

Class 19: Pertussis Mini Project

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Background

Pertussis is a bacteria; lung infection also known as Whooping cough. Lets begin by examining CDC reported case numbers in the US:

```
cdc <- data.frame(  
  
  Year = c(1922L, 1923L, 1924L, 1925L,  
          1926L, 1927L, 1928L, 1929L, 1930L, 1931L,  
          1932L, 1933L, 1934L, 1935L, 1936L,  
          1937L, 1938L, 1939L, 1940L, 1941L, 1942L,  
          1943L, 1944L, 1945L, 1946L, 1947L,  
          1948L, 1949L, 1950L, 1951L, 1952L,  
          1953L, 1954L, 1955L, 1956L, 1957L, 1958L,  
          1959L, 1960L, 1961L, 1962L, 1963L,  
          1964L, 1965L, 1966L, 1967L, 1968L, 1969L,  
          1970L, 1971L, 1972L, 1973L, 1974L,  
          1975L, 1976L, 1977L, 1978L, 1979L, 1980L,  
          1981L, 1982L, 1983L, 1984L, 1985L,  
          1986L, 1987L, 1988L, 1989L, 1990L,  
          1991L, 1992L, 1993L, 1994L, 1995L, 1996L,  
          1997L, 1998L, 1999L, 2000L, 2001L,  
          2002L, 2003L, 2004L, 2005L, 2006L, 2007L,  
          2008L, 2009L, 2010L, 2011L, 2012L,  
          2013L, 2014L, 2015L, 2016L, 2017L, 2018L,  
          2019L, 2020L, 2021L, 2022L, 2023L, 2024L),  
  
  Cases = c(107473, 164191, 165418, 152003,  
           202210, 181411, 161799, 197371,  
           166914, 172559, 215343, 179135, 265269,  
           180518, 147237, 214652, 227319, 103188,
```

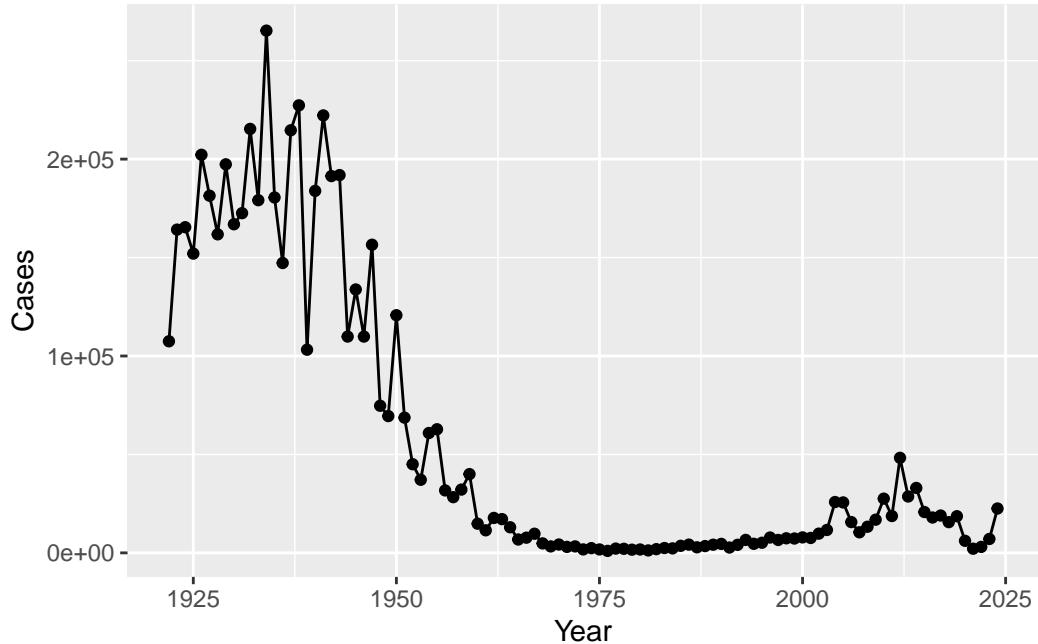
```
183866,222202,191383,191890,109873,  
133792,109860,156517,74715,69479,  
120718,68687,45030,37129,60886,  
62786,31732,28295,32148,40005,  
14809,11468,17749,17135,13005,6799,  
7717,9718,4810,3285,4249,3036,  
3287,1759,2402,1738,1010,2177,2063,  
1623,1730,1248,1895,2463,2276,  
3589,4195,2823,3450,4157,4570,  
2719,4083,6586,4617,5137,7796,6564,  
7405,7298,7867,7580,9771,11647,  
25827,25616,15632,10454,13278,  
16858,27550,18719,48277,28639,32971,  
20762,17972,18975,15609,18617,  
6124,2116,3044,7063,22538))
```

Plot of cases per year for pertussis in the US.

```
library(ggplot2)
```

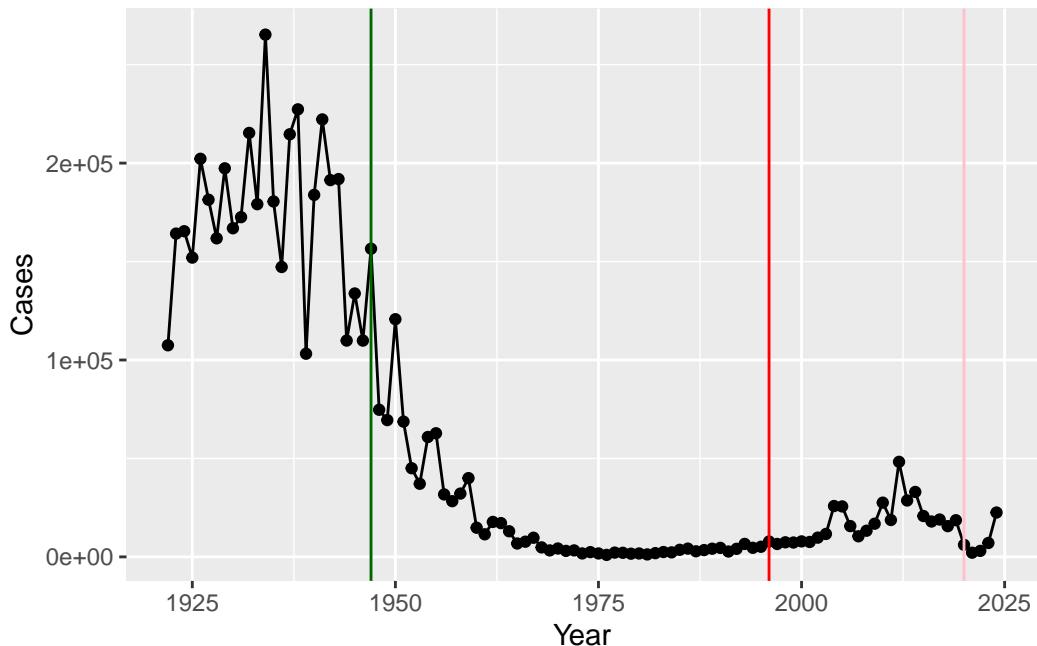
Warning: package 'ggplot2' was built under R version 4.4.3

```
ggplot(cdc)+  
  aes(Year,Cases)+  
  geom_point()  
  geom_line()
```



Add some major milestone timepoints to our plot

```
ggplot(cdc)+  
  aes(Year,Cases)+  
  geom_point()+  
  geom_line()  
  geom_vline(xintercept=1947,col="darkgreen")  
  geom_vline(xintercept=1996,col="red")  
  geom_vline(xintercept=2020,col="pink")
```



The full introduction of mandatory wP (whole-cell Pertussis immunization in the mid 1940s lead to a dramatic reduction in case numbers (from over 200,000 to 100s)

The switch to the aP (newer acellular) formalization will result in less side effects of the drug. There two types of vaccines DTaP and Tdap

The 2020 lock-downs and social distancing measures helped decrease the number of cases.

The CMI-BP project

The mission of CMI-PB is to provide the scientific community with a comprehensive, high-quality and freely accessible resource of Pertussis booster vaccination. website:<https://www.cmi-pb.org/>

They make their data available via JSON format API endpoints- basically database tables in a key:values type format like “infancy_vac”:“wp” to read this we can use the `read_json()` function from the **jsonlite** package.

```
library(jsonlite)
```

```
Warning: package 'jsonlite' was built under R version 4.4.3
```

```
subject<- read_json(path="https://www.cmi-pb.org/api/v5_1/subject",simplifyVector = TRUE)  
head(subject)
```

	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
4	4	wP		Male Not Hispanic or Latino	Asian
5	5	wP		Male Not Hispanic or Latino	Asian
6	6	wP	Female	Not Hispanic or Latino	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
4	1988-01-01	2016-08-29	2020_dataset
5	1991-01-01	2016-08-29	2020_dataset
6	1988-01-01	2016-10-10	2020_dataset

Q. how many “subjects”/individuals are in this dataset?

```
nrow(subject)
```

[1] 172

Q. how many wP and aP subjects are these?

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

aP	wP
87	85

Q. What is the breakdown by “biological_sex” and “race”?

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

Female	Male
112	60

```
table(subject$race)
```

American Indian/Alaska Native	
	1
Asian	
	44
Black or African American	
	5
More Than One Race	
	19
Native Hawaiian or Other Pacific Islander	
	2
Unknown or Not Reported	
	21
White	
	80

```
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

This breakdown is not particulary representative of the US population-This is a serious caveat for this study. However, its still the largest sample of its type every assembled.

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

```
head(specimen)
```

```
specimen_id subject_id actual_day_relative_to_boost
```

1	1	1	-3
2	2	1	1
3	3	1	3
4	4	1	7
5	5	1	11
6	6	1	32

	planned_day_relative_to_boost	specimen_type	visit
1	0	Blood	1
2	1	Blood	2
3	3	Blood	3
4	7	Blood	4
5	14	Blood	5
6	30	Blood	6

we need to “join” or link these tables with the `subject` table so we can begin to analyze this data and know who give Ab sample was collected for and when.

```
library(dplyr)
```

Warning: package 'dplyr' was built under R version 4.4.3

Adjuntando el paquete: 'dplyr'

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

filter, lag

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

intersect, setdiff, setequal, union

```
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 specimen_id
1   1986-01-01  2016-09-12 2020_dataset       1
2   1986-01-01  2016-09-12 2020_dataset       2
3   1986-01-01  2016-09-12 2020_dataset       3
4   1986-01-01  2016-09-12 2020_dataset       4
5   1986-01-01  2016-09-12 2020_dataset       5
6   1986-01-01  2016-09-12 2020_dataset       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

```

Now lets join the `ab_titer` table with our `meta` table so we have all information about given Ab measurements

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

Joining with `by = join_by(specimen_id)`

```
head(ab_titer)
```

	specimen_id	isotype	is_antigen_specific	antigen	MFI	MFI_normalised
1	1	IgE	FALSE	Total	1110.21154	2.493425
2	1	IgE	FALSE	Total	2708.91616	2.493425

```

3      1 IgG      TRUE    PT   68.56614   3.736992
4      1 IgG      TRUE    PRN  332.12718   2.602350
5      1 IgG      TRUE    FHA 1887.12263   34.050956
6      1 IgE      TRUE    ACT   0.10000   1.000000
  unit lower_limit_of_detection
1 UG/ML          2.096133
2 IU/ML          29.170000
3 IU/ML          0.530000
4 IU/ML          6.205949
5 IU/ML          4.679535
6 IU/ML          2.816431

```

Q. How many Ab measurements do we have in total?

```
nrow(ab_data)
```

```
[1] 61956
```

Q. how many different isotypes (types of Ab)?

```
unique(ab_data$isotype)
```

```
[1] "IgE"  "IgG"  "IgG1" "IgG2" "IgG3" "IgG4"
```

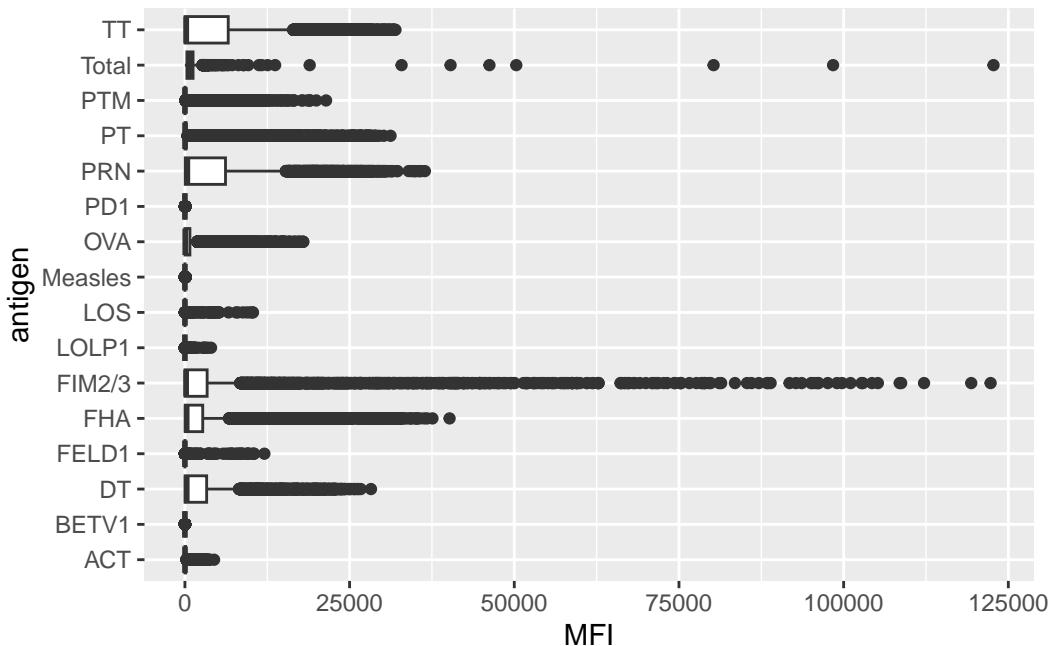
Q. How many different antigens?

```
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()
```

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

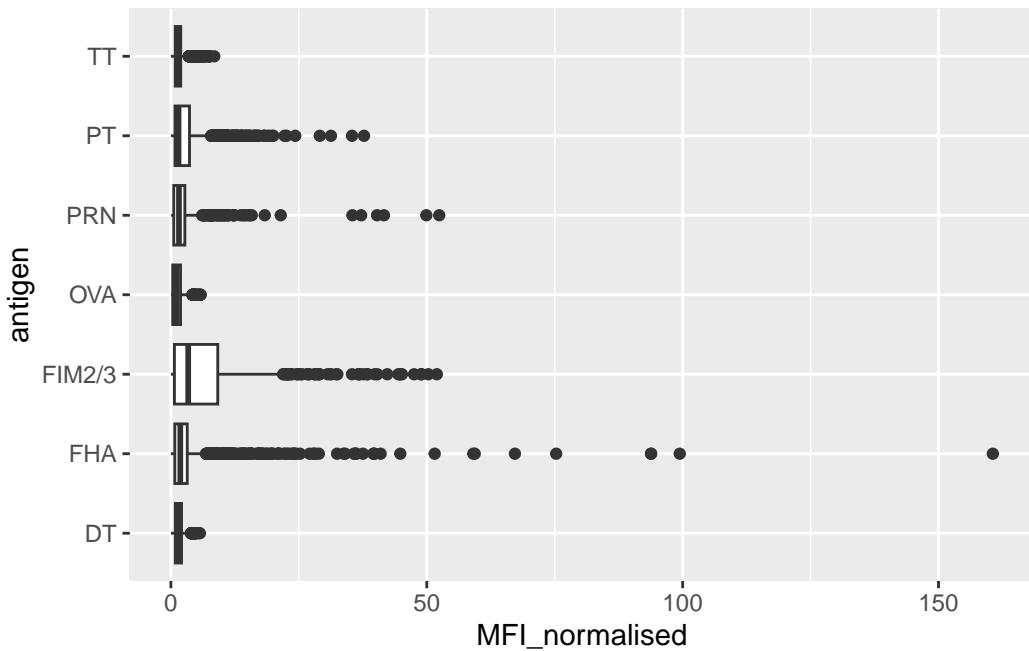


##Examine IgG Ab titer levels

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

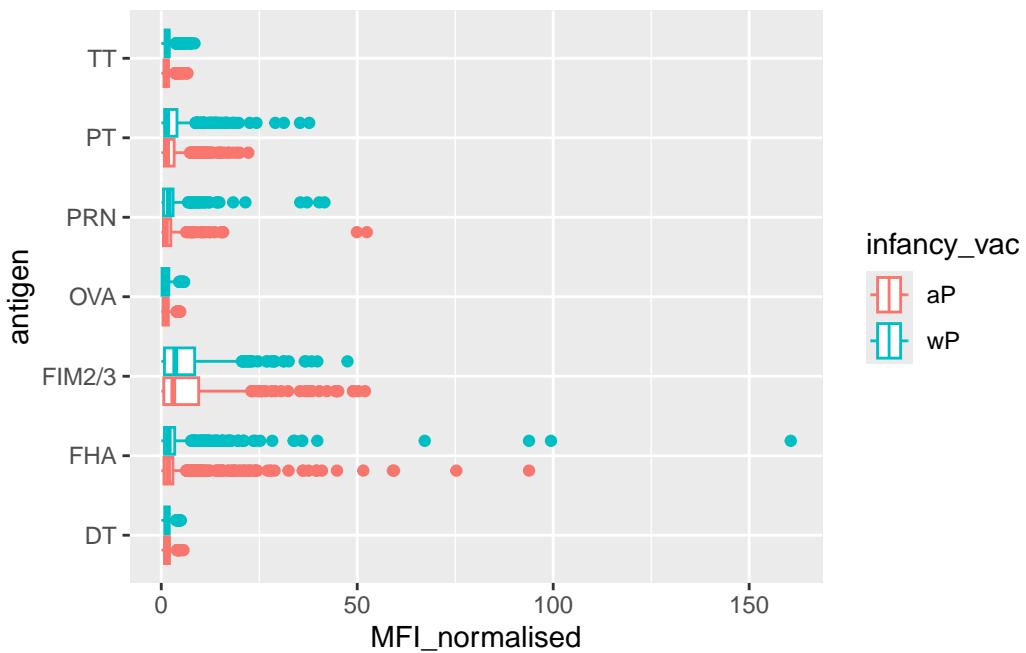
```
igg<-ab_data|>
  filter(isotype=="IgG")
```

```
ggplot(igg)+ 
  aes(MFI_normalised,antigen)+ 
  geom_boxplot()
```

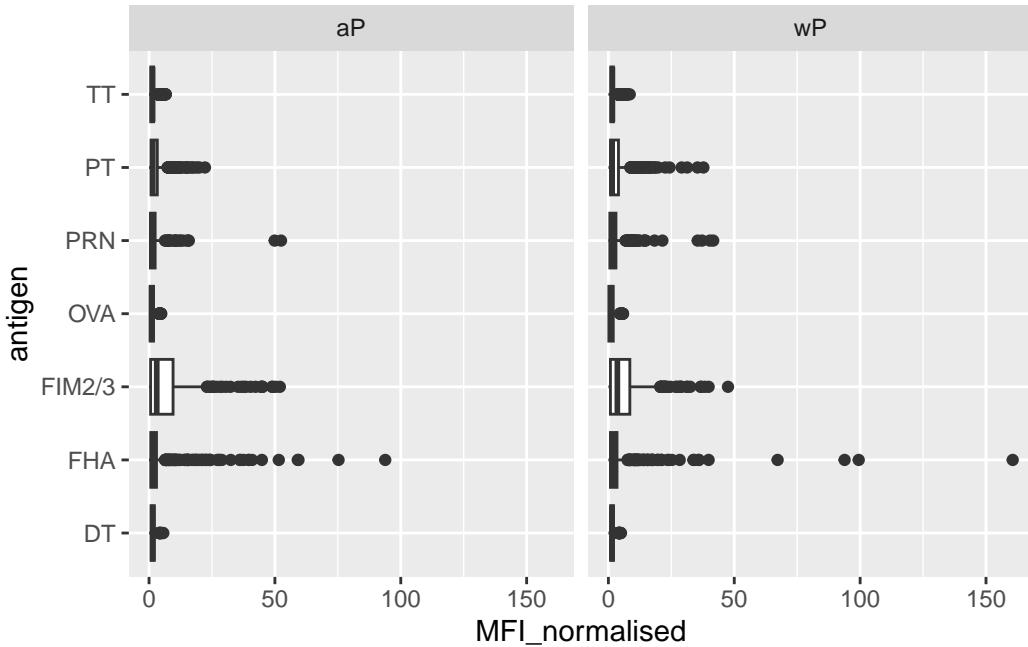


we can “facet” out plot by wP vs aP

```
ggplot(igg)+  
  aes(MFI_normalised,antigen, col=infancy_vac)+  
  geom_boxplot()
```

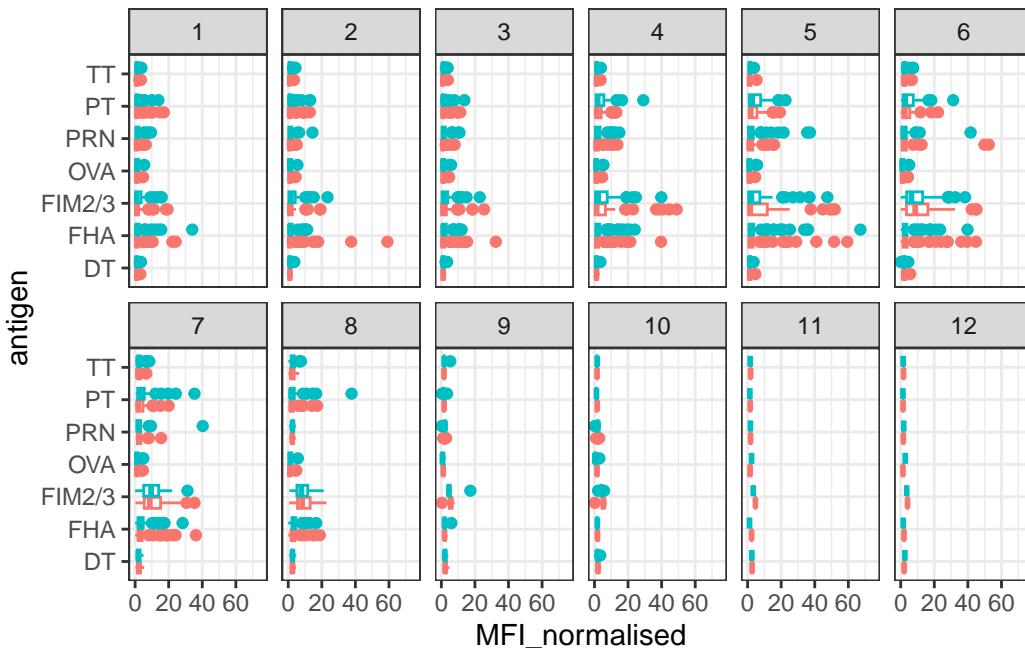


```
ggplot(igg)+  
  aes(MFI_normalised,antigen)+  
  geom_boxplot() +  
  facet_wrap(~infancy_vac)
```



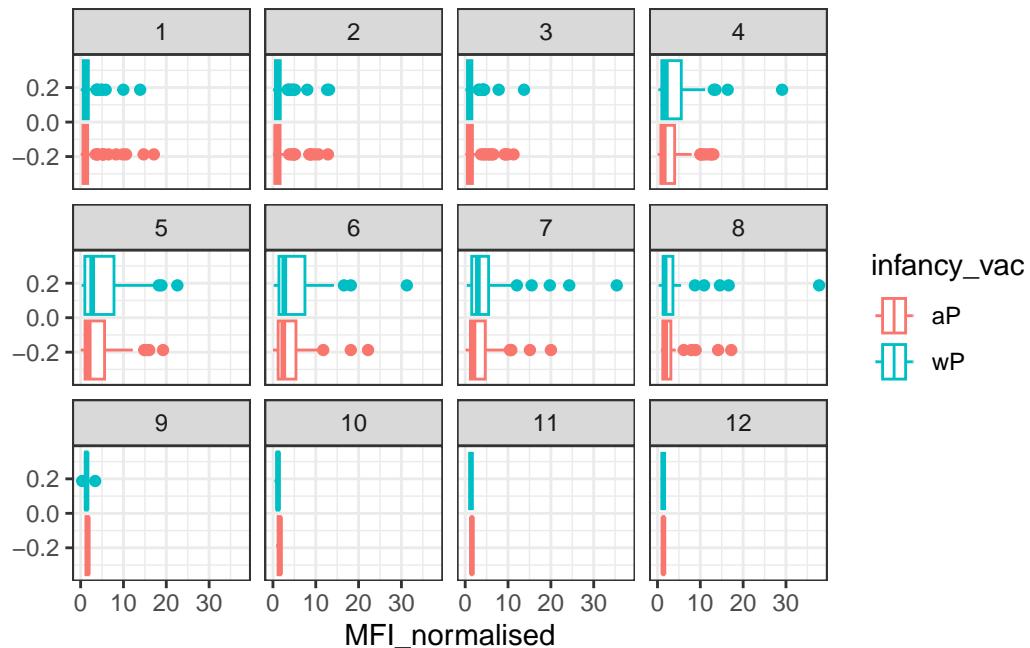
```
ggplot(igg) +
  aes(MFI_normalised, antigen, col=infancy_vac ) +
  geom_boxplot(show.legend = FALSE) +
  facet_wrap(vars(visit), nrow=2) +
  xlim(0,75) +
  theme_bw()
```

Warning: Removed 5 rows containing non-finite outside the scale range
(`stat_boxplot()`).

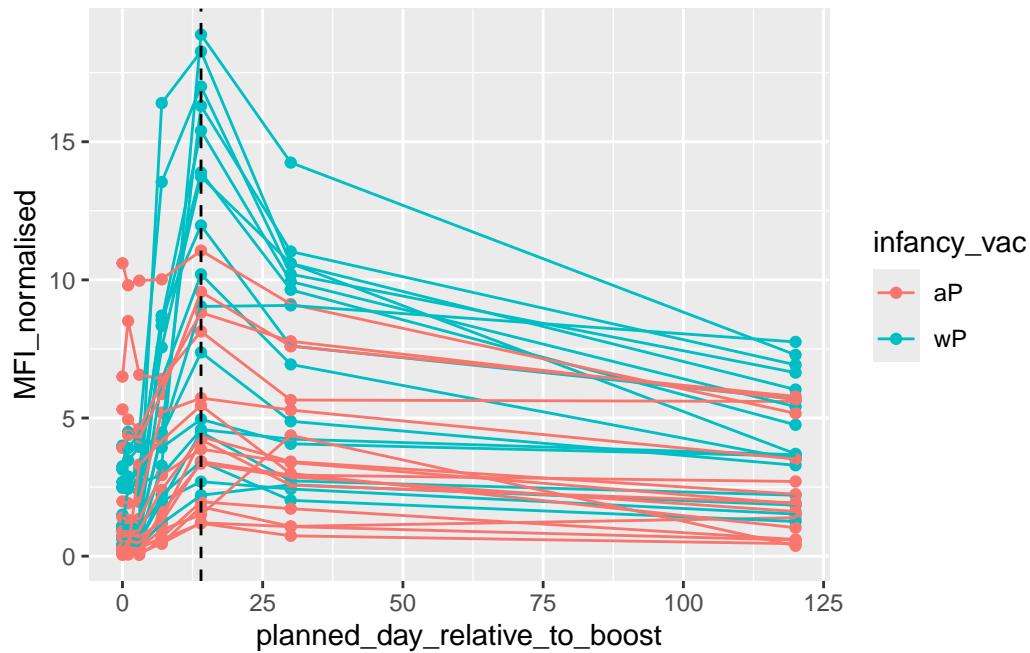


more advanced analysis digging into individual antigen response over time:

```
filter(igg,antigen=="PT") |>
  ggplot() +
  aes(MFI_normalised, col=infancy_vac) +
  geom_boxplot(show.legend = ) +
  facet_wrap(vars(visit))+
  theme_bw()
```



```
filter(igg, antigen == "PT", dataset == "2021_dataset") |>
  ggplot() +
  aes(x=planned_day_relative_to_boost,
      y=MFI_normalised,
      col=infancy_vac,
      group=subject_id) +
  geom_point() +
  geom_line() +
  geom_vline(xintercept=14, linetype="dashed")
```



This plot shows the time course of pertussis toxin(PT) antibody responses for a large set of wP (teal color) and aP(red color) individuals. levels peak at day 14 and are larger in magnitude for wP than aP individuals.

There are lost of cool things to explore in this dataset and we need coding and biology knowledge do do it effectively.