

class18: Pertussis Mini Project

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Pertussis (aka whooping cough) is a serious lung infection caused by the bacteria *Bordetella pertussis*.

The CDC tracks Pertussis case numbers and we can find this data here: <http://tinyurl.com/pertussiscdc>

We can scrape the data from this website using the **datapasta** package.

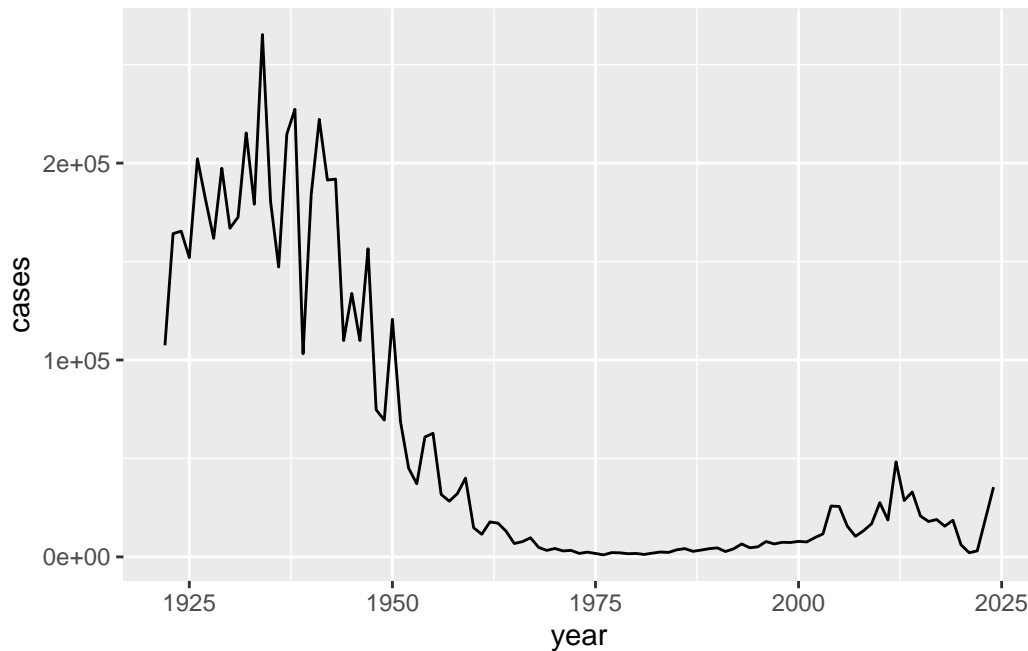
```
head(cdc)
```

```
  year  cases
1 1922 107473
2 1923 164191
3 1924 165418
4 1925 152003
5 1926 202210
6 1927 181411
```

Q1. Make a plot of Pertussis cases per year.

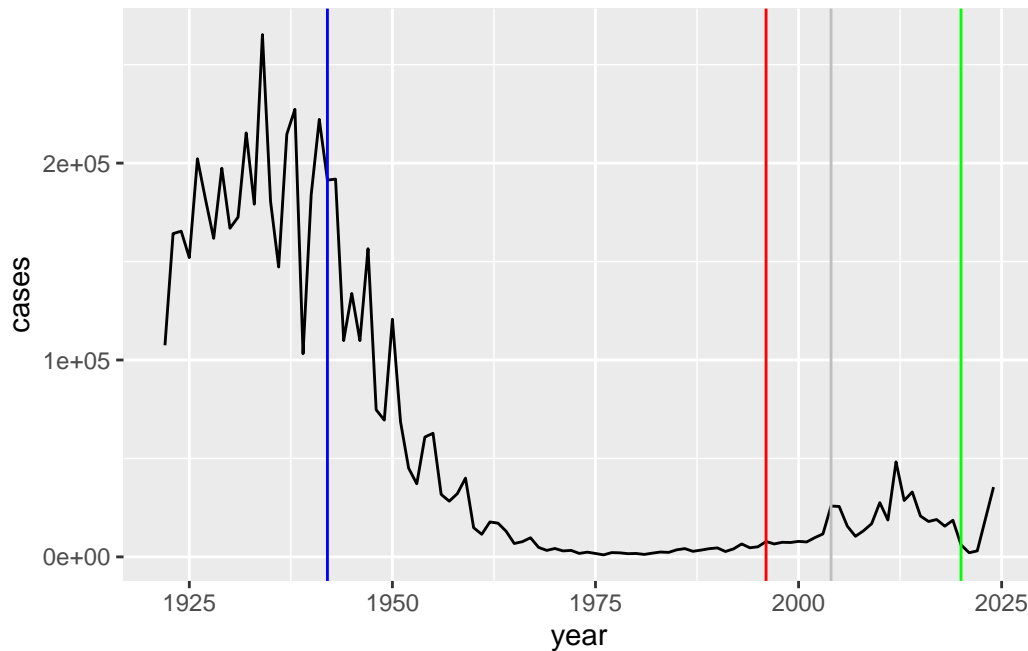
```
library(ggplot2)

ggplot(cdc)+
  aes(year, cases)+
  geom_line()
```



Q2. Lets add the key milestones of the DTP (wP) vaccine roll out in 1942 and the switch to the new aP vaccine in 1996. We can use `geom_vline()` for this. Booster shots started in 2004.

```
ggplot(cdc)+
  aes(year, cases)+
  geom_line()+
  geom_vline(xintercept = 1942, col="blue")+
  geom_vline(xintercept = 1996, col="red")+
  geom_vline(xintercept = 2020, col="green")+
  geom_vline(xintercept = 2004, col="gray")
```



There were high case numbers pre 1946 (before the first (wP) vaccine) then relatively rapid decrease in cases through through the 1970s to 2004 when our first widespread outbreak occurred again.

Mounting evidence shows that if you are primed with an aP vaccine induced immunity wanes faster than the wP vaccine.

Enter the CMI-PB project

Computational Models of Immunity Pertussis Boost.

One of the main goals of this project is to determine what is different in the immune response between wP primed individuals and aP primed individuals.

Using the booster vaccine as a proxy for infection.

All the data is available here: <https://www.cmi-pb.org> in JSON format.

```
library(jsonlite)
```

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

```
subject <- read_json("http://cmi-pb.org/api/v5_1/subject",
                      simplifyVector = T)

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

Q3. How many subjects are there in this dataset?

```
nrow(subject)
```

```
[1] 172
```

Q4. How many aP and wP subjects are there?

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

```
aP wP
87 85
```

Q5. Male/Female numbers?

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

```
Female  Male
112     60
```

Q6. Breakdown of biological sex and race

```
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

Q7. Does this look to be representative of the US population at large?

NO!

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

```
ab_titer <- read_json("http://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

```
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

To use this data we need to “join” the various tables to find all the information I need to know about a particular measurement.

```
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

```
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 we can join meta with ab_titer

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

Q8. How many different antibody isotypes are we measuring?

```
table(ab_data$isotype)
```

```

IgE  IgG  IgG1  IgG2  IgG3  IgG4
6698 7265 11993 12000 12000 12000

```


Q9. How many antigens?

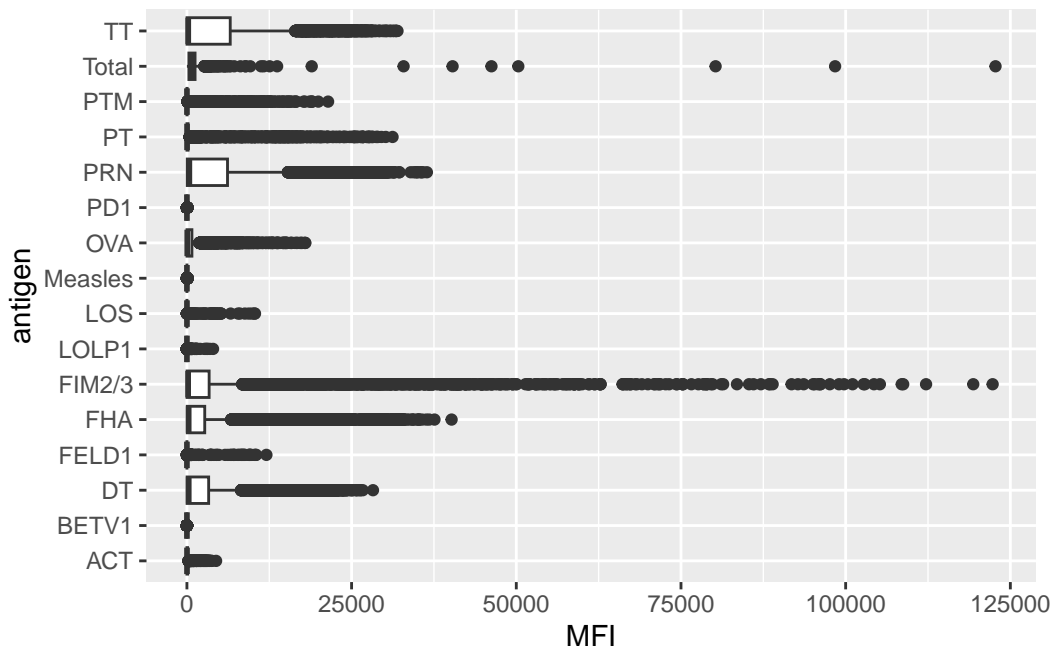
```
table(ab_data$antigen)
```

ACT	BETV1	DT	FELD1	FHA	FIM2/3	LOLP1	LOS	Measles	OVA
1970	1970	6318	1970	6712	6318	1970	1970	1970	6318
PD1	PRN	PT	PTM	Total	TT				
1970	6712	6712	1970	788	6318				

Q10. Lets look at antigen levels over the whole dataset

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

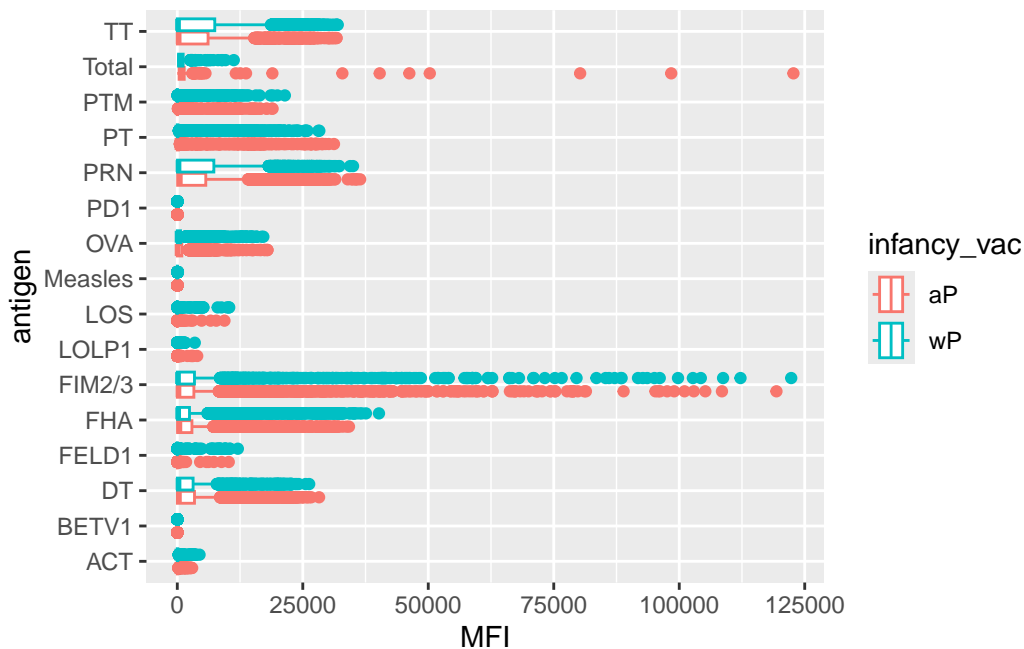
Warning: Removed 1 row containing non-finite outside the scale range (`stat_boxplot()`).



Q11. Break this plot down by aP or wP

```
ggplot(ab_data)+
  aes(MFI, antigen, col= infancy_vac)+
  geom_boxplot()
```

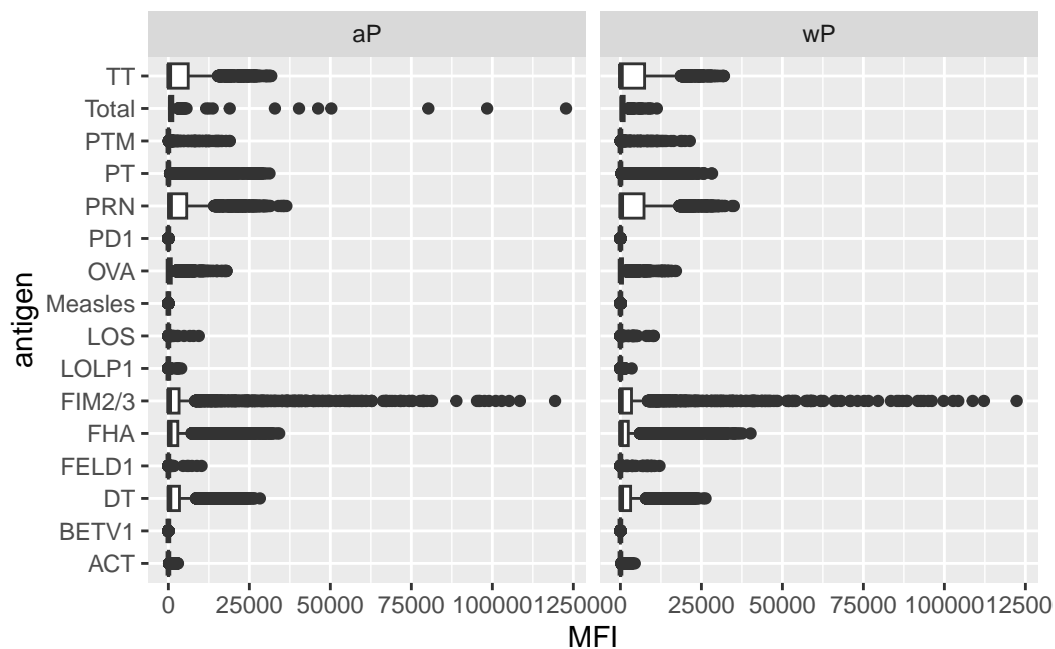
Warning: Removed 1 row containing non-finite outside the scale range (`stat_boxplot()`).



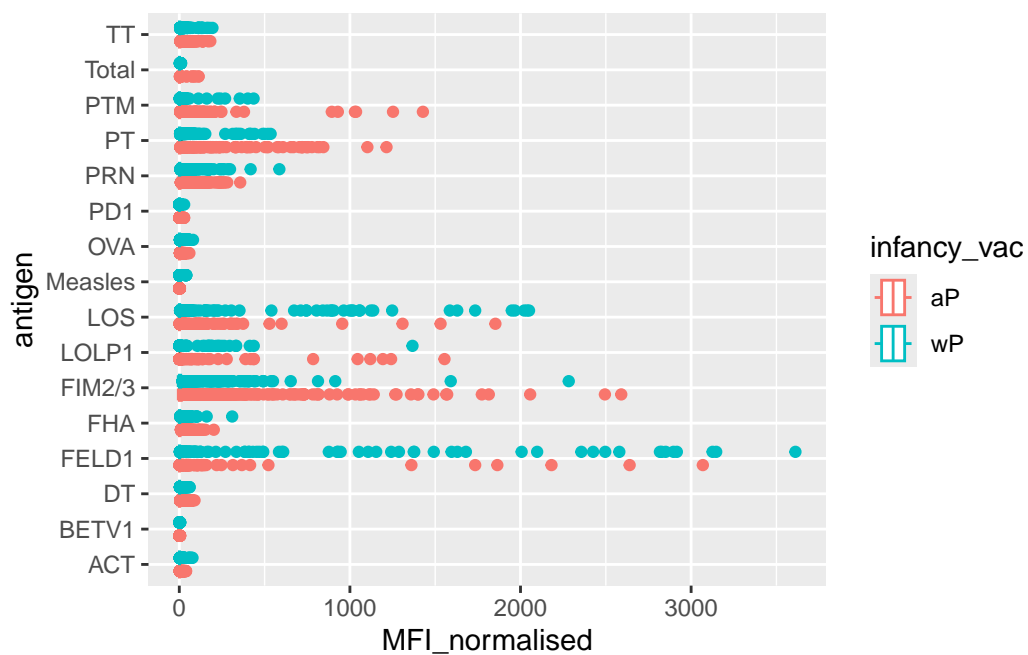
We can also facet the plot by infancy_vac

```
ggplot(ab_data)+
  aes(MFI, antigen)+
  geom_boxplot()+
  facet_wrap(~ infancy_vac)
```

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



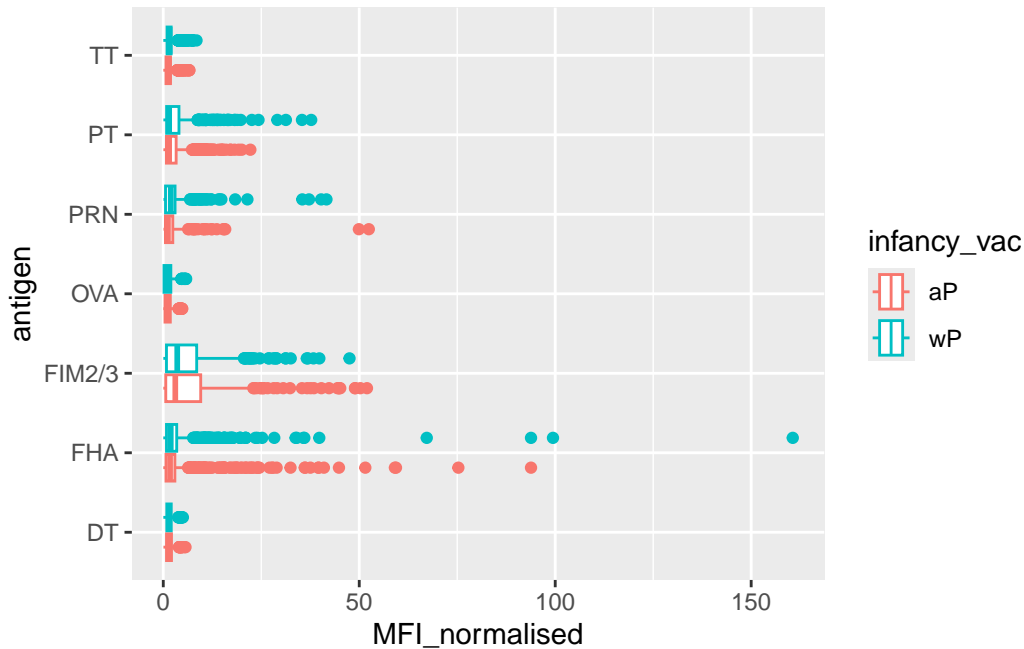
```
ggplot(ab_data)+
  aes(MFI_normalised, antigen, col= infancy_vac)+
  geom_boxplot()
```



Lets focus on just IgG

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

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

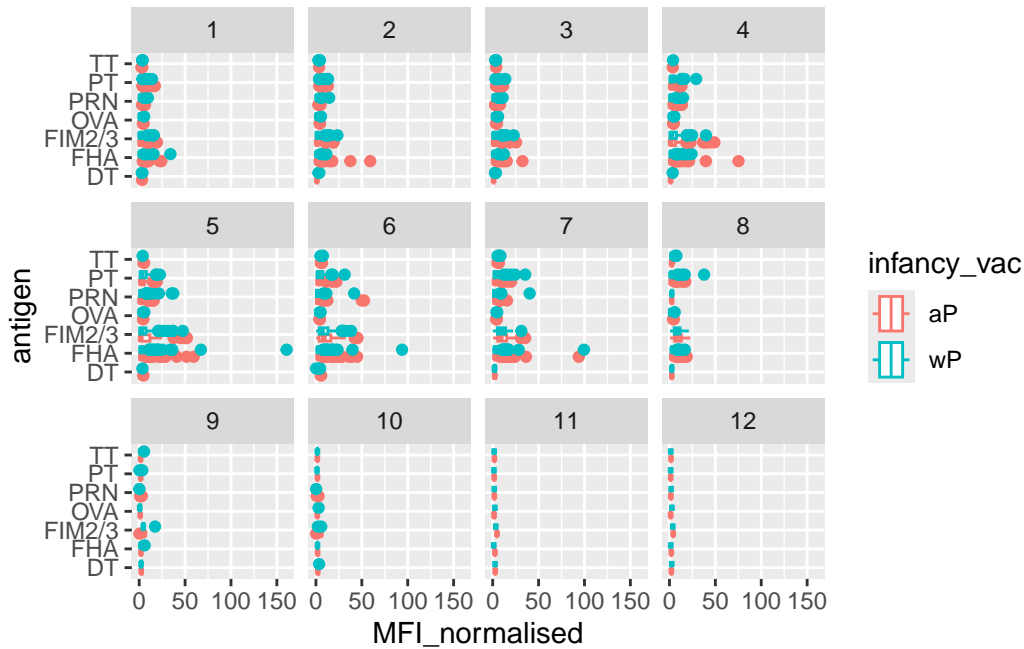


```
head(igg)
```

	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	1	
3	1986-01-01	2016-09-12	2020_dataset	1	

4	1986-01-01	2016-09-12	2020_dataset	2			
5	1986-01-01	2016-09-12	2020_dataset	2			
6	1986-01-01	2016-09-12	2020_dataset	2			
	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	1	1	Blood				
5	1	1	Blood				
6	1	1	Blood				
	visit	isotype	is_antigen_specific	antigen	MFI	MFI_normalised	unit
1	1	IgG	TRUE	PT	68.56614	3.736992	IU/ML
2	1	IgG	TRUE	PRN	332.12718	2.602350	IU/ML
3	1	IgG	TRUE	FHA	1887.12263	34.050956	IU/ML
4	2	IgG	TRUE	PT	41.38442	2.255534	IU/ML
5	2	IgG	TRUE	PRN	174.89761	1.370393	IU/ML
6	2	IgG	TRUE	FHA	246.00957	4.438960	IU/ML
	lower_limit_of_detection						
1	0.530000						
2	6.205949						
3	4.679535						
4	0.530000						
5	6.205949						
6	4.679535						

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

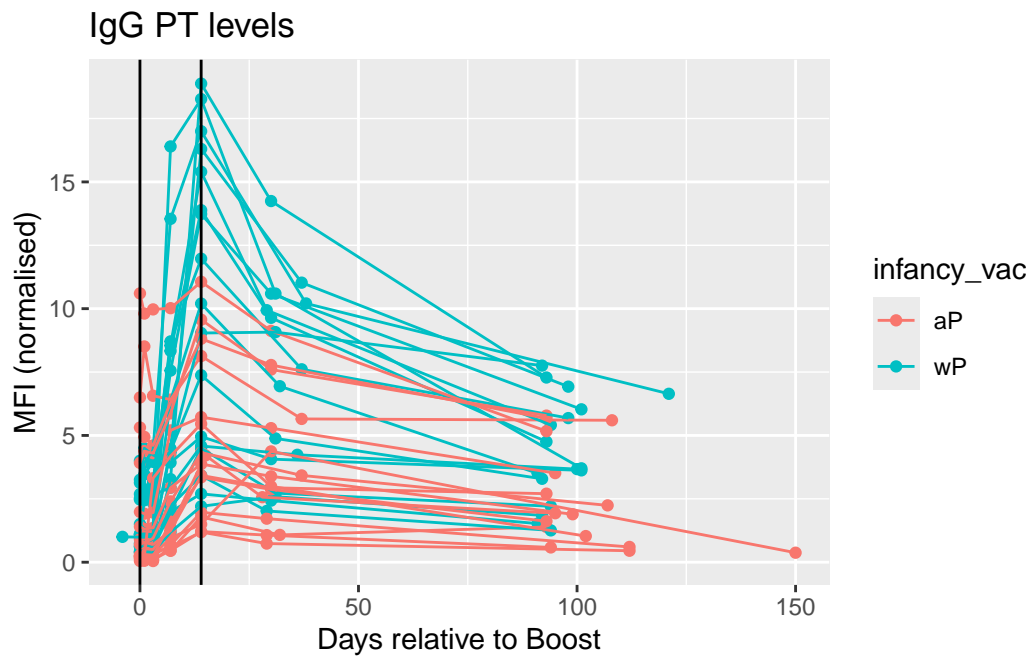


Lets focus on PT (Pertussis Toxin) and IgG levels over time

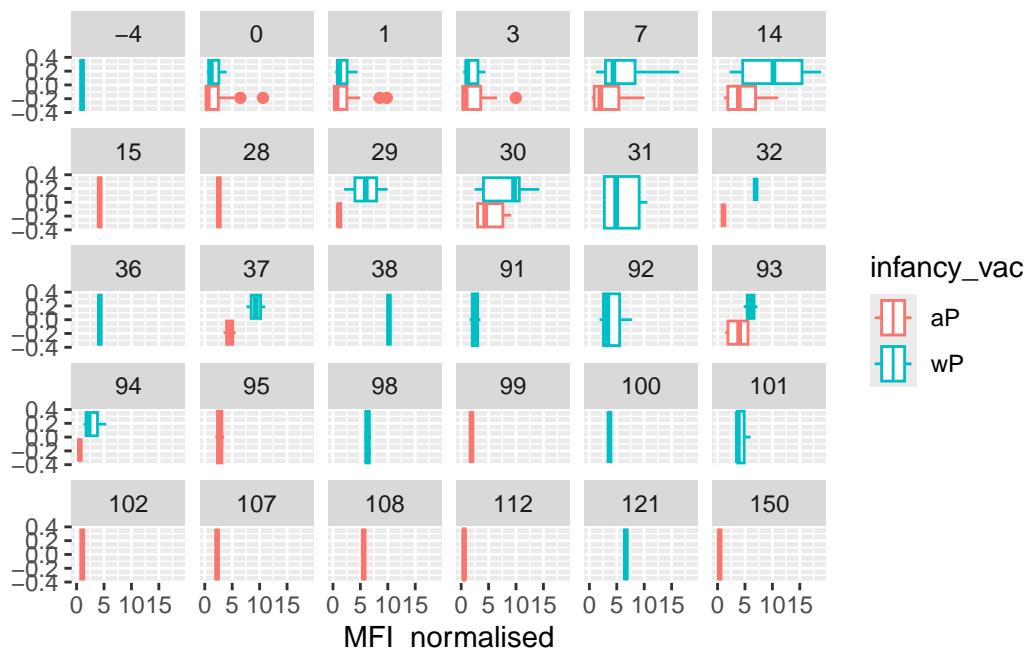
```
pt_igg <- ab_data |>
  filter(isotype=="IgG", antigen=="PT", dataset=="2021_dataset")
```

A plot of actual_day_relative_to_boost vs. MFI_normalised

```
ggplot(pt_igg)+
  aes(actual_day_relative_to_boost, MFI_normalised, col=infancy_vac, group = subject_id)+
  geom_point()+
  geom_line()+
  geom_vline(xintercept = 14)+
  geom_vline(xintercept = 0)+
  labs(title = "IgG PT levels",
       x="Days relative to Boost",
       y="MFI (normalised)")
```



```
ggplot(pt_igg)+
  aes(MFI_normalised, col=infancy_vac)+
  geom_boxplot()+
  facet_wrap(~ actual_day_relative_to_boost)
```



subject\$year_of_birth

```
[1] "1986-01-01" "1968-01-01" "1983-01-01" "1988-01-01" "1991-01-01"
[6] "1988-01-01" "1981-01-01" "1985-01-01" "1996-01-01" "1982-01-01"
[11] "1986-01-01" "1982-01-01" "1997-01-01" "1993-01-01" "1989-01-01"
[16] "1987-01-01" "1980-01-01" "1997-01-01" "1994-01-01" "1981-01-01"
[21] "1983-01-01" "1985-01-01" "1991-01-01" "1992-01-01" "1988-01-01"
[26] "1983-01-01" "1997-01-01" "1982-01-01" "1997-01-01" "1988-01-01"
[31] "1989-01-01" "1997-01-01" "1990-01-01" "1983-01-01" "1991-01-01"
[36] "1997-01-01" "1998-01-01" "1997-01-01" "1985-01-01" "1994-01-01"
[41] "1985-01-01" "1997-01-01" "1998-01-01" "1998-01-01" "1997-01-01"
[46] "1998-01-01" "1996-01-01" "1998-01-01" "1997-01-01" "1997-01-01"
[51] "1997-01-01" "1998-01-01" "1998-01-01" "1997-01-01" "1997-01-01"
[56] "1997-01-01" "1996-01-01" "1997-01-01" "1997-01-01" "1997-01-01"
[61] "1987-01-01" "1993-01-01" "1995-01-01" "1993-01-01" "1990-01-01"
[66] "1976-01-01" "1972-01-01" "1972-01-01" "1990-01-01" "1998-01-01"
[71] "1998-01-01" "1991-01-01" "1995-01-01" "1995-01-01" "1998-01-01"
[76] "1998-01-01" "1988-01-01" "1993-01-01" "1987-01-01" "1992-01-01"
[81] "1993-01-01" "1998-01-01" "1999-01-01" "1997-01-01" "2000-01-01"
[86] "1998-01-01" "2000-01-01" "2000-01-01" "1997-01-01" "1999-01-01"
[91] "1998-01-01" "2000-01-01" "1996-01-01" "1999-01-01" "1998-01-01"
[96] "2000-01-01" "1986-01-01" "1993-01-01" "1999-01-01" "2001-01-01"
```



```

[101] "2003-01-01" "2003-01-01" "1994-01-01" "1989-01-01" "1994-01-01"
[106] "1996-01-01" "1998-01-01" "1995-01-01" "1989-01-01" "1997-01-01"
[111] "1996-01-01" "1996-01-01" "1996-01-01" "1990-01-01" "2002-01-01"
[116] "2000-01-01" "1994-01-01" "1998-01-01" "1998-01-01" "1995-01-01"
[121] "2000-01-01" "1999-01-01" "1996-01-01" "2000-01-01" "1993-01-01"
[126] "1993-01-01" "1996-01-01" "1994-01-01" "1991-01-01" "1996-01-01"
[131] "1998-01-01" "1995-01-01" "1997-01-01" "1990-01-01" "1995-01-01"
[136] "1995-01-01" "1998-01-01" "2000-01-01" "1993-01-01" "2001-01-01"
[141] "1996-01-01" "1991-01-01" "2003-01-01" "1999-01-01" "2002-01-01"
[146] "1992-01-01" "2000-01-01" "1988-01-01" "1991-01-01" "1991-01-01"
[151] "1992-01-01" "1995-01-01" "1998-01-01" "1997-01-01" "1997-01-01"
[156] "2001-01-01" "1997-01-01" "2000-01-01" "1994-01-01" "1996-01-01"
[161] "1993-01-01" "1999-01-01" "1993-01-01" "1991-01-01" "1993-01-01"
[166] "2001-01-01" "1997-01-01" "1991-01-01" "2003-01-01" "1992-01-01"
[171] "2003-01-01" "1986-01-01"

```

```
library(lubridate)
```

Attaching package: 'lubridate'

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

```
date, intersect, setdiff, union
```

```
today() -mdy("04-23-2000")
```

Time difference of 9084 days

```
time_length(today() -mdy("04-23-2000"), "years")
```

```
[1] 24.87064
```

```
subject$age <- time_length(today() - ymd(subject$year_of_birth), "years")
```