```
table(ab_data$dataset)
```

```
2020_dataset 2021_dataset 2022_dataset 2023_dataset
       31520         8085         7301        15050
```

There's a lot more rows in the most recent dataset!

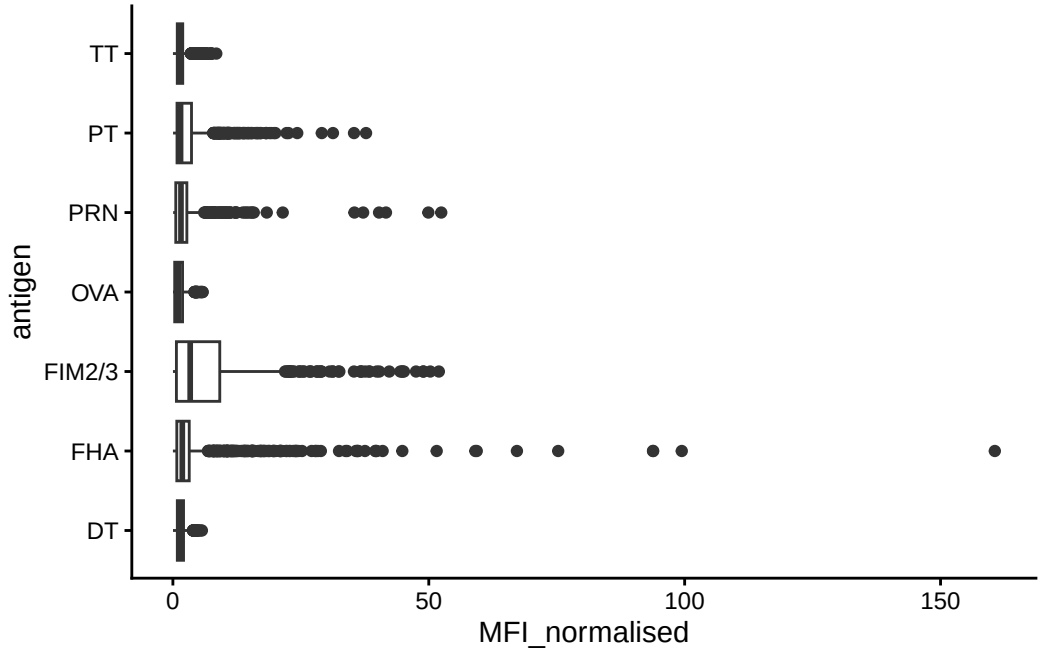
Focus in IgG

IgG is crucial for long-term immunity and responding to bacterial and viral infections

```
ab_data |>
  filter(isotype == "IgG") -> igg_data
```

Plot of antigen levels again but for IgG only

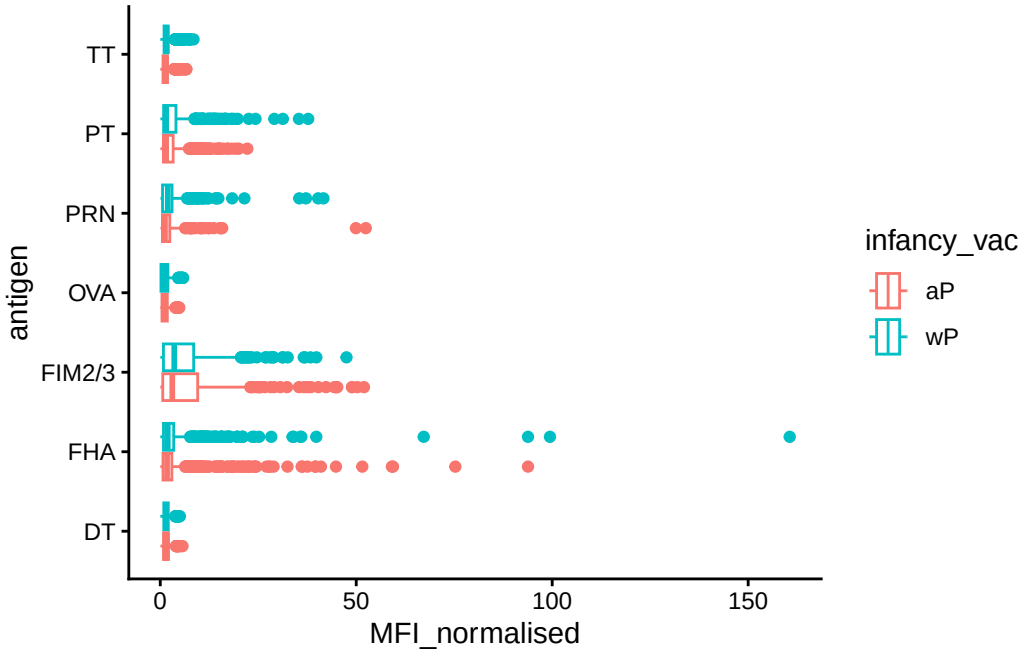
```
igg_dataplot <- ggplot(igg_data) +
  aes(x=MFI_normalised, y=antigen) +
  geom_boxplot() +
  theme_classic()
igg_dataplot
```



Differences between aP and wP?

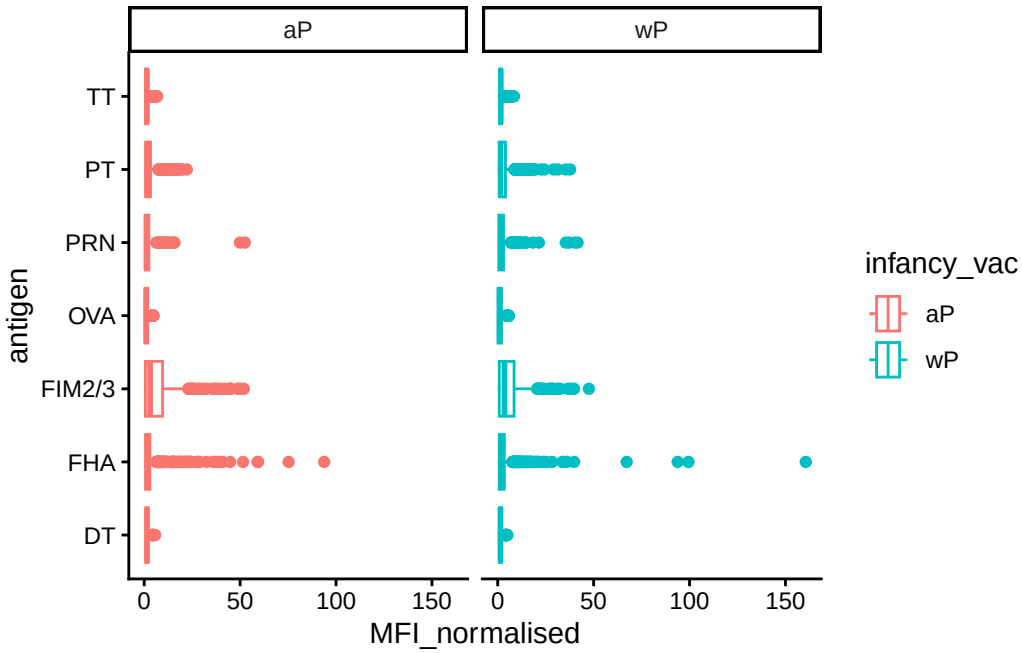
We can color up by the `infancy_vac` values of "wP" or "aP"

```
igg_dataplot +
  aes(color=infancy_vac)
```



We could "facet" by the "aP" vs "wP" column

```
igg_dataplot +
  aes(color=infancy_vac) +
  facet_wrap(~infancy_vac)
```

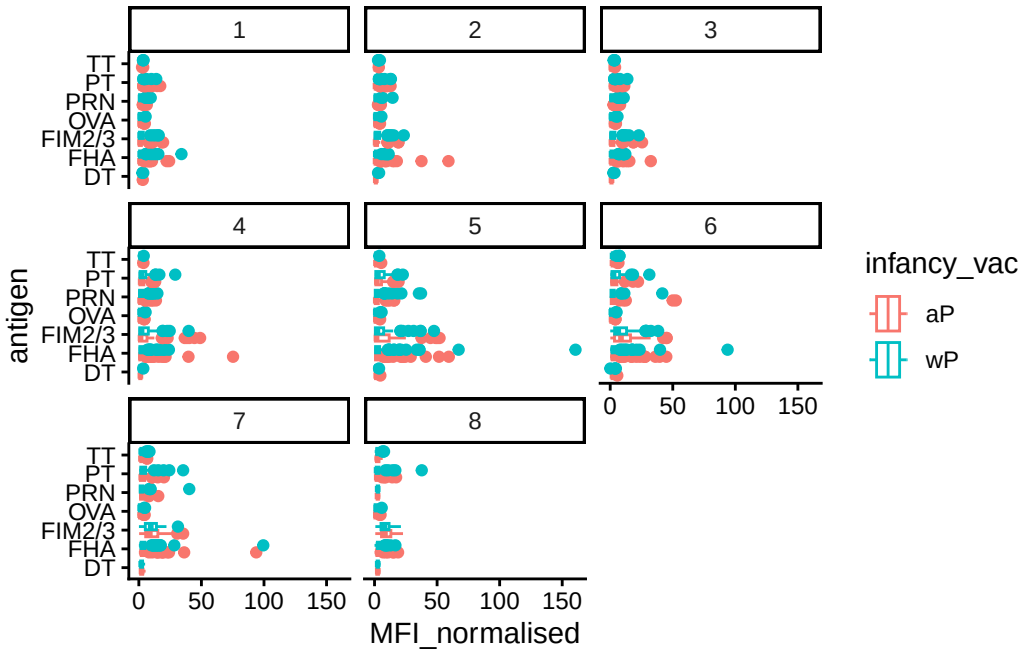


Time course analysis

Q13. Complete the following code to make a summary boxplot of Ab titer levels (MFI) for all antigens:

We can use `visit` as a proxy for time here and facet our plots by this value 1 to 8...

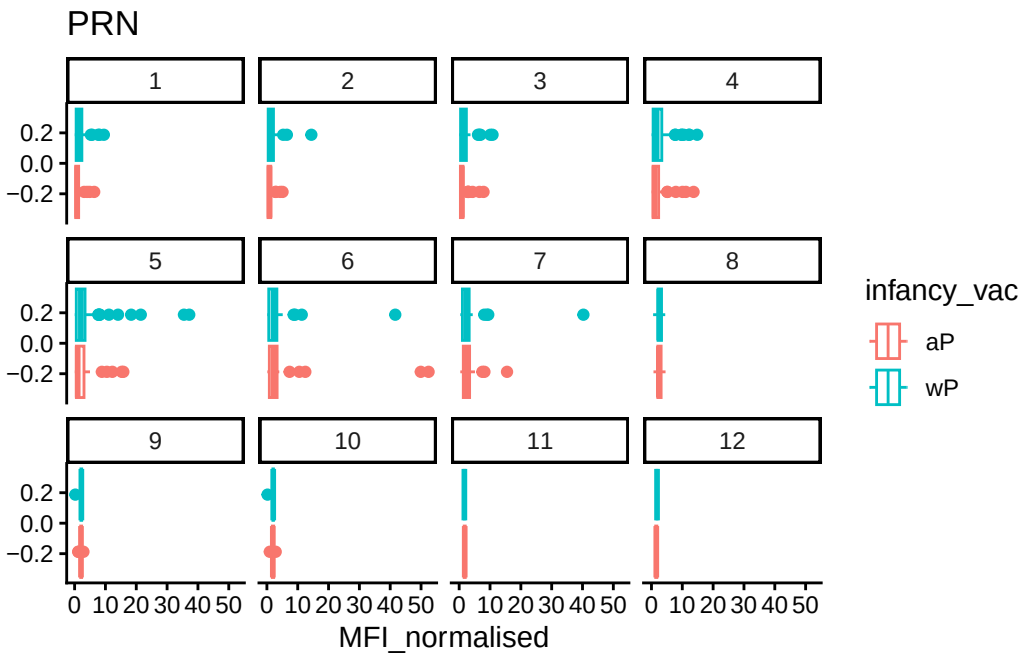
```
igg_data |>
  filter(visit %in% 1:8) |>
  ggplot() +
    aes(x=MFI_normalised,y=antigen,color=infancy_vac) +
    facet_wrap(~visit) +
    geom_boxplot() +
    theme_classic()
```



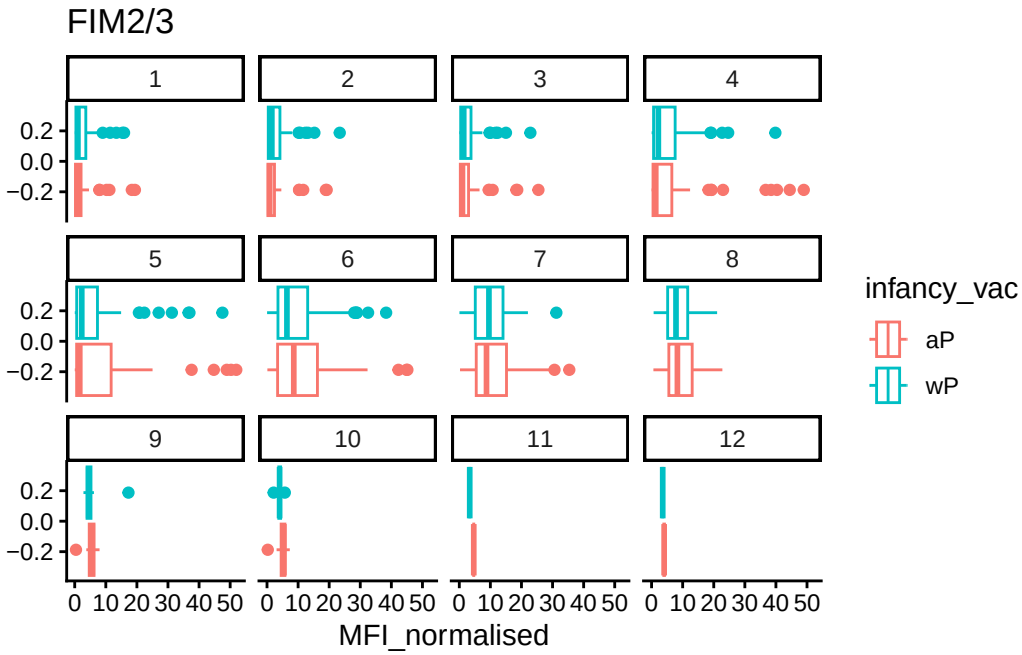
Q14. What antigens show differences in the level of IgG antibody titers recognizing them over time? Why these and not others?

Q15. Filter to pull out only two specific antigens for analysis and create a boxplot for each. You can chose any you like. Below I picked a "control" antigen ("OVA", that is not in our vaccines) and a clear antigen of interest ("PT", Pertussis Toxin, one of the key virulence factors produced by the bacterium B. pertussis).

```
library(dplyr)
filter(igg_data, antigen=="PRN") %>%
  ggplot() +
  aes(MFI_normalised, col=infancy_vac) +
  geom_boxplot(show.legend = TRUE) +
  facet_wrap(vars(visit)) +
  theme_classic() +
  labs(title="PRN")
```




```
filter(igg_data, antigen=="FIM2/3") %>%
  ggplot() +
  aes(MFI_normalised, col=infancy_vac) +
  geom_boxplot(show.legend = TRUE) +
  facet_wrap(vars(visit)) +
  theme_classic() +
  labs(title="FIM2/3")
```



Q16. What do you notice about these two antigens time courses and the PT data in particular?

Of the data presented in the example: PT levels overtime rise and exceed OVA. In this dataset, FIM levels start out large but drop significantly more than PRN (this could be becuse FIM just had a greater range of values than PRN.)

Q17. Do you see any clear difference in aP vs. wP responses?

PRN: Responses about the same FIM: For most part, aP > wP.

Time course of PT (Virulence Factor: Pertussis Toxin)

```
pt_2020 <- igg_data |>
  filter(antigen == "PT") |>
  filter(dataset == "2020_dataset")
pt_2021 <- igg_data |>
  filter(antigen == "PT") |>
  filter(dataset == "2021_dataset")

pt_2020
```

	subject_id	infancy_vac	biological_sex	ethnicity
1	1	wP	Female	Not Hispanic or Latino
2	1	wP	Female	Not Hispanic or Latino
3	1	wP	Female	Not Hispanic or Latino
4	1	wP	Female	Not Hispanic or Latino
5	1	wP	Female	Not Hispanic or Latino
6	1	wP	Female	Not Hispanic or Latino
7	1	wP	Female	Not Hispanic or Latino
8	3	wP	Female	Unknown
9	3	wP	Female	Unknown
10	3	wP	Female	Unknown
11	3	wP	Female	Unknown
12	3	wP	Female	Unknown
13	3	wP	Female	Unknown
14	3	wP	Female	Unknown
15	4	wP	Male	Not Hispanic or Latino
16	4	wP	Male	Not Hispanic or Latino
17	4	wP	Male	Not Hispanic or Latino
18	4	wP	Male	Not Hispanic or Latino
19	4	wP	Male	Not Hispanic or Latino
20	4	wP	Male	Not Hispanic or Latino
21	4	wP	Male	Not Hispanic or Latino
22	5	wP	Male	Not Hispanic or Latino
23	5	wP	Male	Not Hispanic or Latino
24	5	wP	Male	Not Hispanic or Latino
25	5	wP	Male	Not Hispanic or Latino
26	5	wP	Male	Not Hispanic or Latino
27	5	wP	Male	Not Hispanic or Latino
28	5	wP	Male	Not Hispanic or Latino
29	6	wP	Female	Not Hispanic or Latino
30	6	wP	Female	Not Hispanic or Latino
31	6	wP	Female	Not Hispanic or Latino
32	6	wP	Female	Not Hispanic or Latino
33	6	wP	Female	Not Hispanic or Latino
34	6	wP	Female	Not Hispanic or Latino
35	6	wP	Female	Not Hispanic or Latino
36	7	wP	Female	Hispanic or Latino
37	7	wP	Female	Hispanic or Latino
38	7	wP	Female	Hispanic or Latino
39	7	wP	Female	Hispanic or Latino
40	7	wP	Female	Hispanic or Latino
41	7	wP	Female	Hispanic or Latino
42	7	wP	Female	Hispanic or Latino

43	9	aP	Male Not Hispanic or Latino
44	9	aP	Male Not Hispanic or Latino
45	9	aP	Male Not Hispanic or Latino
46	9	aP	Male Not Hispanic or Latino
47	9	aP	Male Not Hispanic or Latino
48	9	aP	Male Not Hispanic or Latino
49	9	aP	Male Not Hispanic or Latino
50	10	wP	Female Not Hispanic or Latino
51	10	wP	Female Not Hispanic or Latino
52	10	wP	Female Not Hispanic or Latino
53	10	wP	Female Not Hispanic or Latino
54	10	wP	Female Not Hispanic or Latino
55	10	wP	Female Not Hispanic or Latino
56	11	wP	Female Hispanic or Latino
57	11	wP	Female Hispanic or Latino
58	11	wP	Female Hispanic or Latino
59	11	wP	Female Hispanic or Latino
60	11	wP	Female Hispanic or Latino
61	11	wP	Female Hispanic or Latino
62	11	wP	Female Hispanic or Latino
63	12	wP	Male Not Hispanic or Latino
64	12	wP	Male Not Hispanic or Latino
65	12	wP	Male Not Hispanic or Latino
66	12	wP	Male Not Hispanic or Latino
67	12	wP	Male Not Hispanic or Latino
68	12	wP	Male Not Hispanic or Latino
69	13	aP	Male Not Hispanic or Latino
70	13	aP	Male Not Hispanic or Latino
71	13	aP	Male Not Hispanic or Latino
72	13	aP	Male Not Hispanic or Latino
73	13	aP	Male Not Hispanic or Latino
74	13	aP	Male Not Hispanic or Latino
75	13	aP	Male Not Hispanic or Latino
76	14	wP	Male Not Hispanic or Latino
77	14	wP	Male Not Hispanic or Latino
78	14	wP	Male Not Hispanic or Latino
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3	White	1986-01-01	2016-09-12
4	White	1986-01-01	2016-09-12
5	White	1986-01-01	2016-09-12
6	White	1986-01-01	2016-09-12
7	White	1986-01-01	2016-09-12
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10	White	1983-01-01	2016-10-10
11	White	1983-01-01	2016-10-10
12	White	1983-01-01	2016-10-10
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15	Asian	1988-01-01	2016-08-29
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291	Asian	1997-01-01	2016-11-28
292	Asian	1997-01-01	2016-11-28

293	Asian	1997-01-01	2016-11-28
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375	Unknown or Not Reported	1997-01-01	2017-01-30
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5   2020_dataset 14586 days 11212 days           5                            11
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8   2020_dataset 15682 days 12336 days          19                            -3
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12  2020_dataset 15682 days 12336 days          23                            14
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15  2020_dataset 13856 days 10468 days          27                            -7
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19  2020_dataset 13856 days 10468 days          31                            14
20  2020_dataset 13856 days 10468 days          32                            32
21  2020_dataset 13856 days 10468 days          33                           108
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25  2020_dataset 12760 days  9372 days          40                             8
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37	2020_dataset	16412 days	13094 days	56	3
38	2020_dataset	16412 days	13094 days	57	7
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40	2020_dataset	16412 days	13094 days	59	30
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42	2020_dataset	16412 days	13094 days	61	386
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63	2020_dataset	16047 days	12624 days	96	-4
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81	2020_dataset	13490 days	10088 days	114	0
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95	2020_dataset	16778 days	13404 days	131	-40
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241	2020_dataset	10568 days	7236 days	295	3

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243 2020_dataset 10568 days  7236 days         297                   14
244 2020_dataset 10568 days  7236 days         298                   36
245 2020_dataset 10568 days  7236 days         299                  106
246 2020_dataset 14951 days 11619 days         300                   -4
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250 2020_dataset 14951 days 11619 days         304                   14
251 2020_dataset 14951 days 11619 days         305                   30
252 2020_dataset 14951 days 11619 days         306                   95
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255 2020_dataset 11664 days  8332 days         312                    3
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257 2020_dataset 11664 days  8332 days         314                   14
258 2020_dataset 11664 days  8332 days         315                   35
259 2020_dataset 11664 days  8332 days         316                   94
260 2020_dataset 14951 days 11633 days         317                  -10
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263 2020_dataset 14951 days 11633 days         320                    7
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265 2020_dataset 14951 days 11633 days         322                   30
266 2020_dataset 14951 days 11633 days         323                   92
267 2020_dataset 10568 days  7250 days         324                   -6
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269 2020_dataset 10568 days  7250 days         326                    3
270 2020_dataset 10568 days  7250 days         327                    7
271 2020_dataset 10568 days  7250 days         328                   14
272 2020_dataset 10568 days  7250 days         329                   30
273 2020_dataset 10568 days  7250 days         330                  107
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293	2020_dataset	10568 days	7271 days	354	99
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295	2020_dataset	10203 days	6885 days	356	1
296	2020_dataset	10203 days	6885 days	357	3
297	2020_dataset	10203 days	6885 days	358	7
298	2020_dataset	10203 days	6885 days	359	14
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302	2020_dataset	10934 days	7637 days	363	7
303	2020_dataset	10934 days	7637 days	364	14
304	2020_dataset	10934 days	7637 days	365	29
305	2020_dataset	10934 days	7637 days	366	94
306	2020_dataset	10203 days	6956 days	369	-63
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309	2020_dataset	10203 days	6956 days	372	7
310	2020_dataset	10203 days	6956 days	373	14
311	2020_dataset	10203 days	6956 days	374	36
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319	2020_dataset	10568 days	7321 days	382	90
320	2020_dataset	10568 days	7271 days	385	-6
321	2020_dataset	10568 days	7271 days	386	1
322	2020_dataset	10568 days	7271 days	387	3
323	2020_dataset	10568 days	7271 days	388	7
324	2020_dataset	10568 days	7271 days	389	15
325	2020_dataset	10568 days	7271 days	390	36
326	2020_dataset	10568 days	7271 days	391	116
327	2020_dataset	10568 days	7271 days	392	-6

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329 2020_dataset 10568 days  7271 days         394                    3
330 2020_dataset 10568 days  7271 days         395                    8
331 2020_dataset 10568 days  7271 days         396                   14
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333 2020_dataset 10203 days  6942 days         398                    1
334 2020_dataset 10203 days  6942 days         399                    3
335 2020_dataset 10203 days  6942 days         400                    8
336 2020_dataset 10203 days  6942 days         401                   14
337 2020_dataset 10203 days  6942 days         402                   31
338 2020_dataset 10203 days  6942 days         403                   90
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343 2020_dataset 10203 days  6942 days         409                   14
344 2020_dataset 10203 days  6942 days         410                   31
345 2020_dataset 10203 days  6942 days         411                  100
346 2020_dataset 10568 days  7321 days         412                  -36
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351 2020_dataset 10568 days  7321 days         417                   42
352 2020_dataset 10568 days  7321 days         418                   94
353 2020_dataset 10568 days  7321 days         419                   -8
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356 2020_dataset 10568 days  7321 days         422                    7
357 2020_dataset 10568 days  7321 days         423                   14
358 2020_dataset 10568 days  7321 days         424                   31
359 2020_dataset 10568 days  7321 days         425                  107
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364 2020_dataset 10568 days  7334 days         431                   14
365 2020_dataset 10568 days  7334 days         432                   29
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370 2020_dataset 10934 days  7700 days         437                    7
```

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387 2020_dataset 10568 days  7334 days         456                          92
388 2020_dataset 10568 days  7334 days         458                          -4
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392 2020_dataset 10568 days  7334 days         462                          14
393 2020_dataset 10568 days  7334 days         463                          29
394 2020_dataset 10568 days  7334 days         464                          98
    planned_day_relative_to_boost specimen_type visit isotype
1                               0         Blood     1     IgG
2                               1         Blood     2     IgG
3                               3         Blood     3     IgG
4                               7         Blood     4     IgG
5                              14         Blood     5     IgG
6                              30         Blood     6     IgG
7                             120         Blood     7     IgG
8                               0         Blood     1     IgG
9                               1         Blood     2     IgG
10                              3         Blood     3     IgG
11                              7         Blood     4     IgG
12                             14         Blood     5     IgG
13                             30         Blood     6     IgG
14                            120         Blood     7     IgG
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17                              3         Blood     3     IgG
18                              7         Blood     4     IgG
```

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24	3	Blood	3	IgG
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32	7	Blood	4	IgG
33	14	Blood	5	IgG
34	30	Blood	6	IgG
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38	3	Blood	3	IgG
39	14	Blood	4	IgG
40	30	Blood	5	IgG
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275	1	Blood	2	IgG
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359	120	Blood	7	IgG
360	0	Blood	1	IgG
361	1	Blood	2	IgG
362	3	Blood	3	IgG

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363                            7         Blood     4     IgG
364                           14         Blood     5     IgG
365                           30         Blood     6     IgG
366                          120         Blood     7     IgG
367                            0         Blood     1     IgG
368                            1         Blood     2     IgG
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370                            7         Blood     4     IgG
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372                           30         Blood     6     IgG
373                          120         Blood     7     IgG
374                            0         Blood     1     IgG
375                            1         Blood     2     IgG
376                            3         Blood     3     IgG
377                            7         Blood     4     IgG
378                           14         Blood     5     IgG
379                           30         Blood     6     IgG
380                          120         Blood     7     IgG
381                            0         Blood     1     IgG
382                            1         Blood     2     IgG
383                            3         Blood     3     IgG
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385                           14         Blood     5     IgG
386                           30         Blood     6     IgG
387                          120         Blood     7     IgG
388                            0         Blood     1     IgG
389                            1         Blood     2     IgG
390                            3         Blood     3     IgG
391                            7         Blood     4     IgG
392                           14         Blood     5     IgG
393                           30         Blood     6     IgG
394                          120         Blood     7     IgG
    is_antigen_specific antigen          MFI MFI_normalised  unit
1                  TRUE      PT 6.856614e+01     3.73699166 IU/ML
2                  TRUE      PT 4.138442e+01     2.25553379 IU/ML
3                  TRUE      PT 5.963762e+01     3.25036934 IU/ML
4                  TRUE      PT 1.995177e+02    10.87411169 IU/ML
5                  TRUE      PT 2.296037e+02    12.51386026 IU/ML
6                  TRUE      PT 2.288146e+02    12.47085353 IU/ML
7                  TRUE      PT 1.985562e+02    10.82171086 IU/ML
8                  TRUE      PT 2.011607e+01     1.09636587 IU/ML
9                  TRUE      PT 1.307630e+01     0.71268463 IU/ML
10                 TRUE      PT 9.473398e+00     0.51631914 IU/ML
```

11	TRUE	PT 1.178683e+02	6.42405817 IU/ML
12	TRUE	PT 1.291980e+02	7.04154687 IU/ML
13	TRUE	PT 1.648531e+02	8.98482346 IU/ML
14	TRUE	PT 1.552430e+02	8.46105386 IU/ML
15	TRUE	PT 3.755222e+01	2.04667118 IU/ML
16	TRUE	PT 2.986034e+01	1.62744809 IU/ML
17	TRUE	PT 2.607730e+01	1.42126489 IU/ML
18	TRUE	PT 1.448853e+02	7.89654060 IU/ML
19	TRUE	PT 1.054266e+02	5.74595904 IU/ML
20	TRUE	PT 1.486644e+02	8.10250666 IU/ML
21	TRUE	PT 1.395544e+02	7.60599157 IU/ML
22	TRUE	PT 6.968565e+01	3.79800697 IU/ML
23	TRUE	PT 5.791494e+01	3.15648000 IU/ML
24	TRUE	PT 4.106182e+01	2.23795148 IU/ML
25	TRUE	PT 1.100317e+02	5.99694906 IU/ML
26	TRUE	PT 9.774326e+01	5.32720297 IU/ML
27	TRUE	PT 1.289116e+02	7.02594046 IU/ML
28	TRUE	PT 1.204283e+02	6.56358324 IU/ML
29	TRUE	PT 3.914130e+00	0.21332789 IU/ML
30	TRUE	PT 3.657555e+00	0.19934407 IU/ML
31	TRUE	PT 3.209682e+00	0.17493411 IU/ML
32	TRUE	PT 1.674964e+02	9.12888622 IU/ML
33	TRUE	PT 1.625000e+02	8.85657487 IU/ML
34	TRUE	PT 1.767945e+02	9.63565138 IU/ML
35	TRUE	PT 1.011998e+02	5.51558979 IU/ML
36	TRUE	PT 9.139656e+00	0.49812954 IU/ML
37	TRUE	PT 6.543368e+00	0.35662666 IU/ML
38	TRUE	PT 4.107241e+01	2.23852839 IU/ML
39	TRUE	PT 9.268763e+01	5.05166119 IU/ML
40	TRUE	PT 6.990745e+01	3.81009595 IU/ML
41	TRUE	PT 2.882964e+01	1.57127294 IU/ML
42	TRUE	PT 1.676128e+01	0.91352323 IU/ML
43	TRUE	PT 4.051410e+00	0.22080995 IU/ML
44	TRUE	PT 3.550618e+00	0.19351580 IU/ML
45	TRUE	PT 6.419504e+00	0.34987579 IU/ML
46	TRUE	PT 1.665922e+01	0.90796079 IU/ML
47	TRUE	PT 1.740970e+01	0.94886320 IU/ML
48	TRUE	PT 1.646815e+01	0.89754717 IU/ML
49	TRUE	PT 1.011236e+01	0.55114405 IU/ML
50	TRUE	PT 5.360000e-01	0.02921307 IU/ML
51	TRUE	PT 5.360000e-01	0.02921307 IU/ML
52	TRUE	PT 4.638202e+00	0.25279129 IU/ML
53	TRUE	PT 3.821589e+00	0.20828423 IU/ML

54	TRUE	PT	5.135951e+00	0.27991960 IU/ML
55	TRUE	PT	3.418229e+00	0.18630034 IU/ML
56	TRUE	PT	4.453207e+01	2.42708675 IU/ML
57	TRUE	PT	3.613811e+01	1.96959897 IU/ML
58	TRUE	PT	3.523752e+01	1.92051552 IU/ML
59	TRUE	PT	5.337719e+02	29.09163758 IU/ML
60	TRUE	PT	4.145139e+02	22.59183883 IU/ML
61	TRUE	PT	1.991238e+02	10.85264293 IU/ML
62	TRUE	PT	1.434999e+02	7.82103317 IU/ML
63	TRUE	PT	2.426124e+00	0.13222859 IU/ML
64	TRUE	PT	2.736522e+00	0.14914591 IU/ML
65	TRUE	PT	5.360000e-01	0.02921307 IU/ML
66	TRUE	PT	2.495638e+01	1.36017276 IU/ML
67	TRUE	PT	9.687427e+01	5.27984158 IU/ML
68	TRUE	PT	3.544540e+01	1.93184542 IU/ML
69	TRUE	PT	2.901240e+01	1.58123355 IU/ML
70	TRUE	PT	3.688192e+01	2.01013838 IU/ML
71	TRUE	PT	4.178865e+01	2.27756513 IU/ML
72	TRUE	PT	4.028783e+01	2.19576744 IU/ML
73	TRUE	PT	5.806193e+01	3.16449137 IU/ML
74	TRUE	PT	2.044619e+02	11.14358372 IU/ML
75	TRUE	PT	1.711338e+02	9.32713483 IU/ML
76	TRUE	PT	2.250771e+01	1.22671504 IU/ML
77	TRUE	PT	2.606545e+01	1.42061899 IU/ML
78	TRUE	PT	8.942424e-01	0.04873800 IU/ML
79	TRUE	PT	2.042297e+02	11.13092955 IU/ML
80	TRUE	PT	2.690013e+02	14.66110672 IU/ML
81	TRUE	PT	5.545653e+00	0.30224919 IU/ML
82	TRUE	PT	3.514701e+00	0.19155823 IU/ML
83	TRUE	PT	2.014169e+01	1.09776245 IU/ML
84	TRUE	PT	1.618016e+01	0.88185086 IU/ML
85	TRUE	PT	1.004895e+02	5.47687617 IU/ML
86	TRUE	PT	1.174317e+01	0.64002640 IU/ML
87	TRUE	PT	6.656937e+00	0.36281637 IU/ML
88	TRUE	PT	5.271166e+01	2.87289077 IU/ML
89	TRUE	PT	2.396038e+01	1.30588864 IU/ML
90	TRUE	PT	3.844803e+00	0.20954945 IU/ML
91	TRUE	PT	8.667540e+01	4.72398240 IU/ML
92	TRUE	PT	9.944042e+01	5.41970147 IU/ML
93	TRUE	PT	5.779780e+01	3.15009551 IU/ML
94	TRUE	PT	4.414412e+01	2.40594281 IU/ML
95	TRUE	PT	1.829349e+02	9.97031964 IU/ML
96	TRUE	PT	1.471305e+02	8.01890564 IU/ML

97	TRUE	PT	1.435148e+02	7.82184318 IU/ML
98	TRUE	PT	1.625990e+02	8.86197308 IU/ML
99	TRUE	PT	1.689009e+02	9.20543572 IU/ML
100	TRUE	PT	1.298864e+02	7.07906798 IU/ML
101	TRUE	PT	9.833932e+01	5.35968966 IU/ML
102	TRUE	PT	4.074401e+01	2.22062993 IU/ML
103	TRUE	PT	2.795453e+01	1.52357789 IU/ML
104	TRUE	PT	2.132857e+01	1.16244994 IU/ML
105	TRUE	PT	1.906822e+02	10.39256335 IU/ML
106	TRUE	PT	1.829061e+02	9.96874747 IU/ML
107	TRUE	PT	1.416498e+02	7.72019871 IU/ML
108	TRUE	PT	1.116795e+02	6.08675823 IU/ML
109	TRUE	PT	6.382116e+01	3.47838076 IU/ML
110	TRUE	PT	6.693838e+01	3.64827565 IU/ML
111	TRUE	PT	7.681929e+01	4.18680488 IU/ML
112	TRUE	PT	1.688730e+02	9.20391366 IU/ML
113	TRUE	PT	1.701837e+02	9.27535380 IU/ML
114	TRUE	PT	8.618554e+01	4.69728443 IU/ML
115	TRUE	PT	7.018579e+01	3.82526577 IU/ML
116	TRUE	PT	8.912066e+01	4.85725419 IU/ML
117	TRUE	PT	9.381605e+01	5.11316216 IU/ML
118	TRUE	PT	2.483628e+01	1.35362715 IU/ML
119	TRUE	PT	1.116587e+02	6.08562490 IU/ML
120	TRUE	PT	1.332696e+02	7.26345933 IU/ML
121	TRUE	PT	9.902579e+01	5.39710358 IU/ML
122	TRUE	PT	6.589953e+01	3.59165598 IU/ML
123	TRUE	PT	1.071943e+02	5.84230335 IU/ML
124	TRUE	PT	9.663384e+00	0.52667375 IU/ML
125	TRUE	PT	3.046665e+00	0.16604934 IU/ML
126	TRUE	PT	2.561991e+01	1.39633657 IU/ML
127	TRUE	PT	3.536885e+01	1.92767308 IU/ML
128	TRUE	PT	2.291502e+01	1.24891414 IU/ML
129	TRUE	PT	1.334159e+01	0.72714312 IU/ML
130	TRUE	PT	6.387587e+01	3.48136253 IU/ML
131	TRUE	PT	5.805951e+00	0.31643595 IU/ML
132	TRUE	PT	1.966594e+00	0.10718333 IU/ML
133	TRUE	PT	1.371755e+02	7.47634110 IU/ML
134	TRUE	PT	8.998965e+01	4.90461599 IU/ML
135	TRUE	PT	1.124450e+02	6.12847970 IU/ML
136	TRUE	PT	7.609423e+01	4.14728768 IU/ML
137	TRUE	PT	5.895038e+00	0.32129134 IU/ML
138	TRUE	PT	6.333229e+00	0.34517365 IU/ML
139	TRUE	PT	5.301253e+00	0.28892887 IU/ML

140	TRUE	PT	7.992845e+01	4.35626048 IU/ML
141	TRUE	PT	1.322196e+02	7.20623213 IU/ML
142	TRUE	PT	1.287069e+02	7.01478560 IU/ML
143	TRUE	PT	7.821953e+01	4.26312098 IU/ML
144	TRUE	PT	3.774999e+00	0.20574500 IU/ML
145	TRUE	PT	2.995838e+00	0.16327916 IU/ML
146	TRUE	PT	2.867299e+00	0.15627354 IU/ML
147	TRUE	PT	2.363176e+01	1.28797842 IU/ML
148	TRUE	PT	1.600102e+01	0.87208731 IU/ML
149	TRUE	PT	1.461359e+01	0.79647014 IU/ML
150	TRUE	PT	1.257752e+01	0.68549982 IU/ML
151	TRUE	PT	1.250248e+01	0.68141033 IU/ML
152	TRUE	PT	5.855506e+00	0.31913680 IU/ML
153	TRUE	PT	9.181613e+00	0.50041625 IU/ML
154	TRUE	PT	2.309943e+01	1.25896521 IU/ML
155	TRUE	PT	9.055533e+00	0.49354466 IU/ML
156	TRUE	PT	1.030604e+01	0.56169992 IU/ML
157	TRUE	PT	1.283892e+01	0.69974671 IU/ML
158	TRUE	PT	1.201846e+01	0.65502996 IU/ML
159	TRUE	PT	3.798321e+00	0.20701609 IU/ML
160	TRUE	PT	1.145785e+01	0.62447577 IU/ML
161	TRUE	PT	1.893884e+01	1.03220454 IU/ML
162	TRUE	PT	4.574896e+01	2.49340964 IU/ML
163	TRUE	PT	1.027561e+02	5.60041042 IU/ML
164	TRUE	PT	3.381657e+01	1.84307076 IU/ML
165	TRUE	PT	1.295780e+01	0.70622597 IU/ML
166	TRUE	PT	3.798321e+00	0.20701609 IU/ML
167	TRUE	PT	9.240235e+00	0.50361130 IU/ML
168	TRUE	PT	5.360000e-01	0.02921307 IU/ML
169	TRUE	PT	4.395969e+01	2.39589088 IU/ML
170	TRUE	PT	4.423585e+01	2.41094249 IU/ML
171	TRUE	PT	3.389009e+01	1.84707760 IU/ML
172	TRUE	PT	2.492037e+01	1.35821005 IU/ML
173	TRUE	PT	1.223861e+01	0.66702882 IU/ML
174	TRUE	PT	2.153587e+01	1.17374816 IU/ML
175	TRUE	PT	1.064620e+02	5.80239345 IU/ML
176	TRUE	PT	1.164783e+02	6.34829906 IU/ML
177	TRUE	PT	1.415592e+02	7.71525868 IU/ML
178	TRUE	PT	8.791129e+01	4.79134103 IU/ML
179	TRUE	PT	1.826877e+01	0.99568429 IU/ML
180	TRUE	PT	1.437091e+01	0.78324334 IU/ML
181	TRUE	PT	1.839418e+01	1.00251948 IU/ML
182	TRUE	PT	3.514443e+01	1.91544177 IU/ML

183	TRUE	PT	7.509077e+01	4.09259703 IU/ML
184	TRUE	PT	7.084239e+01	3.86105190 IU/ML
185	TRUE	PT	5.424624e+01	2.95652855 IU/ML
186	TRUE	PT	1.023357e+01	0.55774987 IU/ML
187	TRUE	PT	7.595422e+00	0.41396569 IU/ML
188	TRUE	PT	3.704702e+00	0.20191367 IU/ML
189	TRUE	PT	2.155469e+01	1.17477360 IU/ML
190	TRUE	PT	6.269973e+01	3.41726062 IU/ML
191	TRUE	PT	4.244389e+01	2.31327662 IU/ML
192	TRUE	PT	1.543155e+01	0.84105042 IU/ML
193	TRUE	PT	2.229580e+00	0.12151655 IU/ML
194	TRUE	PT	2.970301e+00	0.16188733 IU/ML
195	TRUE	PT	1.609199e+00	0.08770455 IU/ML
196	TRUE	PT	1.825555e+01	0.99496392 IU/ML
197	TRUE	PT	3.300308e+01	1.79873358 IU/ML
198	TRUE	PT	2.724314e+01	1.48480542 IU/ML
199	TRUE	PT	4.884167e+00	0.26619685 IU/ML
200	TRUE	PT	3.019657e+01	1.64577368 IU/ML
201	TRUE	PT	2.746527e+01	1.49691198 IU/ML
202	TRUE	PT	2.919055e+01	1.59094337 IU/ML
203	TRUE	PT	1.459129e+02	7.95254476 IU/ML
204	TRUE	PT	2.727172e+02	14.86363460 IU/ML
205	TRUE	PT	4.075844e+02	22.21416301 IU/ML
206	TRUE	PT	1.678208e+02	9.14657064 IU/ML
207	TRUE	PT	1.020937e+01	0.55643096 IU/ML
208	TRUE	PT	1.151975e+01	0.62784956 IU/ML
209	TRUE	PT	1.337095e+01	0.72874345 IU/ML
210	TRUE	PT	3.134043e+01	1.70811604 IU/ML
211	TRUE	PT	1.540787e+02	8.39759673 IU/ML
212	TRUE	PT	1.262250e+02	6.87951327 IU/ML
213	TRUE	PT	7.603800e+01	4.14422283 IU/ML
214	TRUE	PT	2.169251e+01	1.18228510 IU/ML
215	TRUE	PT	2.065205e+01	1.12557828 IU/ML
216	TRUE	PT	2.410600e+01	1.31382533 IU/ML
217	TRUE	PT	1.723144e+02	9.39148179 IU/ML
218	TRUE	PT	1.407706e+02	7.67228073 IU/ML
219	TRUE	PT	3.968596e+01	2.16296414 IU/ML
220	TRUE	PT	2.751197e+01	1.49945725 IU/ML
221	TRUE	PT	2.360127e+01	1.28631632 IU/ML
222	TRUE	PT	3.265219e+01	1.77960983 IU/ML
223	TRUE	PT	4.159569e+01	2.26704815 IU/ML
224	TRUE	PT	7.345474e+01	4.00342993 IU/ML
225	TRUE	PT	7.734049e+01	4.21521124 IU/ML

226	TRUE	PT	6.973527e+01	3.80071177 IU/ML
227	TRUE	PT	4.484448e+01	2.44411398 IU/ML
228	TRUE	PT	1.940079e+01	1.05738162 IU/ML
229	TRUE	PT	9.597456e+00	0.52308055 IU/ML
230	TRUE	PT	1.087948e+01	0.59295350 IU/ML
231	TRUE	PT	2.676206e+01	1.45858577 IU/ML
232	TRUE	PT	4.140028e+01	2.25639777 IU/ML
233	TRUE	PT	2.243961e+01	1.22300337 IU/ML
234	TRUE	PT	7.505371e+00	0.40905771 IU/ML
235	TRUE	PT	4.670559e+00	0.25455480 IU/ML
236	TRUE	PT	2.580434e+01	1.40638789 IU/ML
237	TRUE	PT	2.103225e+01	1.14629948 IU/ML
238	TRUE	PT	2.126563e+01	1.15901953 IU/ML
239	TRUE	PT	1.297263e+01	0.70703442 IU/ML
240	TRUE	PT	9.933649e+00	0.54140374 IU/ML
241	TRUE	PT	8.835470e+00	0.48155077 IU/ML
242	TRUE	PT	9.024783e+01	4.91868692 IU/ML
243	TRUE	PT	1.211634e+02	6.60364528 IU/ML
244	TRUE	PT	5.811900e+01	3.16760167 IU/ML
245	TRUE	PT	1.678167e+01	0.91463437 IU/ML
246	TRUE	PT	7.433043e+00	0.40511568 IU/ML
247	TRUE	PT	2.402022e+02	13.09150273 IU/ML
248	TRUE	PT	4.231762e+00	0.23063950 IU/ML
249	TRUE	PT	7.188113e+01	3.91766514 IU/ML
250	TRUE	PT	1.580558e+02	8.61435564 IU/ML
251	TRUE	PT	1.065845e+02	5.80906991 IU/ML
252	TRUE	PT	4.548803e+01	2.47918867 IU/ML
253	TRUE	PT	1.537562e+01	0.83800194 IU/ML
254	TRUE	PT	1.791079e+01	0.97617404 IU/ML
255	TRUE	PT	1.095040e+01	0.59681859 IU/ML
256	TRUE	PT	9.736591e+01	5.30663653 IU/ML
257	TRUE	PT	1.450357e+02	7.90473632 IU/ML
258	TRUE	PT	1.085604e+02	5.91676096 IU/ML
259	TRUE	PT	3.657272e+01	1.99328622 IU/ML
260	TRUE	PT	2.599431e+01	1.41674185 IU/ML
261	TRUE	PT	2.673853e+01	1.45730338 IU/ML
262	TRUE	PT	2.973470e+01	1.62060080 IU/ML
263	TRUE	PT	7.844682e+01	4.27550833 IU/ML
264	TRUE	PT	1.985910e+02	10.82360502 IU/ML
265	TRUE	PT	1.582781e+02	8.62647047 IU/ML
266	TRUE	PT	1.062967e+02	5.79338157 IU/ML
267	TRUE	PT	2.143544e+01	1.16827445 IU/ML
268	TRUE	PT	1.991070e+01	1.08517287 IU/ML

269	TRUE	PT	1.986568e+01	1.08271954 IU/ML
270	TRUE	PT	1.462475e+02	7.97078041 IU/ML
271	TRUE	PT	1.626313e+02	8.86373049 IU/ML
272	TRUE	PT	1.405726e+02	7.66148966 IU/ML
273	TRUE	PT	6.919271e+01	3.77114100 IU/ML
274	TRUE	PT	1.842714e+01	1.00431571 IU/ML
275	TRUE	PT	1.469892e+01	0.80112055 IU/ML
276	TRUE	PT	1.418438e+01	0.77307707 IU/ML
277	TRUE	PT	2.650881e+01	1.44478329 IU/ML
278	TRUE	PT	4.347727e+01	2.36959803 IU/ML
279	TRUE	PT	3.329199e+01	1.81448018 IU/ML
280	TRUE	PT	2.161737e+01	1.17818975 IU/ML
281	TRUE	PT	1.657742e+01	0.90350269 IU/ML
282	TRUE	PT	1.471312e+01	0.80189472 IU/ML
283	TRUE	PT	1.634493e+01	0.89083146 IU/ML
284	TRUE	PT	2.308181e+02	12.58004938 IU/ML
285	TRUE	PT	2.938809e+02	16.01709610 IU/ML
286	TRUE	PT	1.799022e+02	9.80502883 IU/ML
287	TRUE	PT	6.102118e+01	3.32577632 IU/ML
288	TRUE	PT	1.891160e+00	0.10307198 IU/ML
289	TRUE	PT	2.467442e+00	0.13448051 IU/ML
290	TRUE	PT	5.360000e-01	0.02921307 IU/ML
291	TRUE	PT	7.765449e+00	0.42323251 IU/ML
292	TRUE	PT	3.849907e+01	2.09827627 IU/ML
293	TRUE	PT	4.788488e+00	0.26098216 IU/ML
294	TRUE	PT	1.805916e+02	9.84260193 IU/ML
295	TRUE	PT	1.954764e+02	10.65385586 IU/ML
296	TRUE	PT	1.731525e+02	9.43715476 IU/ML
297	TRUE	PT	2.393218e+02	13.04351917 IU/ML
298	TRUE	PT	2.012391e+02	10.96793431 IU/ML
299	TRUE	PT	9.749316e+01	5.31357197 IU/ML
300	TRUE	PT	9.446639e+01	5.14860711 IU/ML
301	TRUE	PT	1.039093e+02	5.66326261 IU/ML
302	TRUE	PT	2.251260e+02	12.26981730 IU/ML
303	TRUE	PT	2.808927e+02	15.30921334 IU/ML
304	TRUE	PT	2.154813e+02	11.74416023 IU/ML
305	TRUE	PT	1.707925e+02	9.30853210 IU/ML
306	TRUE	PT	5.360000e-01	0.02921307 IU/ML
307	TRUE	PT	5.360000e-01	0.02921307 IU/ML
308	TRUE	PT	5.360000e-01	0.02921307 IU/ML
309	TRUE	PT	3.574487e+00	0.19481668 IU/ML
310	TRUE	PT	5.360000e-01	0.02921307 IU/ML
311	TRUE	PT	5.383180e+00	0.29339408 IU/ML

312	TRUE	PT	1.736680e+00	0.09465256 IU/ML
313	TRUE	PT	1.623514e+01	0.88484777 IU/ML
314	TRUE	PT	1.359047e+01	0.74070760 IU/ML
315	TRUE	PT	1.627634e+01	0.88709323 IU/ML
316	TRUE	PT	1.023437e+02	5.57793682 IU/ML
317	TRUE	PT	1.399996e+02	7.63025546 IU/ML
318	TRUE	PT	1.158109e+02	6.31192769 IU/ML
319	TRUE	PT	5.811900e+01	3.16760167 IU/ML
320	TRUE	PT	7.738694e+00	0.42177432 IU/ML
321	TRUE	PT	6.993442e+00	0.38115658 IU/ML
322	TRUE	PT	3.478644e+00	0.18959303 IU/ML
323	TRUE	PT	1.656378e+01	0.90275896 IU/ML
324	TRUE	PT	5.288206e+01	2.88217808 IU/ML
325	TRUE	PT	4.468982e+01	2.43568435 IU/ML
326	TRUE	PT	2.099432e+01	1.14423265 IU/ML
327	TRUE	PT	2.889154e+01	1.57464676 IU/ML
328	TRUE	PT	2.841253e+01	1.54853942 IU/ML
329	TRUE	PT	2.086143e+01	1.13698953 IU/ML
330	TRUE	PT	3.855953e+01	2.10157135 IU/ML
331	TRUE	PT	7.357354e+01	4.00990527 IU/ML
332	TRUE	PT	5.363396e+01	2.92315807 IU/ML
333	TRUE	PT	4.938502e+01	2.69158207 IU/ML
334	TRUE	PT	5.360000e-01	0.02921307 IU/ML
335	TRUE	PT	6.486963e+01	3.53552427 IU/ML
336	TRUE	PT	1.099980e+02	5.99511003 IU/ML
337	TRUE	PT	3.593304e+01	1.95842264 IU/ML
338	TRUE	PT	2.182097e+01	1.18928641 IU/ML
339	TRUE	PT	3.135649e+02	17.08991541 IU/ML
340	TRUE	PT	1.626649e+02	8.86556036 IU/ML
341	TRUE	PT	1.126574e+02	6.14005148 IU/ML
342	TRUE	PT	1.235583e+02	6.73417266 IU/ML
343	TRUE	PT	2.192793e+02	11.95116199 IU/ML
344	TRUE	PT	1.401067e+02	7.63609789 IU/ML
345	TRUE	PT	1.270450e+02	6.92420856 IU/ML
346	TRUE	PT	6.455294e+01	3.51826438 IU/ML
347	TRUE	PT	5.466709e+01	2.97946590 IU/ML
348	TRUE	PT	3.128600e+01	1.70514930 IU/ML
349	TRUE	PT	1.342113e+02	7.31478393 IU/ML
350	TRUE	PT	1.723631e+02	9.39413524 IU/ML
351	TRUE	PT	1.583413e+02	8.62991960 IU/ML
352	TRUE	PT	1.506017e+02	8.20809541 IU/ML
353	TRUE	PT	6.236853e+00	0.33992094 IU/ML
354	TRUE	PT	8.250169e+00	0.44965073 IU/ML

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356                TRUE      PT 4.716210e+01     2.57042853 IU/ML
357                TRUE      PT 1.206523e+02     6.57578973 IU/ML
358                TRUE      PT 9.477905e+01     5.16564782 IU/ML
359                TRUE      PT 9.057606e+01     4.93657616 IU/ML
360                TRUE      PT 1.520603e+02     8.28759185 IU/ML
361                TRUE      PT 1.637493e+02     8.92466390 IU/ML
362                TRUE      PT 1.690590e+02     9.21405607 IU/ML
363                TRUE      PT 1.975188e+02    10.76516737 IU/ML
364                TRUE      PT 2.025211e+02    11.03780589 IU/ML
365                TRUE      PT 1.766280e+02     9.62657769 IU/ML
366                TRUE      PT 1.500179e+02     8.17627776 IU/ML
367                TRUE      PT 3.751622e+00     0.20447092 IU/ML
368                TRUE      PT 1.427234e+00     0.07778712 IU/ML
369                TRUE      PT 4.464164e+00     0.24330586 IU/ML
370                TRUE      PT 6.028974e+01     3.28591154 IU/ML
371                TRUE      PT 8.300331e+01     4.52384648 IU/ML
372                TRUE      PT 7.641164e+01     4.16458701 IU/ML
373                TRUE      PT 3.410543e+01     1.85881424 IU/ML
374                TRUE      PT 1.598721e+01     0.87133475 IU/ML
375                TRUE      PT 2.552458e+01     1.39114064 IU/ML
376                TRUE      PT 3.062824e+01     1.66930048 IU/ML
377                TRUE      PT 1.850249e+02    10.08422490 IU/ML
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379                TRUE      PT 1.962044e+02    10.69353185 IU/ML
380                TRUE      PT 8.720626e+01     4.75291554 IU/ML
381                TRUE      PT 1.254752e+01     0.68386505 IU/ML
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384                TRUE      PT 1.058576e+02     5.76945289 IU/ML
385                TRUE      PT 3.529587e+02    19.23695317 IU/ML
386                TRUE      PT 1.533711e+04     0.02888606 IU/ML
387                TRUE      PT 1.920847e+02    10.46900269 IU/ML
388                TRUE      PT 5.360000e-01     0.02921307 IU/ML
389                TRUE      PT 5.360000e-01     0.02921307 IU/ML
390                TRUE      PT 5.360000e-01     0.02921307 IU/ML
391                TRUE      PT 2.118372e+01     1.15455529 IU/ML
392                TRUE      PT 3.155439e+01     1.71977739 IU/ML
393                TRUE      PT 4.176455e+01     2.27625121 IU/ML
394                TRUE      PT 1.048244e+01     0.57131410 IU/ML
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53		White	1972-01-01	2019-01-28
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57		White	1990-01-01	2019-01-28
58		White	1990-01-01	2019-01-28
59		White	1990-01-01	2019-01-28

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98                                    White    1995-01-01    2019-02-25
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101 Native Hawaiian or Other Pacific Islander    1998-01-01    2019-02-25
102 Native Hawaiian or Other Pacific Islander    1998-01-01    2019-02-25
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188	Asian	1999-01-01	2019-06-03

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191	Unknown or Not Reported	1998-01-01	2019-06-03
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201	White	2000-01-01	2019-06-24
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203	White	2000-01-01	2019-06-24
204	More Than One Race	1996-01-01	2019-06-24
205	More Than One Race	1996-01-01	2019-06-24
206	More Than One Race	1996-01-01	2019-06-24
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2	2021_dataset	14221 days	11785 days	469	1
3	2021_dataset	14221 days	11785 days	470	3
4	2021_dataset	14221 days	11785 days	471	7
5	2021_dataset	14221 days	11785 days	472	14
6	2021_dataset	14221 days	11785 days	473	30
7	2021_dataset	14221 days	11785 days	474	91
8	2021_dataset	12029 days	9460 days	475	0
9	2021_dataset	12029 days	9460 days	476	1
10	2021_dataset	12029 days	9460 days	477	3
11	2021_dataset	12029 days	9460 days	478	7
12	2021_dataset	12029 days	9460 days	479	14
13	2021_dataset	12029 days	9460 days	480	30
14	2021_dataset	12029 days	9460 days	481	101
15	2021_dataset	11299 days	8730 days	483	0
16	2021_dataset	11299 days	8730 days	484	1
17	2021_dataset	11299 days	8730 days	485	3
18	2021_dataset	11299 days	8730 days	486	7
19	2021_dataset	11299 days	8730 days	487	14
20	2021_dataset	11299 days	8730 days	488	38
21	2021_dataset	11299 days	8730 days	489	121
22	2021_dataset	12029 days	9460 days	490	0
23	2021_dataset	12029 days	9460 days	491	1
24	2021_dataset	12029 days	9460 days	492	3
25	2021_dataset	12029 days	9460 days	493	7
26	2021_dataset	12029 days	9460 days	494	14
27	2021_dataset	12029 days	9460 days	495	30
28	2021_dataset	12029 days	9460 days	496	101
29	2021_dataset	13125 days	10563 days	498	0
30	2021_dataset	13125 days	10563 days	499	1
31	2021_dataset	13125 days	10563 days	500	3
32	2021_dataset	13125 days	10563 days	501	7
33	2021_dataset	13125 days	10563 days	502	14
34	2021_dataset	13125 days	10563 days	503	37
35	2021_dataset	13125 days	10563 days	504	98
36	2021_dataset	18239 days	15677 days	506	0
37	2021_dataset	18239 days	15677 days	507	1
38	2021_dataset	18239 days	15677 days	508	3
39	2021_dataset	18239 days	15677 days	509	7
40	2021_dataset	18239 days	15677 days	510	14
41	2021_dataset	18239 days	15677 days	511	31
42	2021_dataset	18239 days	15677 days	512	101

43	2021_dataset	19700 days	17194 days	513	0
44	2021_dataset	19700 days	17194 days	514	1
45	2021_dataset	19700 days	17194 days	515	3
46	2021_dataset	19700 days	17194 days	516	7
47	2021_dataset	19700 days	17194 days	517	14
48	2021_dataset	19700 days	17194 days	518	30
49	2021_dataset	19700 days	17194 days	519	93
50	2021_dataset	19700 days	17194 days	521	0
51	2021_dataset	19700 days	17194 days	522	1
52	2021_dataset	19700 days	17194 days	523	3
53	2021_dataset	19700 days	17194 days	524	7
54	2021_dataset	19700 days	17194 days	525	14
55	2021_dataset	19700 days	17194 days	526	30
56	2021_dataset	19700 days	17194 days	527	93
57	2021_dataset	13125 days	10619 days	529	0
58	2021_dataset	13125 days	10619 days	530	1
59	2021_dataset	13125 days	10619 days	531	3
60	2021_dataset	13125 days	10619 days	532	7
61	2021_dataset	13125 days	10619 days	533	14
62	2021_dataset	13125 days	10619 days	534	32
63	2021_dataset	13125 days	10619 days	535	91
64	2021_dataset	10203 days	7697 days	537	0
65	2021_dataset	10203 days	7697 days	538	1
66	2021_dataset	10203 days	7697 days	539	3
67	2021_dataset	10203 days	7697 days	540	7
68	2021_dataset	10203 days	7697 days	541	14
69	2021_dataset	10203 days	7697 days	542	32
70	2021_dataset	10203 days	7697 days	543	93
71	2021_dataset	10203 days	7697 days	546	0
72	2021_dataset	10203 days	7697 days	547	1
73	2021_dataset	10203 days	7697 days	548	3
74	2021_dataset	10203 days	7697 days	549	7
75	2021_dataset	10203 days	7697 days	550	14
76	2021_dataset	10203 days	7697 days	551	37
77	2021_dataset	10203 days	7697 days	552	108
78	2021_dataset	12760 days	10282 days	554	0
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80	2021_dataset	12760 days	10282 days	556	3
81	2021_dataset	12760 days	10282 days	557	7
82	2021_dataset	12760 days	10282 days	558	14
83	2021_dataset	12760 days	10282 days	559	29
84	2021_dataset	12760 days	10282 days	560	94
85	2021_dataset	11299 days	8821 days	562	0

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87  2021_dataset 11299 days  8821 days         564                  3
88  2021_dataset 11299 days  8821 days         565                  7
89  2021_dataset 11299 days  8821 days         566                 14
90  2021_dataset 11299 days  8821 days         567                 37
91  2021_dataset 11299 days  8821 days         568                 98
92  2021_dataset 11299 days  8821 days         569                  0
93  2021_dataset 11299 days  8821 days         570                  1
94  2021_dataset 11299 days  8821 days         571                  3
95  2021_dataset 11299 days  8821 days         572                  7
96  2021_dataset 11299 days  8821 days         573                 14
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98  2021_dataset 11299 days  8821 days         575                 94
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101 2021_dataset 10203 days  7725 days         579                  3
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103 2021_dataset 10203 days  7725 days         581                 14
104 2021_dataset 10203 days  7725 days         582                 29
105 2021_dataset 10203 days  7725 days         583                 94
106 2021_dataset 10203 days  7725 days         585                  0
107 2021_dataset 10203 days  7725 days         586                  1
108 2021_dataset 10203 days  7725 days         587                  3
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110 2021_dataset 10203 days  7725 days         589                 14
111 2021_dataset 10203 days  7725 days         590                 30
112 2021_dataset 10203 days  7725 days         591                 93
113 2021_dataset 13856 days 11399 days         593                  0
114 2021_dataset 13856 days 11399 days         594                  1
115 2021_dataset 13856 days 11399 days         595                  3
116 2021_dataset 13856 days 11399 days         596                  7
117 2021_dataset 13856 days 11399 days         597                 14
118 2021_dataset 13856 days 11399 days         598                 31
119 2021_dataset 13856 days 11399 days         599                 94
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122 2021_dataset 12029 days  9572 days         603                  3
123 2021_dataset 12029 days  9572 days         604                  7
124 2021_dataset 12029 days  9572 days         605                 14
125 2021_dataset 12029 days  9572 days         606                 31
126 2021_dataset 12029 days  9572 days         607                 92
127 2021_dataset 14221 days 11764 days         608                  0
128 2021_dataset 14221 days 11764 days         609                  1
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132	2021_dataset	14221 days	11764 days	613	31
133	2021_dataset	14221 days	11764 days	614	92
134	2021_dataset	12395 days	9938 days	616	0
135	2021_dataset	12395 days	9938 days	617	1
136	2021_dataset	12395 days	9938 days	618	3
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138	2021_dataset	12395 days	9938 days	620	14
139	2021_dataset	12395 days	9938 days	621	31
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146	2021_dataset	12029 days	9572 days	628	36
147	2021_dataset	12029 days	9572 days	629	100
148	2021_dataset	9838 days	7402 days	636	0
149	2021_dataset	9838 days	7402 days	637	1
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151	2021_dataset	9838 days	7402 days	639	7
152	2021_dataset	9838 days	7402 days	640	14
153	2021_dataset	9838 days	7402 days	641	30
154	2021_dataset	9838 days	7402 days	642	99
155	2021_dataset	10568 days	8132 days	643	0
156	2021_dataset	10568 days	8132 days	644	1
157	2021_dataset	10568 days	8132 days	645	3
158	2021_dataset	10568 days	8132 days	646	7
159	2021_dataset	10568 days	8132 days	647	15
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161	2021_dataset	10568 days	8132 days	649	95
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163	2021_dataset	9473 days	7058 days	651	1
164	2021_dataset	9473 days	7058 days	652	3
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167	2021_dataset	9473 days	7058 days	655	30
168	2021_dataset	9473 days	7058 days	656	150
169	2021_dataset	10203 days	7788 days	657	0
170	2021_dataset	10203 days	7788 days	658	1
171	2021_dataset	10203 days	7788 days	659	3

172	2021_dataset	10203 days	7788 days	660	7
173	2021_dataset	10203 days	7788 days	661	14
174	2021_dataset	10203 days	7788 days	662	30
175	2021_dataset	10203 days	7788 days	663	102
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179	2021_dataset	10568 days	8188 days	677	7
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185	2021_dataset	9838 days	7458 days	683	3
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189	2021_dataset	9838 days	7458 days	687	112
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201	2021_dataset	9473 days	7114 days	699	14
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203	2021_dataset	9473 days	7114 days	701	93
204	2021_dataset	10934 days	8575 days	702	0
205	2021_dataset	10934 days	8575 days	703	1
206	2021_dataset	10934 days	8575 days	704	3
207	2021_dataset	10934 days	8575 days	705	7
208	2021_dataset	10934 days	8575 days	706	14
209	2021_dataset	10934 days	8575 days	707	30
210	2021_dataset	10934 days	8575 days	708	95
211	2021_dataset	9838 days	7479 days	709	0
212	2021_dataset	9838 days	7479 days	710	1
213	2021_dataset	9838 days	7479 days	711	3
214	2021_dataset	9838 days	7479 days	712	7

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216 2021_dataset  9838 days  7479 days         714                          30
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222 2021_dataset 10203 days  7844 days         720                          14
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224 2021_dataset 10203 days  7844 days         722                          93
225 2021_dataset  9473 days  7114 days         723                           0
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227 2021_dataset  9473 days  7114 days         725                           3
228 2021_dataset  9473 days  7114 days         726                           7
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231 2021_dataset  9473 days  7114 days         729                          93
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2                               1         Blood     2     IgG
3                               3         Blood     3     IgG
4                               7         Blood     4     IgG
5                              14         Blood     5     IgG
6                              30         Blood     6     IgG
7                             120         Blood     7     IgG
8                               0         Blood     1     IgG
9                               1         Blood     2     IgG
10                              3         Blood     3     IgG
11                              7         Blood     4     IgG
12                             14         Blood     5     IgG
13                             30         Blood     6     IgG
14                            120         Blood     7     IgG
15                              0         Blood     1     IgG
16                              1         Blood     2     IgG
17                              3         Blood     3     IgG
18                              7         Blood     4     IgG
19                             14         Blood     5     IgG
20                             30         Blood     6     IgG
21                            120         Blood     7     IgG
22                              0         Blood     1     IgG
23                              1         Blood     2     IgG
24                              3         Blood     3     IgG
25                              7         Blood     4     IgG
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27	30	Blood	6	IgG
28	120	Blood	7	IgG
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30	1	Blood	2	IgG
31	3	Blood	3	IgG
32	7	Blood	4	IgG
33	14	Blood	5	IgG
34	30	Blood	6	IgG
35	120	Blood	7	IgG
36	0	Blood	1	IgG
37	1	Blood	2	IgG
38	3	Blood	3	IgG
39	7	Blood	4	IgG
40	14	Blood	5	IgG
41	30	Blood	6	IgG
42	120	Blood	7	IgG
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44	1	Blood	2	IgG
45	3	Blood	3	IgG
46	7	Blood	4	IgG
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48	30	Blood	6	IgG
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54	14	Blood	5	IgG
55	30	Blood	6	IgG
56	120	Blood	7	IgG
57	0	Blood	1	IgG
58	1	Blood	2	IgG
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60	7	Blood	4	IgG
61	14	Blood	5	IgG
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65	1	Blood	2	IgG
66	3	Blood	3	IgG
67	7	Blood	4	IgG
68	14	Blood	5	IgG

69	30	Blood	6	IgG
70	120	Blood	7	IgG
71	0	Blood	1	IgG
72	1	Blood	2	IgG
73	3	Blood	3	IgG
74	7	Blood	4	IgG
75	14	Blood	5	IgG
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228                            7         Blood     4     IgG
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8                 FALSE      PT  124.951277     1.10821532  MFI
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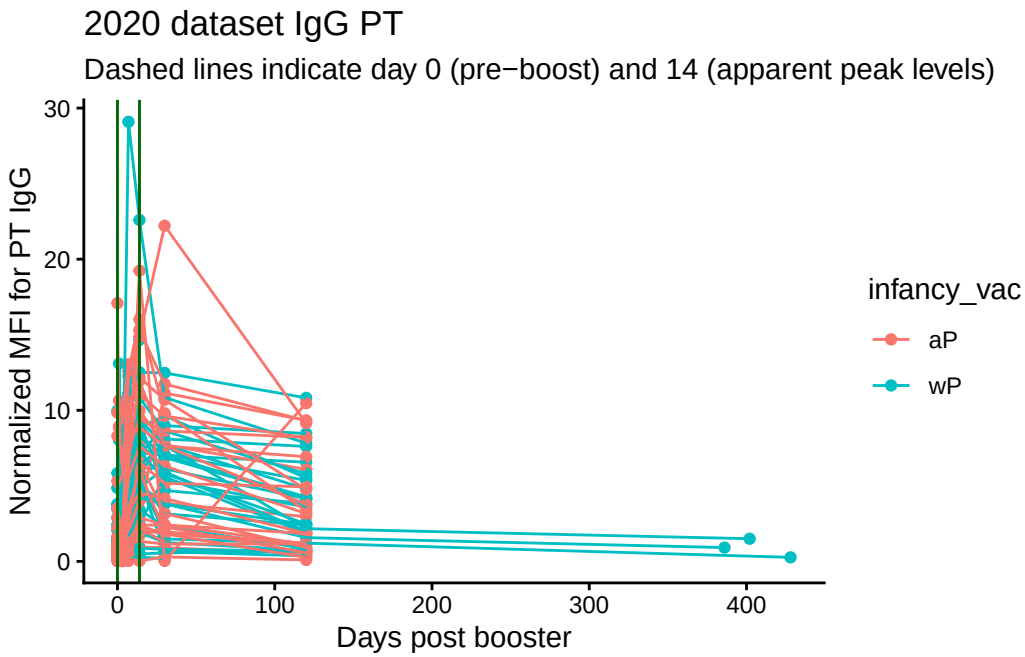
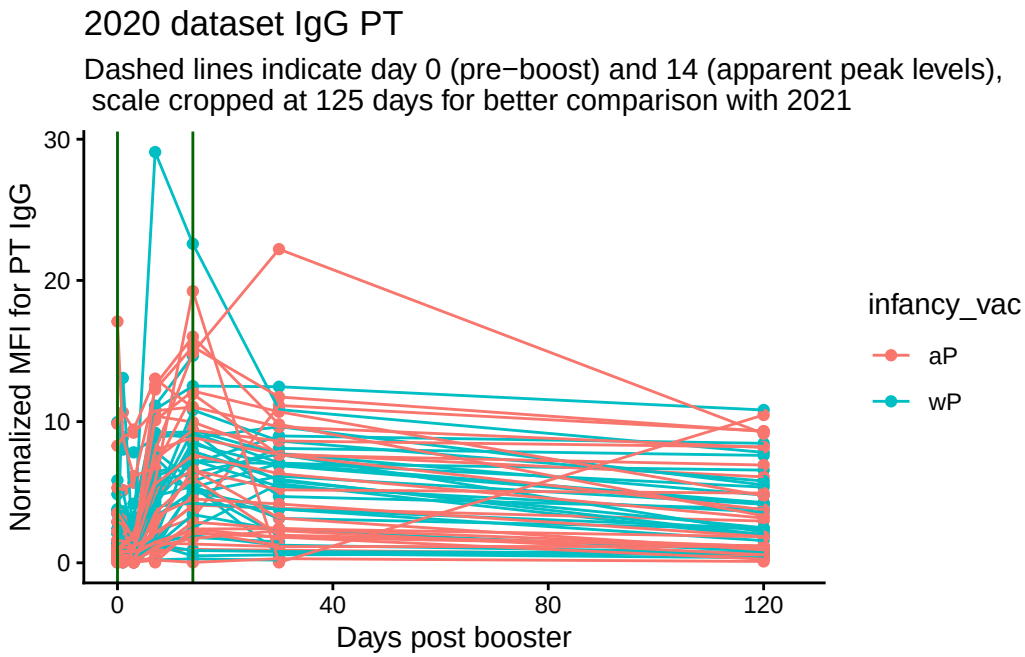
```
pt_2020 |>
  ggplot() +
    aes(planned_day_relative_to_boost,
        MFI_normalised,
        color=infancy_vac,
        group=subject_id) +
    geom_point() +
    geom_line() +
    theme_classic() +
    geom_vline(xintercept=0, col="darkgreen") +
    geom_vline(xintercept =14, col="darkgreen") +
    labs(title="2020 dataset IgG PT",
       subtitle = "Dashed lines indicate day 0 (pre-boost) and 14 (apparent peak levels)",x="
```



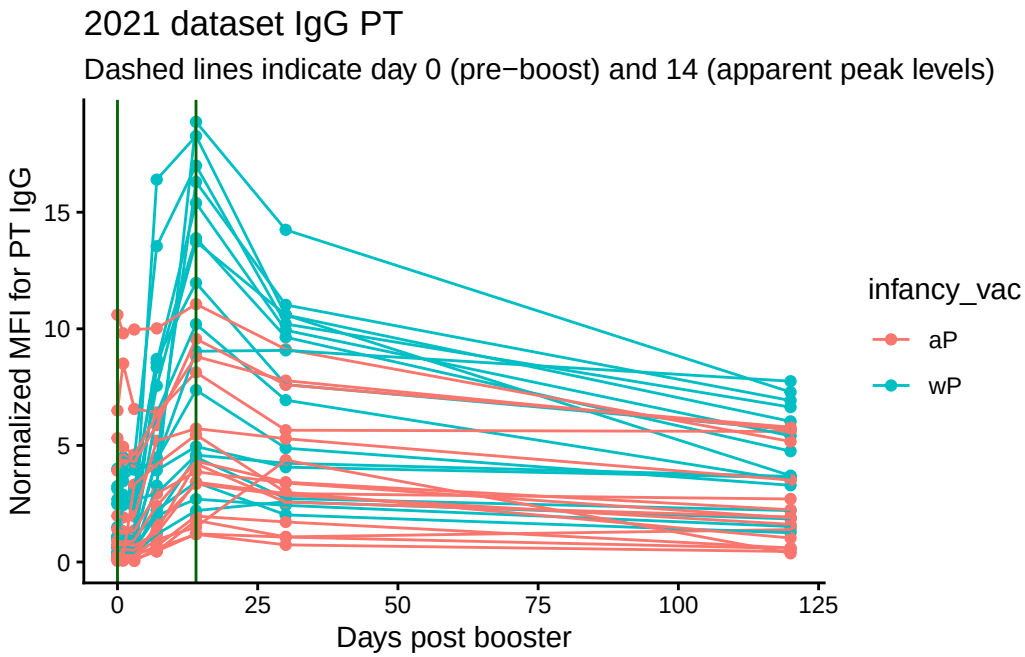

```
pt_2020 |>
  ggplot() +
    aes(planned_day_relative_to_boost,
        MFI_normalised,
        color=infancy_vac,
        group=subject_id) +
    geom_point() +
    geom_line() +
    theme_classic() +
    geom_vline(xintercept=0, col="darkgreen") +
    geom_vline(xintercept =14, col="darkgreen") +
    scale_x_continuous(limits = c(0, 125)) +
    labs(title="2020 dataset IgG PT",
       subtitle = "Dashed lines indicate day 0 (pre-boost) and 14 (apparent peak levels), \n
```

```
Warning: Removed 3 rows containing missing values or values outside the scale range
(`geom_point()`).
```

```
Warning: Removed 3 rows containing missing values or values outside the scale range
(`geom_line()`).
```




```
pt_2021 |>
  ggplot() +
    aes(planned_day_relative_to_boost,
        MFI_normalised,
        color=infancy_vac,
        group=subject_id) +
    geom_point() +
    geom_line() +
    theme_classic() +
    geom_vline(xintercept=0, col="darkgreen") +
    geom_vline(xintercept =14, col="darkgreen") +
    labs(title="2021 dataset IgG PT",
       subtitle = "Dashed lines indicate day 0 (pre-boost) and 14 (apparent peak levels)",x="
```



Q18. Does this trend look similar for the 2020 dataset?

Hard to tell - the 2020 trend looks quite smushed bnecause of twice the number of days being recorded. I would guess probably.

Actually, no, MFIs were HIGHER in 2020 at 14 days.

System setup

```
sessionInfo()
```

```
R version 4.5.1 (2025-06-13 ucrt)
Platform: x86_64-w64-mingw32/x64
Running under: Windows 11 x64 (build 26200)

Matrix products: default
  LAPACK version 3.12.1

locale:
[1] LC_COLLATE=English_United States.utf8
[2] LC_CTYPE=English_United States.utf8
[3] LC_MONETARY=English_United States.utf8
```

```
[4] LC_NUMERIC=C
[5] LC_TIME=English_United States.utf8

time zone: America/Los_Angeles
tzcode source: internal

attached base packages:
[1] stats     graphics  grDevices utils     datasets  methods   base

other attached packages:
[1] dplyr_1.1.4     lubridate_1.9.4 jsonlite_2.0.0  ggplot2_4.0.1

loaded via a namespace (and not attached):
 [1] vctrs_0.6.5        cli_3.6.5          knitr_1.50         rlang_1.1.6
 [5] xfun_0.54          generics_0.1.4     S7_0.2.1           labeling_0.4.3
 [9] glue_1.8.0         htmltools_0.5.8.1  scales_1.4.0       rmarkdown_2.30
[13] grid_4.5.1         evaluate_1.0.5     tibble_3.3.0       fastmap_1.2.0
[17] yaml_2.3.10        lifecycle_1.0.4    compiler_4.5.1     RColorBrewer_1.1-3
[21] timechange_0.3.0   pkgconfig_2.0.3    rstudioapi_0.17.1  farver_2.1.2
[25] digest_0.6.39      R6_2.6.1           tidyselect_1.2.1   pillar_1.11.1
[29] magrittr_2.0.4     withr_3.0.2        tools_4.5.1        gtable_0.3.6
```