Class 15

Mudit

Pertussis, a.k.a. Whooping Cough, is a highly contagious lung infection caused by the *B. Pertussis*.

The CDC tracks Pertussis case numbers and they can be accessed here

We need to "scrape" this data so we can do stuff with it in R. Let's try the **datapasta** package to do this

```
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, 2024L
  ),
  Cases = c(
    107473, 164191, 165418, 152003,
    202210, 181411, 161799, 197371,
```

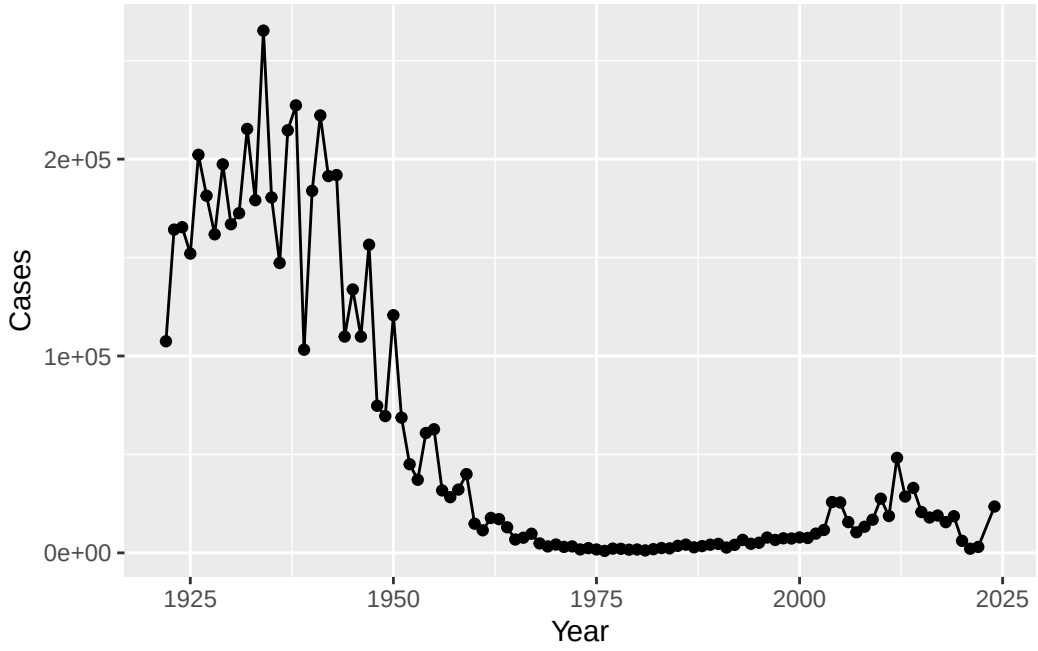
```
    166914, 172559, 215343, 179135, 265269,
    180518, 147237, 214652, 227319, 103188,
    183866, 222202, 191383, 191890, 109873,
    133792, 109860, 156517, 74715, 69479,
    120718, 68687, 45030, 37129, 60886,
    62786, 31732, 28295, 32148, 40005,
    14809, 11468, 17749, 17135, 13005, 6799,
    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, 23544
  )
)
```

Let's plot year vs cases to see the trend over time in the US

```
library(ggplot2)

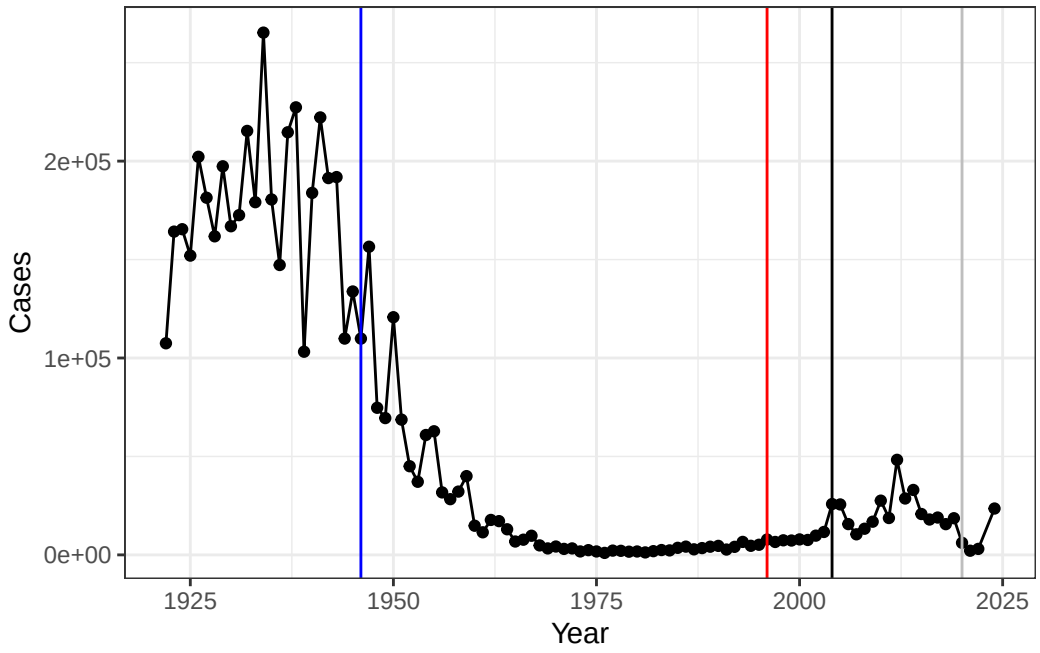
baseplot <- ggplot(cdc) +
  aes(Year, Cases) +
  geom_point() +
  geom_line()

baseplot
```



Let's add the date of wP vaccine (1946) roll out completion and new aP vaccine (1996).

```
baseplot +
  theme_bw() +
  geom_vline(xintercept = 1946, col = "blue") +
  geom_vline(xintercept = 1996, col = "red") +
  geom_vline(xintercept = 2004) +
  geom_vline(xintercept = 2020, col = "gray")
```



The ap vaccine has a shorter period after which a booster is required compared to wp vaccine

CMI-PB (computational Models of Immunity - Pertussis Boost)

This project collects and makes freely available data about the immune reponse to Pertussis vaccination

You can access the data via an API which returns JSON format (key:value pairs)

We can use **jsonlite** package and it's `read_json()` function

```
library(jsonlite)
subject <- read_json("https://www.cmi-pb.org/api/v5/subject", simplifyVector = TRUE)

subject
```

```
    subject_id infancy_vac biological_sex              ethnicity
1            1          wP         Female Not Hispanic or Latino
2            2          wP         Female Not Hispanic or Latino
3            3          wP         Female                Unknown
4            4          wP           Male Not Hispanic or Latino
5            5          wP           Male Not Hispanic or Latino
6            6          wP         Female Not Hispanic or Latino
```

7	7	wP	Female	Hispanic or Latino
8	8	wP	Female	Not Hispanic or Latino
9	9	aP	Male	Not Hispanic or Latino
10	10	wP	Female	Not Hispanic or Latino
11	11	wP	Female	Hispanic or Latino
12	12	wP	Male	Not Hispanic or Latino
13	13	aP	Male	Not Hispanic or Latino
14	14	wP	Male	Not Hispanic or Latino
15	15	wP	Male	Not Hispanic or Latino
16	16	wP	Female	Hispanic or Latino
17	17	wP	Female	Hispanic or Latino
18	18	aP	Female	Hispanic or Latino
19	19	wP	Male	Not Hispanic or Latino
20	20	wP	Female	Not Hispanic or Latino
21	21	wP	Male	Not Hispanic or Latino
22	22	wP	Female	Not Hispanic or Latino
23	23	wP	Female	Not Hispanic or Latino
24	24	wP	Female	Not Hispanic or Latino
25	25	wP	Female	Not Hispanic or Latino
26	26	wP	Female	Hispanic or Latino
27	27	aP	Female	Not Hispanic or Latino
28	28	wP	Male	Unknown
29	29	aP	Male	Hispanic or Latino
30	30	wP	Female	Hispanic or Latino
31	31	wP	Female	Not Hispanic or Latino
32	32	aP	Male	Not Hispanic or Latino
33	33	wP	Male	Hispanic or Latino
34	34	wP	Female	Hispanic or Latino
35	35	wP	Male	Unknown
36	36	aP	Female	Hispanic or Latino
37	37	aP	Female	Not Hispanic or Latino
38	38	aP	Female	Not Hispanic or Latino
39	39	wP	Female	Not Hispanic or Latino
40	40	wP	Female	Not Hispanic or Latino
41	41	wP	Male	Not Hispanic or Latino
42	42	aP	Female	Not Hispanic or Latino
43	43	aP	Female	Not Hispanic or Latino
44	44	aP	Female	Hispanic or Latino
45	45	aP	Female	Not Hispanic or Latino
46	46	aP	Female	Not Hispanic or Latino
47	47	aP	Female	Not Hispanic or Latino
48	48	aP	Female	Not Hispanic or Latino
49	49	aP	Female	Not Hispanic or Latino

50	50	aP	Female	Not Hispanic or Latino
51	51	aP	Male	Not Hispanic or Latino
52	52	aP	Male	Not Hispanic or Latino
53	53	aP	Female	Hispanic or Latino
54	54	aP	Female	Not Hispanic or Latino
55	55	aP	Female	Not Hispanic or Latino
56	56	aP	Female	Not Hispanic or Latino
57	57	aP	Female	Not Hispanic or Latino
58	58	aP	Female	Hispanic or Latino
59	59	aP	Female	Hispanic or Latino
60	60	aP	Male	Hispanic or Latino
61	61	wP	Female	Not Hispanic or Latino
62	62	wP	Female	Not Hispanic or Latino
63	63	wP	Female	Not Hispanic or Latino
64	64	wP	Male	Not Hispanic or Latino
65	65	wP	Male	Not Hispanic or Latino
66	66	wP	Female	Not Hispanic or Latino
67	67	wP	Female	Hispanic or Latino
68	68	wP	Male	Hispanic or Latino
69	69	wP	Female	Hispanic or Latino
70	70	aP	Male	Not Hispanic or Latino
71	71	aP	Female	Not Hispanic or Latino
72	72	wP	Female	Not Hispanic or Latino
73	73	wP	Female	Not Hispanic or Latino
74	74	wP	Female	Not Hispanic or Latino
75	75	aP	Female	Not Hispanic or Latino
76	76	aP	Female	Not Hispanic or Latino
77	77	wP	Male	Not Hispanic or Latino
78	78	wP	Female	Not Hispanic or Latino
79	79	wP	Male	Not Hispanic or Latino
80	80	wP	Female	Not Hispanic or Latino
81	81	wP	Male	Not Hispanic or Latino
82	82	aP	Female	Not Hispanic or Latino
83	83	aP	Female	Not Hispanic or Latino
84	84	aP	Female	Not Hispanic or Latino
85	85	aP	Female	Hispanic or Latino
86	86	aP	Female	Not Hispanic or Latino
87	87	aP	Male	Not Hispanic or Latino
88	88	aP	Male	Not Hispanic or Latino
89	89	aP	Female	Not Hispanic or Latino
90	90	aP	Female	Not Hispanic or Latino
91	91	aP	Male	Unknown
92	92	aP	Female	Hispanic or Latino

93	93	aP	Female	Not Hispanic or Latino
94	94	aP	Male	Not Hispanic or Latino
95	95	aP	Female	Hispanic or Latino
96	96	aP	Male	Hispanic or Latino
97	97	wP	Male	Not Hispanic or Latino
98	98	wP	Female	Not Hispanic or Latino
99	99	aP	Female	Hispanic or Latino
100	100	aP	Female	Not Hispanic or Latino
101	101	aP	Male	Not Hispanic or Latino
102	102	aP	Male	Not Hispanic or Latino
103	103	wP	Female	Not Hispanic or Latino
104	104	wP	Female	Not Hispanic or Latino
105	105	wP	Female	Not Hispanic or Latino
106	106	aP	Female	Not Hispanic or Latino
107	107	aP	Female	Not Hispanic or Latino
108	108	wP	Female	Not Hispanic or Latino
109	109	wP	Female	Not Hispanic or Latino
110	110	aP	Female	Hispanic or Latino
111	111	wP	Male	Not Hispanic or Latino
112	112	aP	Male	Not Hispanic or Latino
113	113	aP	Male	Not Hispanic or Latino
114	114	wP	Male	Not Hispanic or Latino
115	115	aP	Female	Not Hispanic or Latino
116	116	aP	Male	Not Hispanic or Latino
117	117	aP	Female	Hispanic or Latino
118	118	aP	Male	Not Hispanic or Latino
119	119	aP	Female	Not Hispanic or Latino
120	120	wP	Female	Hispanic or Latino
121	121	aP	Female	Not Hispanic or Latino
122	122	aP	Female	Hispanic or Latino
123	123	wP	Female	Hispanic or Latino
124	124	aP	Male	Hispanic or Latino
125	125	wP	Male	Hispanic or Latino
126	126	wP	Male	Not Hispanic or Latino
127	127	aP	Female	Hispanic or Latino
128	128	wP	Female	Hispanic or Latino
129	129	wP	Male	Not Hispanic or Latino
130	130	wP	Male	Not Hispanic or Latino
131	131	aP	Female	Hispanic or Latino
132	132	wP	Male	Not Hispanic or Latino
133	133	aP	Female	Unknown
134	134	wP	Male	Not Hispanic or Latino
135	135	wP	Male	Hispanic or Latino

136	136	wP	Female	Not Hispanic or Latino	
137	137	aP	Female	Not Hispanic or Latino	
138	138	aP	Male	Hispanic or Latino	
139	139	wP	Female	Not Hispanic or Latino	
140	140	aP	Female	Not Hispanic or Latino	
141	141	wP	Female	Not Hispanic or Latino	
142	142	aP	Female	Not Hispanic or Latino	
143	143	aP	Female	Hispanic or Latino	
144	144	aP	Female	Not Hispanic or Latino	
145	145	aP	Male	Not Hispanic or Latino	
146	146	wP	Male	Not Hispanic or Latino	
147	147	aP	Female	Hispanic or Latino	
148	148	wP	Male	Not Hispanic or Latino	
149	149	wP	Female	Hispanic or Latino	
150	150	wP	Male	Hispanic or Latino	
151	151	wP	Female	Not Hispanic or Latino	
152	152	wP	Female	Hispanic or Latino	
153	153	aP	Female	Not Hispanic or Latino	
154	154	aP	Female	Not Hispanic or Latino	
155	155	aP	Female	Not Hispanic or Latino	
156	156	aP	Female	Not Hispanic or Latino	
157	157	aP	Female	Not Hispanic or Latino	
158	158	aP	Male	Not Hispanic or Latino	
159	159	wP	Female	Not Hispanic or Latino	
160	160	aP	Male	Not Hispanic or Latino	
161	161	aP	Female	Not Hispanic or Latino	
162	162	aP	Female	Not Hispanic or Latino	
163	163	wP	Female	Not Hispanic or Latino	
164	164	wP	Male	Not Hispanic or Latino	
165	165	wP	Female	Not Hispanic or Latino	
166	166	aP	Female	Not Hispanic or Latino	
167	167	aP	Male	Not Hispanic or Latino	
168	168	wP	Male	Not Hispanic or Latino	
169	169	aP	Male	Not Hispanic or Latino	
170	170	wP	Male	Not Hispanic or Latino	
171	171	wP	Female	Not Hispanic or Latino	
172	172	wP	Male	Not Hispanic or Latino	

	race	year_of_birth	date_of_boost
1	White	1986-01-01	2016-09-12
2	White	1968-01-01	2019-01-28
3	White	1983-01-01	2016-10-10
4	Asian	1988-01-01	2016-08-29
5	Asian	1991-01-01	2016-08-29

6	White	1988-01-01	2016-10-10
7	More Than One Race	1981-01-01	2016-11-07
8	White	1985-01-01	2019-02-25
9	Asian	1996-01-01	2016-07-25
10	Asian	1982-01-01	2016-07-25
11	Unknown or Not Reported	1986-01-01	2016-08-29
12	Asian	1982-01-01	2016-07-25
13	White	1997-01-01	2016-07-25
14	White	1993-01-01	2016-08-15
15	Asian	1989-01-01	2016-08-15
16	Unknown or Not Reported	1987-01-01	2016-07-25
17	White	1980-01-01	2016-09-12
18	Unknown or Not Reported	1997-01-01	2016-08-29
19	Asian	1994-01-01	2016-09-26
20	White	1981-01-01	2016-08-29
21	White	1983-01-01	2016-08-29
22	White	1985-01-01	2016-08-29
23	White	1991-01-01	2016-09-26
24	Asian	1992-01-01	2016-09-13
25	Black or African American	1988-01-01	2016-09-13
26	Unknown or Not Reported	1983-01-01	2016-09-26
27	Asian	1997-01-01	2016-09-26
28	Unknown or Not Reported	1982-01-01	2016-09-26
29	White	1997-01-01	2016-09-26
30	White	1988-01-01	2016-09-26
31	Asian	1989-01-01	2016-09-26
32	Native Hawaiian or Other Pacific Islander	1997-01-01	2016-10-24
33	More Than One Race	1990-01-01	2016-10-10
34	Unknown or Not Reported	1983-01-01	2016-10-24
35	White	1991-01-01	2016-10-10
36	White	1997-01-01	2016-10-24
37	More Than One Race	1998-01-01	2016-11-07
38	White	1997-01-01	2016-10-24
39	White	1985-01-01	2016-10-24
40	Asian	1994-01-01	2016-10-24
41	White	1985-01-01	2016-11-07
42	Asian	1997-01-01	2016-11-07
43	More Than One Race	1998-01-01	2016-11-07
44	More Than One Race	1998-01-01	2016-11-07
45	Asian	1997-01-01	2016-11-28
46	Unknown or Not Reported	1998-01-01	2016-11-07
47	White	1996-01-01	2016-11-28
48	White	1998-01-01	2017-01-17

49	White	1997-01-01	2017-01-17
50	Asian	1997-01-01	2016-11-28
51	White	1997-01-01	2016-11-28
52	More Than One Race	1998-01-01	2017-01-03
53	Unknown or Not Reported	1998-01-01	2017-01-03
54	Asian	1997-01-01	2017-01-17
55	Asian	1997-01-01	2017-01-17
56	Asian	1997-01-01	2017-01-30
57	Asian	1996-01-01	2017-01-30
58	Unknown or Not Reported	1997-01-01	2017-01-30
59	More Than One Race	1997-01-01	2017-01-30
60	White	1997-01-01	2017-01-30
61	Unknown or Not Reported	1987-01-01	2019-04-08
62	Asian	1993-01-01	2018-11-26
63	White	1995-01-01	2018-11-26
64	Asian	1993-01-01	2018-11-26
65	White	1990-01-01	2018-12-03
66	Black or African American	1976-01-01	2018-12-03
67	White	1972-01-01	2019-01-28
68	White	1972-01-01	2019-01-28
69	White	1990-01-01	2019-01-28
70	American Indian/Alaska Native	1998-01-01	2019-01-28
71	White	1998-01-01	2019-01-28
72	White	1991-01-01	2019-02-25
73	White	1995-01-01	2019-02-25
74	White	1995-01-01	2019-02-25
75	Native Hawaiian or Other Pacific Islander	1998-01-01	2019-02-25
76	Asian	1998-01-01	2019-02-25
77	White	1988-01-01	2019-03-18
78	White	1993-01-01	2019-03-18
79	White	1987-01-01	2019-03-18
80	Asian	1992-01-01	2019-03-18
81	White	1993-01-01	2019-03-18
82	More Than One Race	1998-01-01	2019-03-18
83	White	1999-01-01	2019-04-08
84	More Than One Race	1997-01-01	2019-04-08
85	White	2000-01-01	2019-04-29
86	Asian	1998-01-01	2019-04-29
87	Asian	2000-01-01	2019-04-29
88	Asian	2000-01-01	2019-04-29
89	Asian	1997-01-01	2019-06-03
90	Asian	1999-01-01	2019-06-03
91	Unknown or Not Reported	1998-01-01	2019-06-03

92	White	2000-01-01	2019-06-24
93	More Than One Race	1996-01-01	2019-06-24
94	Unknown or Not Reported	1999-01-01	2019-06-24
95	Unknown or Not Reported	1998-01-01	2019-06-24
96	Unknown or Not Reported	2000-01-01	2019-06-24
97	White	1986-01-01	2021-11-29
98	White	1993-01-01	2021-09-27
99	Unknown or Not Reported	1999-01-01	2021-09-07
100	White	2001-01-01	2021-11-01
101	White	2003-01-01	2021-11-01
102	White	2003-01-01	2021-11-01
103	White	1994-01-01	2021-09-07
104	Asian	1989-01-01	2021-09-07
105	White	1994-01-01	2021-09-07
106	White	1996-01-01	2021-09-07
107	Asian	1998-01-01	2021-09-07
108	White	1995-01-01	2021-09-27
109	White	1989-01-01	2021-09-27
110	White	1997-01-01	2021-09-27
111	White	1996-01-01	2021-10-18
112	White	1996-01-01	2021-10-18
113	White	1996-01-01	2021-10-18
114	Asian	1990-01-01	2021-10-18
115	Asian	2002-01-01	2021-11-01
116	White	2000-01-01	2021-11-29
117	More Than One Race	1994-01-01	2021-11-29
118	Asian	1998-01-01	2022-01-24
119	White	1998-01-01	2021-11-29
120	Unknown or Not Reported	1995-01-01	2022-02-14
121	Asian	2000-01-01	2022-02-14
122	More Than One Race	1999-01-01	2022-02-14
123	More Than One Race	1996-01-01	2022-03-07
124	Unknown or Not Reported	2000-01-01	2022-03-07
125	Unknown or Not Reported	1993-01-01	2022-03-07
126	White	1993-01-01	2022-03-28
127	More Than One Race	1996-01-01	2022-03-28
128	White	1994-01-01	2022-04-18
129	White	1991-01-01	2022-04-18
130	White	1996-01-01	2022-04-18
131	White	1998-01-01	2022-05-09
132	White	1995-01-01	2022-05-09
133	Unknown or Not Reported	1997-01-01	2022-05-31
134	More Than One Race	1990-01-01	2022-05-31

```
135                         More Than One Race    1995-01-01    2022-07-25
136                                      Asian    1995-01-01    2022-05-31
137                                      White    1998-01-01    2022-07-05
138                    Unknown or Not Reported    2000-01-01    2022-07-25
139                                      Asian    1993-01-01    2022-07-25
140                                      Asian    2001-01-01    2022-09-12
141                                      White    1996-01-01    2022-09-12
142                                      Asian    1991-01-01    2022-11-28
143                         More Than One Race    2003-01-01    2022-11-28
144                                      White    1999-01-01    2022-11-28
145                                      White    2002-01-01    2022-11-28
146                  Black or African American    1992-01-01    2023-01-03
147                                      White    2000-01-01    2023-01-03
148                  Black or African American    1988-01-01    2023-01-03
149                    Unknown or Not Reported    1991-01-01    2023-01-03
150                                      White    1991-01-01    2023-01-03
151                                      Asian    1992-01-01    2023-01-17
152                         More Than One Race    1995-01-01    2023-02-14
153                                      Asian    1998-01-01    2023-02-14
154                                      Asian    1997-01-01    2023-02-14
155                                      White    1997-01-01    2023-03-13
156                                      White    2001-01-01    2023-03-13
157                                      White    1997-01-01    2023-03-13
158                                      White    2000-01-01    2023-03-13
159                                      Asian    1994-01-01    2023-03-13
160                  Black or African American    1996-01-01    2023-05-01
161                         More Than One Race    1993-01-01    2023-05-01
162                                      White    1999-01-01    2023-07-24
163                                      White    1993-01-01    2023-07-24
164                                      White    1991-01-01    2023-07-24
165                                      White    1993-01-01    2023-07-24
166                                      Asian    2001-01-01    2023-09-05
167                                      White    1997-01-01    2023-09-05
168                                      White    1991-01-01    2023-09-05
169                                      Asian    2003-01-01    2023-09-05
170                                      White    1992-01-01    2023-10-02
171                                      Asian    2003-01-01    2023-11-13
172                                      White    1986-01-01    2022-01-24
        dataset
1   2020_dataset
2   2020_dataset
3   2020_dataset
4   2020_dataset
```

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5   2020_dataset
6   2020_dataset
7   2020_dataset
8   2020_dataset
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114 2022_dataset
115 2022_dataset
116 2022_dataset
117 2022_dataset
118 2022_dataset
119 2023_dataset
120 2023_dataset
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130 2023_dataset
131 2023_dataset
132 2023_dataset
133 2023_dataset
```

```
134 2023_dataset
135 2023_dataset
136 2023_dataset
137 2023_dataset
138 2023_dataset
139 2023_dataset
140 2023_dataset
141 2023_dataset
142 2023_dataset
143 2023_dataset
144 2023_dataset
145 2023_dataset
146 2023_dataset
147 2023_dataset
148 2023_dataset
149 2023_dataset
150 2023_dataset
151 2023_dataset
152 2023_dataset
153 2023_dataset
154 2023_dataset
155 2023_dataset
156 2023_dataset
157 2023_dataset
158 2023_dataset
159 2023_dataset
160 2023_dataset
161 2023_dataset
162 2023_dataset
163 2023_dataset
164 2023_dataset
165 2023_dataset
166 2023_dataset
167 2023_dataset
168 2023_dataset
169 2023_dataset
170 2023_dataset
171 2023_dataset
172 2023_dataset
```

Let's have a wee peak and explore of this

```
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 do we have?

```
nrow(subject)
```

```
[1] 172
```

Q.How many male/femlae do we have?

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

```
Female   Male
   112     60
```

Q. How many wP and aP do we have?

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

```
aP wP
87 85
```

Q. Breakdown of Biological sex and race?

```r
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
```

```r
library(lubridate)
```

```
Attaching package: 'lubridate'

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

    date, intersect, setdiff, union
```

```r
today()
```

```
[1] "2024-11-24"
```

```r
today() - ymd("2000-01-01")
```

```
Time difference of 9094 days
```

```r
time_length( today() - ymd("2000-01-01"),  "years")
```

```
[1] 24.89802
```

```r
# Check for NA values in the dob column
sum(is.na(subject$dob))
```

```
[1] 0
```

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

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

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
```

```
ap <- subject %>% filter(infancy_vac == "aP")
wp <- subject %>% filter(infancy_vac == "wP")

# Convert age from days to years and round the results
ap_age <- time_length(ap$age, "years")
wp_age <- time_length(wp$age, "years")

# Summarize and calculate average ages
ap_summary <- summary(ap_age)
wp_summary <- summary(wp_age)
```

```
# Print the summaries
print("aP group summary:")
```

```
[1] "aP group summary:"
```

```
print(ap_summary)
```

```
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
  21.90   25.90   26.90   26.79   27.90   33.90
```

```
print("wP group summary:")
```

```
[1] "wP group summary:"
```

```
print(wp_summary)
```

```
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max. 
  21.90   31.90   33.90   35.54   38.90   56.90 
```

```
# Calculate and print average age for each group
mean_ap_age <- mean(ap_age)
mean_wp_age <- mean(wp_age)

cat("Average age of aP group:", round(mean_ap_age, 2), "years\n")
```

```
Average age of aP group: 26.79 years
```

```
cat("Average age of wP group:", round(mean_wp_age, 2), "years\n")
```

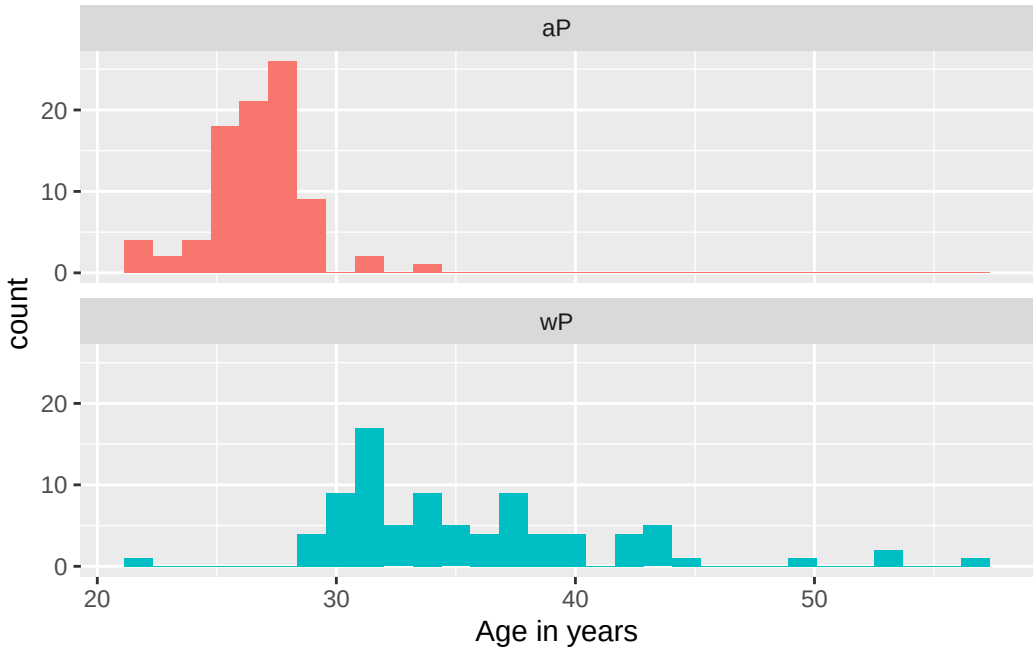
```
Average age of wP group: 35.54 years
```

```
int <- ymd(subject$date_of_boost) - ymd(subject$year_of_birth)
age_at_boost <- time_length(int, "year")
head(age_at_boost)
```

```
[1] 30.69678 51.07461 33.77413 28.65982 25.65914 28.77481
```

```
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 with `binwidth`.
```



There is a notable difference between these two based on age in years, most likely this is significant diffence

```
subject[subject$biological_sex == 'Female' & subject$race == 'Black']
```

```
data frame with 0 columns and 172 rows
```

Q. Does this break down refelct the US population?

No

```
table(subject$dataset)
```

```
2020_dataset 2021_dataset 2022_dataset 2023_dataset
          60           36           22           54
```

```
specimen <- read_json("http://cmi-pb.org/api/v5/specimen", simplifyVector = TRUE)

abtiter <- read_json("http://cmi-pb.org/api/v5/plasma_ab_titer", simplifyVector = TRUE)

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
7	7	1	100
8	8	1	464
9	9	1	542
10	10	1	736
11	11	2	1
12	12	2	1
13	13	2	3
14	14	2	7
15	15	2	14
16	16	2	31
17	17	2	102
18	18	2	361
19	19	3	-3
20	20	3	1
21	21	3	3
22	22	3	7
23	23	3	14
24	24	3	30
25	25	3	92
26	26	3	772
27	27	4	-7
28	28	4	1
29	29	4	3
30	30	4	8
31	31	4	14
32	32	4	32
33	33	4	108
34	34	4	464
35	35	4	547
36	36	4	802
37	37	5	-5
38	38	5	1
39	39	5	3
40	40	5	8
41	41	5	14
42	42	5	30

43	43	5	92
44	44	5	800
45	45	6	-6
46	46	6	1
47	47	6	3
48	48	6	7
49	49	6	14
50	50	6	31
51	51	6	92
52	52	6	423
53	53	6	542
54	54	6	723
55	55	7	-6
56	56	7	3
57	57	7	7
58	58	7	14
59	59	7	30
60	60	7	100
61	61	7	386
62	62	7	546
63	63	8	0
64	64	8	1
65	65	8	3
66	66	8	7
67	67	8	14
68	68	8	30
69	69	8	94
70	70	9	-4
71	71	9	1
72	72	9	3
73	73	9	7
74	74	9	14
75	75	9	30
76	76	9	126
77	77	10	-4
78	78	10	1
79	79	10	3
80	80	10	7
81	81	10	14
82	82	10	31
83	83	10	91
84	84	10	514
85	85	10	582

86	86	10	849
87	87	11	-12
88	88	11	1
89	89	11	3
90	90	11	8
91	91	11	14
92	92	11	30
93	93	11	91
94	94	11	799
95	95	11	1141
96	96	12	-4
97	97	12	1
98	98	12	3
99	99	12	7
100	100	12	14
101	101	12	31
102	102	13	0
103	103	13	1
104	104	13	3
105	105	13	7
106	106	13	14
107	107	13	39
108	108	13	126
109	109	14	-5
110	110	14	1
111	111	14	3
112	112	14	7
113	113	14	14
114	114	15	0
115	115	15	1
116	116	15	3
117	117	15	7
118	118	15	14
119	119	15	31
120	120	15	92
121	121	16	0
122	122	16	1
123	123	16	3
124	124	16	7
125	125	16	14
126	126	16	31
127	127	16	92
128	128	16	511

129	129	16	582
130	130	16	771
131	131	17	-40
132	132	17	1
133	133	17	3
134	134	17	7
135	135	17	14
136	136	17	38
137	137	17	91
138	138	18	-12
139	139	18	1
140	140	18	3
141	141	18	8
142	142	18	14
143	143	18	30
144	144	18	93
145	145	18	505
146	146	19	-34
147	147	19	1
148	148	19	3
149	149	19	7
150	150	19	14
151	151	19	30
152	152	19	120
153	153	20	0
154	154	20	1
155	155	20	3
156	156	20	8
157	157	20	14
158	158	20	37
159	159	20	93
160	160	21	0
161	161	21	1
162	162	21	3
163	163	21	8
164	164	21	14
165	165	21	30
166	166	21	93
167	167	22	0
168	168	22	1
169	169	22	3
170	170	22	8
171	171	22	14

172	172	22	30
173	173	22	93
174	174	23	-26
175	175	23	1
176	176	23	3
177	177	23	7
178	178	23	14
179	179	23	37
180	180	23	115
181	181	24	-13
182	182	24	0
183	183	24	2
184	184	24	6
185	185	24	13
186	186	24	29
187	187	24	94
188	188	24	447
189	189	24	576
190	190	24	734
191	191	25	-6
192	192	25	0
193	193	25	2
194	194	25	6
195	195	25	13
196	196	25	55
197	197	25	112
198	198	25	448
199	199	25	547
200	200	25	758
201	201	26	-7
202	202	26	1
203	203	26	3
204	204	26	7
205	205	26	14
206	206	26	30
207	207	26	107
208	208	27	-5
209	209	27	1
210	210	27	3
211	211	27	7
212	212	27	14
213	213	27	30
214	214	27	108

215	215	27	777
216	216	28	-4
217	217	28	1
218	218	28	3
219	219	28	7
220	220	28	14
221	221	28	36
222	222	28	163
223	223	29	-4
224	224	29	1
225	225	29	3
226	226	29	7
227	227	29	18
228	228	29	37
229	229	29	93
230	230	29	774
231	231	29	1143
232	232	30	-4
233	233	30	1
234	234	30	3
235	235	30	7
236	236	30	14
237	237	30	32
238	238	30	129
239	239	30	542
240	240	30	743
241	241	31	0
242	242	31	1
243	243	31	3
244	244	31	7
245	245	31	14
246	246	31	31
247	247	31	428
248	248	32	-19
249	249	32	1
250	250	32	3
251	251	32	7
252	252	32	16
253	253	32	30
254	254	32	112
255	255	33	-6
256	256	33	1
257	257	33	3

258	258	33	7
259	259	33	15
260	260	33	30
261	261	33	92
262	262	33	415
263	263	33	543
264	264	33	725
265	265	33	1022
266	266	34	-18
267	267	34	1
268	268	34	3
269	269	34	14
270	270	34	30
271	271	34	92
272	272	34	402
273	273	34	578
274	274	35	-4
275	275	35	1
276	276	35	3
277	277	35	7
278	278	35	14
279	279	35	37
280	280	35	94
281	281	36	-6
282	282	36	1
283	283	36	3
284	284	36	7
285	285	36	14
286	286	36	30
287	287	36	588
288	288	37	-20
289	289	37	1
290	290	37	7
291	291	37	30
292	292	37	99
293	293	38	-5
294	294	38	1
295	295	38	3
296	296	38	7
297	297	38	14
298	298	38	36
299	299	38	106
300	300	39	-4

301	301	39	1
302	302	39	3
303	303	39	7
304	304	39	14
305	305	39	30
306	306	39	95
307	307	39	407
308	308	39	548
309	309	39	721
310	310	40	-3
311	311	40	1
312	312	40	3
313	313	40	7
314	314	40	14
315	315	40	35
316	316	40	94
317	317	41	-10
318	318	41	1
319	319	41	3
320	320	41	7
321	321	41	14
322	322	41	30
323	323	41	92
324	324	42	-6
325	325	42	1
326	326	42	3
327	327	42	7
328	328	42	14
329	329	42	30
330	330	42	107
331	331	42	736
332	332	43	-6
333	333	43	1
334	334	43	3
335	335	43	7
336	336	43	14
337	337	43	32
338	338	43	101
339	339	43	396
340	340	43	553
341	341	43	744
342	342	44	-5
343	343	44	1

344	344	44	3
345	345	44	7
346	346	44	14
347	347	44	30
348	348	44	100
349	349	45	-26
350	350	45	1
351	351	45	3
352	352	45	7
353	353	45	14
354	354	45	99
355	355	46	-4
356	356	46	1
357	357	46	3
358	358	46	7
359	359	46	14
360	360	47	-13
361	361	47	1
362	362	47	3
363	363	47	7
364	364	47	14
365	365	47	29
366	366	47	94
367	367	47	375
368	368	47	543
369	369	48	-63
370	370	48	1
371	371	48	7
372	372	48	7
373	373	48	14
374	374	48	36
375	375	48	105
376	376	49	-56
377	377	49	1
378	378	49	7
379	379	49	7
380	380	49	14
381	381	49	31
382	382	49	90
383	383	49	366
384	384	49	549
385	385	50	-6
386	386	50	1

387	387	50	3
388	388	50	7
389	389	50	15
390	390	50	36
391	391	50	116
392	392	51	-6
393	393	51	1
394	394	51	3
395	395	51	8
396	396	51	14
397	397	52	-34
398	398	52	1
399	399	52	3
400	400	52	8
401	401	52	14
402	402	52	31
403	403	52	90
404	404	52	973
405	405	53	-28
406	406	53	1
407	407	53	3
408	408	53	8
409	409	53	14
410	410	53	31
411	411	53	100
412	412	54	-36
413	413	54	1
414	414	54	7
415	415	54	7
416	416	54	14
417	417	54	42
418	418	54	94
419	419	55	-8
420	420	55	1
421	421	55	7
422	422	55	7
423	423	55	14
424	424	55	31
425	425	55	107
426	426	55	573
427	427	56	-18
428	428	56	1
429	429	56	3

430	430	56	8
431	431	56	14
432	432	56	29
433	433	56	116
434	434	57	-6
435	435	57	1
436	436	57	4
437	437	57	7
438	438	57	14
439	439	57	30
440	440	57	95
441	441	58	-5
442	442	58	1
443	443	58	3
444	444	58	7
445	445	58	14
446	446	58	29
447	447	58	92
448	448	58	371
449	449	58	578
450	450	59	-5
451	451	59	1
452	452	59	3
453	453	59	7
454	454	59	14
455	455	59	29
456	456	59	92
457	457	59	365
458	458	60	-4
459	459	60	1
460	460	60	3
461	461	60	7
462	462	60	14
463	463	60	29
464	464	60	98
465	465	60	366
466	466	60	550
467	467	60	953
468	468	61	-4
469	469	61	1
470	470	61	3
471	471	61	7
472	472	61	14

473	473	61	30
474	474	61	91
475	475	62	0
476	476	62	1
477	477	62	3
478	478	62	7
479	479	62	14
480	480	62	30
481	481	62	101
482	482	62	361
483	483	63	0
484	484	63	1
485	485	63	3
486	486	63	7
487	487	63	14
488	488	63	38
489	489	63	121
490	490	64	0
491	491	64	1
492	492	64	3
493	493	64	7
494	494	64	14
495	495	64	30
496	496	64	101
497	497	64	358
498	498	65	0
499	499	65	1
500	500	65	3
501	501	65	7
502	502	65	14
503	503	65	37
504	504	65	98
505	505	65	359
506	506	66	0
507	507	66	1
508	508	66	3
509	509	66	7
510	510	66	14
511	511	66	31
512	512	66	101
513	513	67	0
514	514	67	1
515	515	67	3

516	516	67	7
517	517	67	14
518	518	67	30
519	519	67	93
520	520	67	368
521	521	68	0
522	522	68	1
523	523	68	3
524	524	68	7
525	525	68	14
526	526	68	30
527	527	68	93
528	528	68	368
529	529	69	0
530	530	69	1
531	531	69	3
532	532	69	7
533	533	69	14
534	534	69	32
535	535	69	91
536	536	69	371
537	537	70	0
538	538	70	1
539	539	70	3
540	540	70	7
541	541	70	14
542	542	70	32
543	543	70	93
544	544	70	367
545	545	70	924
546	546	71	0
547	547	71	1
548	548	71	3
549	549	71	7
550	550	71	14
551	551	71	37
552	552	71	108
553	553	71	373
554	554	72	0
555	555	72	1
556	556	72	3
557	557	72	7
558	558	72	14

559	559	72	29
560	560	72	94
561	561	72	367
562	562	73	0
563	563	73	1
564	564	73	3
565	565	73	7
566	566	73	14
567	567	73	37
568	568	73	98
569	569	74	0
570	570	74	1
571	571	74	3
572	572	74	7
573	573	74	14
574	574	74	29
575	575	74	94
576	576	74	169
577	577	75	0
578	578	75	1
579	579	75	3
580	580	75	7
581	581	75	14
582	582	75	29
583	583	75	94
584	584	75	365
585	585	76	0
586	586	76	1
587	587	76	3
588	588	76	7
589	589	76	14
590	590	76	30
591	591	76	93
592	592	76	361
593	593	77	0
594	594	77	1
595	595	77	3
596	596	77	7
597	597	77	14
598	598	77	31
599	599	77	94
600	600	77	357
601	601	78	0

602	602	78	1
603	603	78	3
604	604	78	7
605	605	78	14
606	606	78	31
607	607	78	92
608	608	79	0
609	609	79	1
610	610	79	3
611	611	79	7
612	612	79	14
613	613	79	31
614	614	79	92
615	615	79	357
616	616	80	0
617	617	80	1
618	618	80	3
619	619	80	7
620	620	80	14
621	621	80	31
622	622	80	92
623	623	81	0
624	624	81	1
625	625	81	3
626	626	81	7
627	627	81	14
628	628	81	36
629	629	81	100
630	630	82	0
631	631	82	1
632	632	82	3
633	633	82	7
634	634	82	14
635	635	82	32
636	636	83	0
637	637	83	1
638	638	83	3
639	639	83	7
640	640	83	14
641	641	83	30
642	642	83	99
643	643	84	0
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planned_day_relative_to_boost specimen_type visit

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792	0	Blood	3
793	1	Blood	4
794	3	Blood	5
795	7	Blood	6
796	14	Blood	7
797	30	Blood	8
798	60	Blood	9
799	120	Blood	10
800	-30	Blood	1
801	-15	Blood	2
802	0	Blood	3
803	1	Blood	4
804	3	Blood	5
805	7	Blood	6
806	14	Blood	7
807	30	Blood	8
808	60	Blood	9
809	-30	Blood	1
810	-15	Blood	2
811	0	Blood	3
812	1	Blood	4
813	3	Blood	5
814	7	Blood	6
815	14	Blood	7
816	30	Blood	8
817	60	Blood	9

818	120	Blood	10
819	-30	Blood	2
820	-15	Blood	2
821	0	Blood	3
822	1	Blood	4
823	3	Blood	5
824	7	Blood	6
825	14	Blood	7
826	30	Blood	8
827	60	Blood	9
828	120	Blood	10
829	-30	Blood	1
830	-15	Blood	2
831	0	Blood	3
832	1	Blood	4
833	3	Blood	5
834	7	Blood	6
835	14	Blood	7
836	30	Blood	8
837	60	Blood	9
838	120	Blood	10
839	-30	Blood	1
840	-15	Blood	2
841	0	Blood	3
842	1	Blood	4
843	3	Blood	5
844	7	Blood	6
845	14	Blood	7
846	30	Blood	8
847	60	Blood	9
848	120	Blood	10
849	-30	Blood	1
850	-15	Blood	2
851	0	Blood	3
852	1	Blood	4
853	3	Blood	5
854	7	Blood	6
855	14	Blood	7
856	30	Blood	8
857	60	Blood	9
858	120	Blood	10
859	-30	Blood	1
860	-15	Blood	2

861	0	Blood	3
862	1	Blood	4
863	3	Blood	5
864	7	Blood	6
865	14	Blood	7
866	30	Blood	8
867	60	Blood	9
868	120	Blood	10
869	-30	Blood	1
870	-15	Blood	2
871	0	Blood	3
872	1	Blood	4
873	3	Blood	5
874	7	Blood	6
875	14	Blood	7
876	30	Blood	8
877	60	Blood	9
878	120	Blood	10
879	-30	Blood	1
880	45	Blood	1
881	-15	Blood	2
882	0	Blood	3
883	1	Blood	4
884	3	Blood	5
885	7	Blood	6
886	14	Blood	7
887	30	Blood	8
888	60	Blood	9
889	120	Blood	10
890	-30	Blood	1
891	-15	Blood	2
892	0	Blood	3
893	1	Blood	4
894	3	Blood	5
895	7	Blood	6
896	14	Blood	7
897	30	Blood	8
898	60	Blood	9
899	120	Blood	10
900	-30	Blood	1
901	-15	Blood	2
902	0	Blood	3
903	1	Blood	4

904	3	Blood	5
905	7	Blood	6
906	14	Blood	7
907	30	Blood	8
908	60	Blood	9
909	120	Blood	10
910	-30	Blood	1
911	-15	Blood	2
912	0	Blood	3
913	1	Blood	4
914	3	Blood	5
915	7	Blood	6
916	14	Blood	7
917	30	Blood	8
918	60	Blood	9
919	120	Blood	10
920	-30	Blood	1
921	-15	Blood	2
922	0	Blood	3
923	1	Blood	4
924	3	Blood	5
925	7	Blood	6
926	14	Blood	7
927	30	Blood	8
928	60	Blood	9
929	120	Blood	10
930	-30	Blood	1
931	-15	Blood	2
932	0	Blood	3
933	1	Blood	4
934	3	Blood	5
935	7	Blood	6
936	14	Blood	7
937	30	Blood	8
938	60	Blood	9
939	120	Blood	10
940	-30	Blood	1
941	120	Blood	10
942	-14	Blood	2
943	0	Blood	3
944	1	Blood	4
945	3	Blood	5
946	7	Blood	6

947	14	Blood	7
948	28	Blood	8
949	60	Blood	9
950	-696	Blood	1
951	60	Blood	10
952	120	Blood	11
953	365	Blood	12
954	-679	Blood	2
955	-30	Blood	3
956	-14	Blood	4
957	0	Blood	5
958	1	Blood	6
959	7	Blood	7
960	14	Blood	8
961	28	Blood	9
962	-30	Blood	1
963	120	Blood	10
964	365	Blood	11
965	-14	Blood	2
966	0	Blood	3
967	1	Blood	4
968	3	Blood	5
969	7	Blood	6
970	14	Blood	7
971	28	Blood	8
972	60	Blood	9
973	-30	Blood	1
974	120	Blood	10
975	365	Blood	11
976	-14	Blood	2
977	0	Blood	3
978	1	Blood	4
979	3	Blood	5
980	7	Blood	6
981	14	Blood	7
982	28	Blood	8
983	60	Blood	9
984	-30	Blood	1
985	120	Blood	10
986	-14	Blood	2
987	0	Blood	3
988	1	Blood	4
989	3	Blood	5

990	7	Blood	6
991	14	Blood	7
992	28	Blood	8
993	60	Blood	9
994	-30	Blood	1
995	365	Blood	10
996	-14	Blood	2
997	0	Blood	3
998	1	Blood	4
999	7	Blood	5
1000	14	Blood	6
1001	28	Blood	7
1002	60	Blood	8
1003	120	Blood	9
1004	-30	Blood	1
1005	120	Blood	10
1006	-14	Blood	2
1007	0	Blood	3
1008	1	Blood	4
1009	3	Blood	5
1010	7	Blood	6
1011	14	Blood	7
1012	28	Blood	8
1013	60	Blood	9
1014	-30	Blood	1
1015	120	Blood	10
1016	365	Blood	11
1017	-14	Blood	2
1018	0	Blood	3
1019	1	Blood	4
1020	3	Blood	5
1021	7	Blood	6
1022	14	Blood	7
1023	28	Blood	8
1024	60	Blood	9
1025	-30	Blood	1
1026	120	Blood	10
1027	365	Blood	11
1028	-14	Blood	2
1029	0	Blood	3
1030	1	Blood	4
1031	3	Blood	5
1032	7	Blood	6

1033	14	Blood	7
1034	28	Blood	8
1035	60	Blood	9
1036	-30	Blood	1
1037	-14	Blood	2
1038	0	Blood	3
1039	1	Blood	4
1040	3	Blood	5
1041	7	Blood	6
1042	14	Blood	7
1043	28	Blood	8
1044	60	Blood	9
1045	-30	Blood	1
1046	120	Blood	10
1047	365	Blood	11
1048	-14	Blood	2
1049	0	Blood	3
1050	1	Blood	4
1051	3	Blood	5
1052	7	Blood	6
1053	14	Blood	7
1054	28	Blood	8
1055	60	Blood	9
1056	-30	Blood	1
1057	-14	Blood	2
1058	0	Blood	3
1059	1	Blood	4
1060	3	Blood	5
1061	7	Blood	6
1062	14	Blood	7
1063	28	Blood	8
1064	-30	Blood	1
1065	120	Blood	10
1066	-14	Blood	2
1067	0	Blood	3
1068	1	Blood	4
1069	3	Blood	5
1070	7	Blood	6
1071	14	Blood	7
1072	28	Blood	8
1073	60	Blood	9
1074	-30	Blood	1
1075	120	Blood	10

1076	365	Blood	11
1077	-14	Blood	2
1078	0	Blood	3
1079	1	Blood	4
1080	3	Blood	5
1081	7	Blood	6
1082	14	Blood	7
1083	28	Blood	8
1084	60	Blood	9
1085	-30	Blood	1
1086	120	Blood	10
1087	365	Blood	11
1088	-14	Blood	2
1089	0	Blood	3
1090	1	Blood	4
1091	3	Blood	5
1092	7	Blood	6
1093	14	Blood	7
1094	28	Blood	8
1095	60	Blood	9
1096	-30	Blood	1
1097	-14	Blood	2
1098	0	Blood	3
1099	1	Blood	4
1100	3	Blood	5
1101	7	Blood	6
1102	14	Blood	7
1103	28	Blood	8
1104	60	Blood	9
1105	-30	Blood	1
1106	120	Blood	10
1107	-14	Blood	2
1108	0	Blood	3
1109	1	Blood	4
1110	3	Blood	5
1111	7	Blood	6
1112	14	Blood	7
1113	28	Blood	8
1114	60	Blood	9
1115	-30	Blood	1
1116	120	Blood	10
1117	365	Blood	11
1118	-14	Blood	2

1119	0	Blood	3
1120	1	Blood	4
1121	3	Blood	5
1122	7	Blood	6
1123	14	Blood	7
1124	28	Blood	8
1125	60	Blood	9
1126	-30	Blood	1
1127	120	Blood	10
1128	365	Blood	11
1129	-14	Blood	2
1130	0	Blood	3
1131	1	Blood	4
1132	3	Blood	5
1133	7	Blood	6
1134	14	Blood	7
1135	28	Blood	8
1136	60	Blood	9
1137	-30	Blood	1
1138	120	Blood	10
1139	365	Blood	11
1140	-14	Blood	2
1141	0	Blood	3
1142	1	Blood	4
1143	3	Blood	5
1144	7	Blood	6
1145	14	Blood	7
1146	28	Blood	8
1147	60	Blood	9
1148	-30	Blood	1
1149	120	Blood	10
1150	365	Blood	11
1151	-14	Blood	2
1152	0	Blood	3
1153	1	Blood	4
1154	3	Blood	5
1155	7	Blood	6
1156	14	Blood	7
1157	28	Blood	8
1158	60	Blood	9
1159	-30	Blood	1
1160	120	Blood	10
1161	365	Blood	11

1162	-14	Blood	2
1163	0	Blood	3
1164	1	Blood	4
1165	3	Blood	5
1166	7	Blood	6
1167	14	Blood	7
1168	28	Blood	8
1169	60	Blood	9
1170	-30	Blood	1
1171	120	Blood	10
1172	365	Blood	11
1173	-14	Blood	2
1174	0	Blood	3
1175	1	Blood	4
1176	3	Blood	5
1177	7	Blood	6
1178	14	Blood	7
1179	28	Blood	8
1180	60	Blood	9
1181	-30	Blood	1
1182	365	Blood	10
1183	-14	Blood	2
1184	0	Blood	3
1185	1	Blood	4
1186	3	Blood	5
1187	7	Blood	6
1188	14	Blood	7
1189	28	Blood	8
1190	120	Blood	9
1191	-30	Blood	1
1192	120	Blood	10
1193	365	Blood	11
1194	-14	Blood	2
1195	0	Blood	3
1196	1	Blood	4
1197	3	Blood	5
1198	7	Blood	6
1199	14	Blood	7
1200	28	Blood	8
1201	60	Blood	9
1202	-30	Blood	1
1203	120	Blood	10
1204	365	Blood	11

1205	-14	Blood	2
1206	0	Blood	3
1207	1	Blood	4
1208	3	Blood	5
1209	7	Blood	6
1210	14	Blood	7
1211	28	Blood	8
1212	60	Blood	9
1213	-30	Blood	1
1214	120	Blood	10
1215	365	Blood	11
1216	-14	Blood	2
1217	0	Blood	3
1218	1	Blood	4
1219	3	Blood	5
1220	7	Blood	6
1221	14	Blood	7
1222	28	Blood	8
1223	60	Blood	9
1224	-30	Blood	1
1225	120	Blood	10
1226	-14	Blood	2
1227	0	Blood	3
1228	1	Blood	4
1229	3	Blood	5
1230	7	Blood	6
1231	14	Blood	7
1232	28	Blood	8
1233	60	Blood	9
1234	-30	Blood	1
1235	120	Blood	10
1236	365	Blood	11
1237	-14	Blood	2
1238	0	Blood	3
1239	1	Blood	4
1240	3	Blood	5
1241	7	Blood	6
1242	14	Blood	7
1243	28	Blood	8
1244	60	Blood	9
1245	-30	Blood	1
1246	120	Blood	10
1247	-14	Blood	2

1248	0	Blood	3
1249	1	Blood	4
1250	3	Blood	5
1251	7	Blood	6
1252	14	Blood	7
1253	28	Blood	8
1254	60	Blood	9
1255	-30	Blood	1
1256	120	Blood	10
1257	-14	Blood	2
1258	0	Blood	3
1259	1	Blood	4
1260	3	Blood	5
1261	7	Blood	6
1262	14	Blood	7
1263	28	Blood	8
1264	60	Blood	9
1265	-30	Blood	1
1266	120	Blood	10
1267	365	Blood	11
1268	-14	Blood	2
1269	0	Blood	3
1270	1	Blood	4
1271	3	Blood	5
1272	7	Blood	6
1273	14	Blood	7
1274	28	Blood	8
1275	60	Blood	9
1276	-30	Blood	1
1277	120	Blood	10
1278	-14	Blood	2
1279	0	Blood	3
1280	1	Blood	4
1281	3	Blood	5
1282	7	Blood	6
1283	14	Blood	7
1284	28	Blood	8
1285	60	Blood	9
1286	-30	Blood	1
1287	120	Blood	10
1288	365	Blood	11
1289	-14	Blood	2
1290	0	Blood	3

1291	1	Blood	4
1292	3	Blood	5
1293	7	Blood	6
1294	14	Blood	7
1295	28	Blood	8
1296	60	Blood	9
1297	-30	Blood	1
1298	120	Blood	10
1299	-14	Blood	2
1300	0	Blood	3
1301	1	Blood	4
1302	3	Blood	5
1303	7	Blood	6
1304	14	Blood	7
1305	28	Blood	8
1306	60	Blood	9
1307	-30	Blood	1
1308	120	Blood	10
1309	365	Blood	11
1310	-14	Blood	2
1311	0	Blood	3
1312	1	Blood	4
1313	3	Blood	5
1314	7	Blood	6
1315	14	Blood	7
1316	28	Blood	8
1317	60	Blood	9
1318	-30	Blood	1
1319	120	Blood	10
1320	365	Blood	11
1321	-14	Blood	2
1322	0	Blood	3
1323	1	Blood	4
1324	3	Blood	5
1325	7	Blood	6
1326	14	Blood	7
1327	28	Blood	8
1328	60	Blood	9
1329	-30	Blood	1
1330	120	Blood	10
1331	-14	Blood	2
1332	0	Blood	3
1333	1	Blood	4

1334	3	Blood	5
1335	7	Blood	6
1336	14	Blood	7
1337	28	Blood	8
1338	60	Blood	9
1339	-30	Blood	1
1340	120	Blood	10
1341	365	Blood	11
1342	-14	Blood	2
1343	0	Blood	3
1344	1	Blood	4
1345	3	Blood	5
1346	7	Blood	6
1347	14	Blood	7
1348	28	Blood	8
1349	60	Blood	9
1350	-30	Blood	1
1351	-14	Blood	2
1352	0	Blood	3
1353	1	Blood	4
1354	3	Blood	5
1355	7	Blood	6
1356	14	Blood	7
1357	28	Blood	8
1358	60	Blood	9
1359	-30	Blood	1
1360	120	Blood	10
1361	365	Blood	11
1362	-14	Blood	2
1363	0	Blood	3
1364	1	Blood	4
1365	3	Blood	5
1366	7	Blood	6
1367	14	Blood	7
1368	28	Blood	8
1369	60	Blood	9
1370	-30	Blood	1
1371	120	Blood	10
1372	365	Blood	11
1373	-14	Blood	2
1374	0	Blood	3
1375	1	Blood	4
1376	3	Blood	5

1377	7	Blood	6
1378	14	Blood	7
1379	28	Blood	8
1380	60	Blood	9
1381	-30	Blood	1
1382	120	Blood	10
1383	365	Blood	11
1384	-14	Blood	2
1385	0	Blood	3
1386	1	Blood	4
1387	3	Blood	5
1388	7	Blood	6
1389	14	Blood	7
1390	28	Blood	8
1391	60	Blood	9
1392	-30	Blood	1
1393	120	Blood	10
1394	365	Blood	11
1395	-14	Blood	2
1396	0	Blood	3
1397	1	Blood	4
1398	3	Blood	5
1399	7	Blood	6
1400	14	Blood	7
1401	28	Blood	8
1402	60	Blood	9
1403	-30	Blood	1
1404	120	Blood	10
1405	365	Blood	11
1406	-14	Blood	2
1407	0	Blood	3
1408	1	Blood	4
1409	3	Blood	5
1410	7	Blood	6
1411	14	Blood	7
1412	28	Blood	8
1413	60	Blood	9
1414	-30	Blood	1
1415	120	Blood	10
1416	-14	Blood	2
1417	0	Blood	3
1418	1	Blood	4
1419	3	Blood	5

1420	7	Blood	6
1421	14	Blood	7
1422	28	Blood	8
1423	60	Blood	9
1424	-30	Blood	1
1425	120	Blood	10
1426	-14	Blood	2
1427	0	Blood	3
1428	1	Blood	4
1429	3	Blood	5
1430	7	Blood	6
1431	14	Blood	7
1432	28	Blood	8
1433	60	Blood	9
1434	-30	Blood	1
1435	120	Blood	10
1436	-14	Blood	2
1437	0	Blood	3
1438	1	Blood	4
1439	3	Blood	5
1440	7	Blood	6
1441	14	Blood	7
1442	28	Blood	8
1443	60	Blood	9
1444	-30	Blood	1
1445	120	Blood	10
1446	-14	Blood	2
1447	0	Blood	3
1448	1	Blood	4
1449	3	Blood	5
1450	7	Blood	6
1451	14	Blood	7
1452	28	Blood	8
1453	60	Blood	9
1454	-30	Blood	1
1455	120	Blood	10
1456	-14	Blood	2
1457	0	Blood	3
1458	1	Blood	4
1459	3	Blood	5
1460	7	Blood	6
1461	14	Blood	7
1462	28	Blood	8

1463	60	Blood	9
1464	-30	Blood	1
1465	120	Blood	10
1466	-14	Blood	2
1467	0	Blood	3
1468	1	Blood	4
1469	3	Blood	5
1470	7	Blood	6
1471	14	Blood	7
1472	28	Blood	8
1473	60	Blood	9
1474	-30	Blood	1
1475	120	Blood	10
1476	-14	Blood	2
1477	0	Blood	3
1478	1	Blood	4
1479	3	Blood	5
1480	7	Blood	6
1481	14	Blood	7
1482	28	Blood	8
1483	60	Blood	9
1484	-30	Blood	1
1485	120	Blood	10
1486	-14	Blood	2
1487	0	Blood	3
1488	1	Blood	4
1489	3	Blood	5
1490	7	Blood	6
1491	14	Blood	7
1492	28	Blood	8
1493	60	Blood	9
1494	-30	Blood	1
1495	120	Blood	10
1496	-14	Blood	2
1497	0	Blood	3
1498	1	Blood	4
1499	3	Blood	5
1500	7	Blood	6
1501	14	Blood	7
1502	28	Blood	8
1503	60	Blood	9

```
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(abtiter)
```

```
  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
```

We want to merge or "join" these tables so we can have all the info we need about a given antibody measurement.

```
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 specimen_id
1    1986-01-01    2016-09-12 2020_dataset 14207 days           1
2    1986-01-01    2016-09-12 2020_dataset 14207 days           2
3    1986-01-01    2016-09-12 2020_dataset 14207 days           3
4    1986-01-01    2016-09-12 2020_dataset 14207 days           4
5    1986-01-01    2016-09-12 2020_dataset 14207 days           5
6    1986-01-01    2016-09-12 2020_dataset 14207 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
```

and one last join of `ab_titer` and `meta`

```
abdata <- inner_join(abtiter, meta)
```

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

```
head(abdata)
```

```
  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 subject_id infancy_vac biological_sex
1 UG/ML                 2.096133          1          wP         Female
2 IU/ML                29.170000          1          wP         Female
3 IU/ML                 0.530000          1          wP         Female
4 IU/ML                 6.205949          1          wP         Female
5 IU/ML                 4.679535          1          wP         Female
6 IU/ML                 2.816431          1          wP         Female
               ethnicity  race year_of_birth date_of_boost      dataset
1 Not Hispanic or Latino White    1986-01-01    2016-09-12 2020_dataset
2 Not Hispanic or Latino White    1986-01-01    2016-09-12 2020_dataset
3 Not Hispanic or Latino White    1986-01-01    2016-09-12 2020_dataset
4 Not Hispanic or Latino White    1986-01-01    2016-09-12 2020_dataset
5 Not Hispanic or Latino White    1986-01-01    2016-09-12 2020_dataset
6 Not Hispanic or Latino White    1986-01-01    2016-09-12 2020_dataset
        age actual_day_relative_to_boost planned_day_relative_to_boost
1 14207 days                          -3                             0
2 14207 days                          -3                             0
3 14207 days                          -3                             0
4 14207 days                          -3                             0
5 14207 days                          -3                             0
6 14207 days                          -3                             0
  specimen_type visit
1         Blood     1
2         Blood     1
3         Blood     1
4         Blood     1
5         Blood     1
6         Blood     1
```

```
nrow(abdata)
```

```
[1] 52576
```

```
head(abdata)
```

```
  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 subject_id infancy_vac biological_sex
1 UG/ML                 2.096133          1          wP         Female
2 IU/ML                29.170000          1          wP         Female
3 IU/ML                 0.530000          1          wP         Female
4 IU/ML                 6.205949          1          wP         Female
5 IU/ML                 4.679535          1          wP         Female
6 IU/ML                 2.816431          1          wP         Female
               ethnicity  race year_of_birth date_of_boost      dataset
1 Not Hispanic or Latino White    1986-01-01    2016-09-12 2020_dataset
2 Not Hispanic or Latino White    1986-01-01    2016-09-12 2020_dataset
3 Not Hispanic or Latino White    1986-01-01    2016-09-12 2020_dataset
4 Not Hispanic or Latino White    1986-01-01    2016-09-12 2020_dataset
5 Not Hispanic or Latino White    1986-01-01    2016-09-12 2020_dataset
6 Not Hispanic or Latino White    1986-01-01    2016-09-12 2020_dataset
        age actual_day_relative_to_boost planned_day_relative_to_boost
1 14207 days                          -3                            0
2 14207 days                          -3                            0
3 14207 days                          -3                            0
4 14207 days                          -3                            0
5 14207 days                          -3                            0
6 14207 days                          -3                            0
  specimen_type visit
1         Blood     1
2         Blood     1
3         Blood     1
4         Blood     1
5         Blood     1
6         Blood     1
```

```
table(abdata$isotype)
```

```
  IgE   IgG  IgG1  IgG2  IgG3  IgG4
 6698  5389 10117 10124 10124 10124
```

```
table(abdata$antigen)
```

```
   ACT   BETV1      DT   FELD1     FHA  FIM2/3   LOLP1     LOS Measles     OVA
  1970    1970    4978    1970    5372    4978    1970    1970    1970    4978
   PD1     PRN      PT     PTM   Total      TT
  1970    5372    5372    1970     788    4978
```

Let's begin with IgG

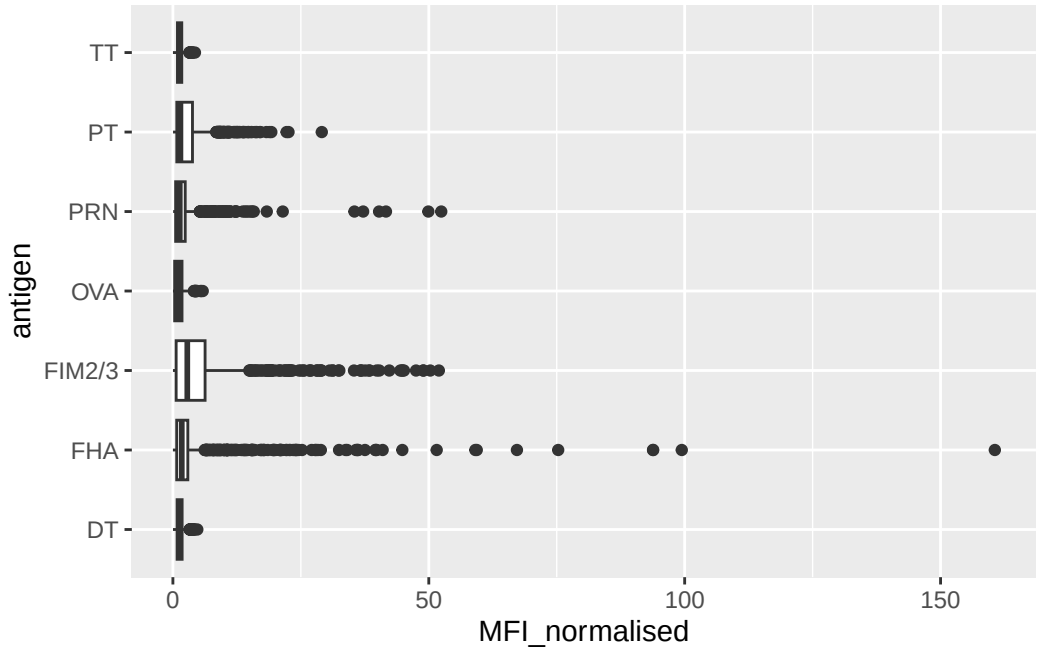
```
igg <- filter(abdata, isotype == "IgG")
head(igg)
```

```
  specimen_id isotype is_antigen_specific antigen        MFI MFI_normalised
1           1     IgG                TRUE      PT   68.56614       3.736992
2           1     IgG                TRUE     PRN  332.12718       2.602350
3           1     IgG                TRUE     FHA 1887.12263      34.050956
4          19     IgG                TRUE      PT   20.11607       1.096366
5          19     IgG                TRUE     PRN  976.67419       7.652635
6          19     IgG                TRUE     FHA   60.76626       1.096457
   unit lower_limit_of_detection subject_id infancy_vac biological_sex
1 IU/ML                0.530000          1          wP         Female
2 IU/ML                6.205949          1          wP         Female
3 IU/ML                4.679535          1          wP         Female
4 IU/ML                0.530000          3          wP         Female
5 IU/ML                6.205949          3          wP         Female
6 IU/ML                4.679535          3          wP         Female
              ethnicity  race year_of_birth date_of_boost      dataset
1 Not Hispanic or Latino White    1986-01-01    2016-09-12 2020_dataset
2 Not Hispanic or Latino White    1986-01-01    2016-09-12 2020_dataset
3 Not Hispanic or Latino White    1986-01-01    2016-09-12 2020_dataset
4               Unknown White    1983-01-01    2016-10-10 2020_dataset
5               Unknown White    1983-01-01    2016-10-10 2020_dataset
6               Unknown White    1983-01-01    2016-10-10 2020_dataset
        age actual_day_relative_to_boost planned_day_relative_to_boost
1 14207 days                         -3                            0
2 14207 days                         -3                            0
3 14207 days                         -3                            0
```

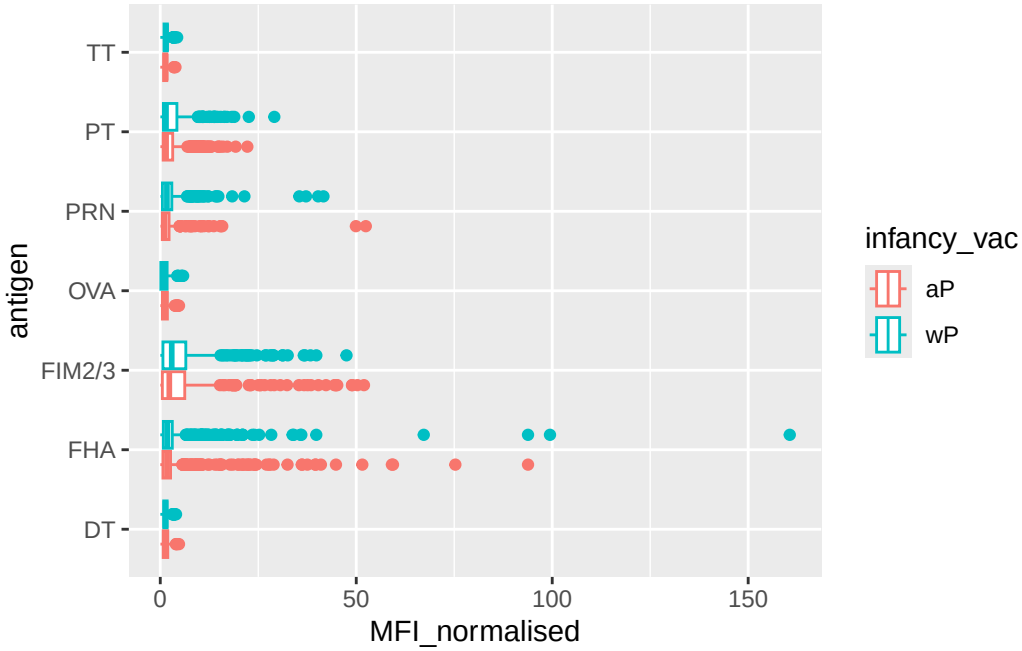
```
4 15303 days                          -3                          0
5 15303 days                          -3                          0
6 15303 days                          -3                          0
  specimen_type visit
1         Blood     1
2         Blood     1
3         Blood     1
4         Blood     1
5         Blood     1
6         Blood     1
```

Make a boxplot of IgG antigen levels - this will be a plot of MFI vs antigen

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

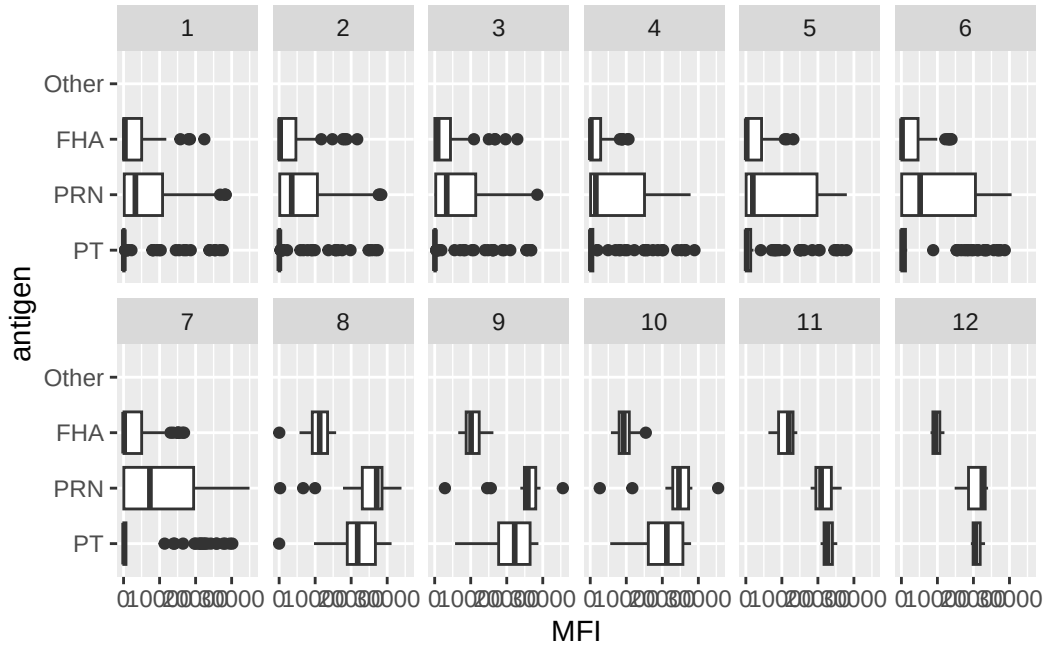



```
ggplot(igg) +
  aes(MFI_normalised, antigen, col = infancy_vac) +
  geom_boxplot()
```




```
ggplot(igg) +
  aes(y = antigen, x = MFI) +  # Swap antigen to y-axis and MFI to x-axis
  geom_boxplot() +  # Create the boxplot
  scale_y_discrete(limits = c("PT", "PRN", "FHA", "Other")) +  # Optionally customize y-axis
  facet_wrap(vars(visit), nrow = 2)  # Facet by visit, arrange in 2 rows
```

```
Warning: Removed 2404 rows containing missing values or values outside the scale range
(`stat_boxplot()`).
```

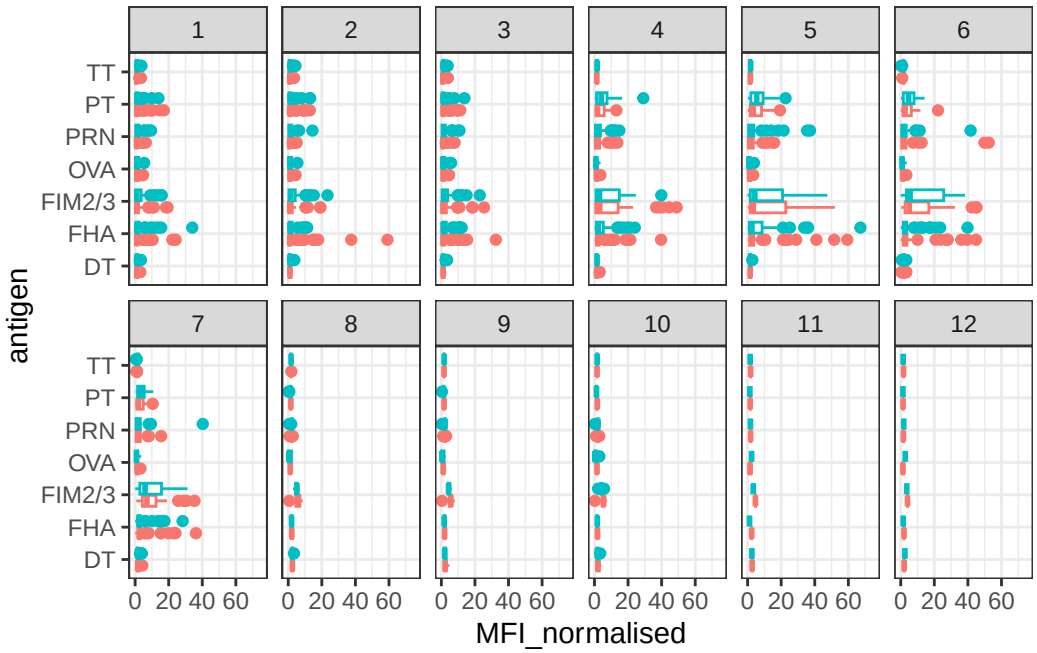


The boxplot shows changes in IgG antibody titers over time for several antigens. This could be due to factors like waning immunity, booster doses, or exposure to new variants. More analysis is needed to fully understand the underlying reasons.

Ideally, I would like to see how these Ab levels change over time relative to the booster shot.

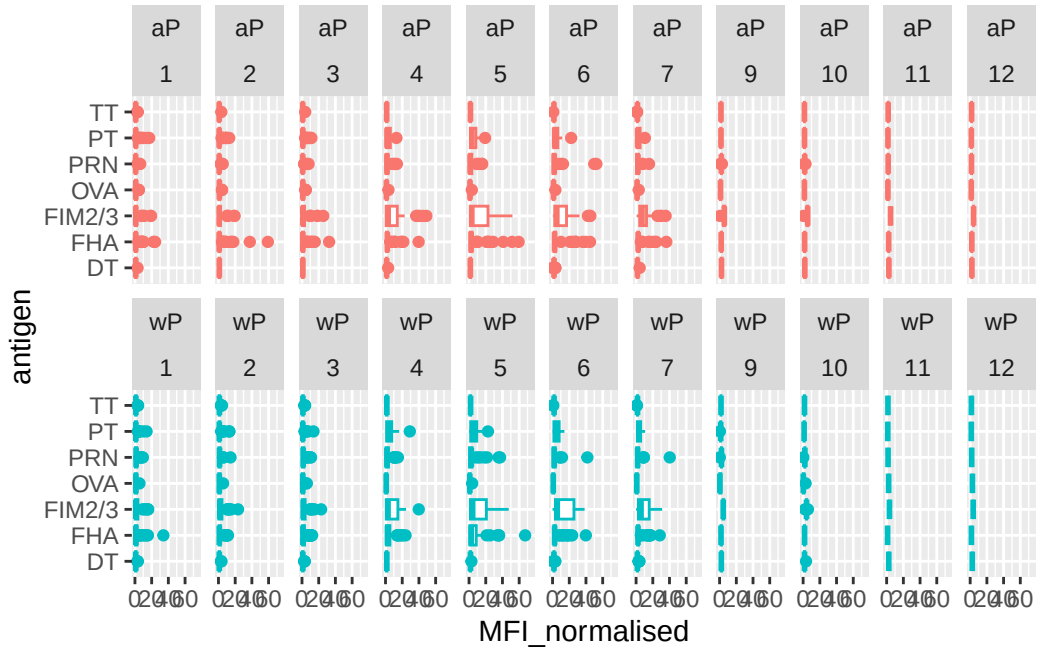
```
ggplot(igg) +
  aes(MFI_normalised, antigen, col=infancy_vac ) +
  geom_boxplot(show.legend = FALSE) +
  facet_wrap(vars(visit), nrow=2) +
  xlim(0,75) +
  theme_bw()
```

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

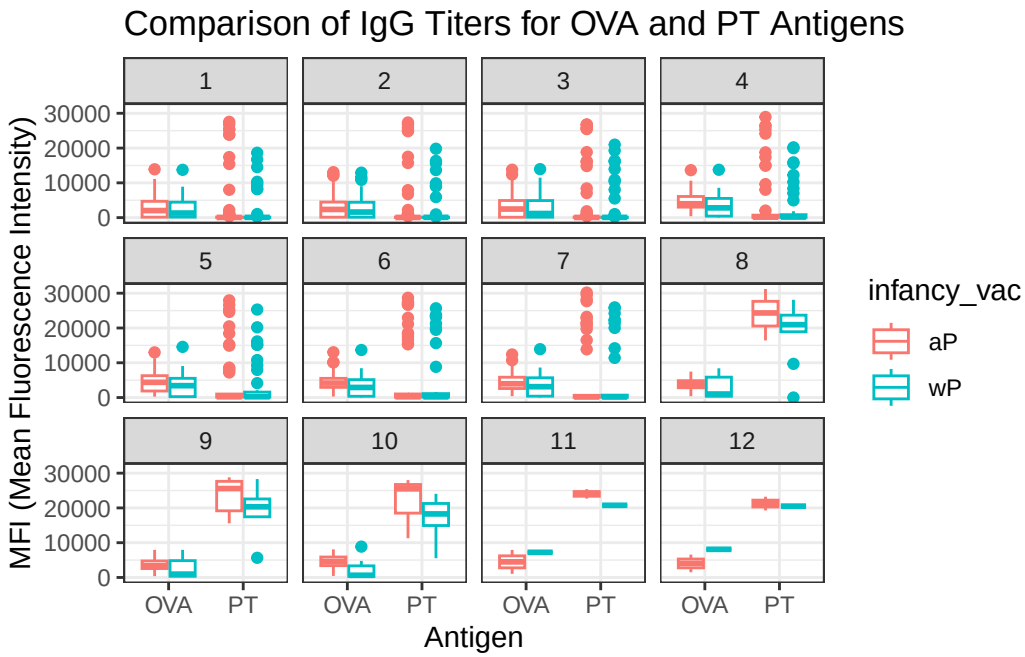



```
igg %>% filter(visit != 8) %>%
ggplot() +
  aes(MFI_normalised, antigen, col=infancy_vac ) +
  geom_boxplot(show.legend = FALSE) +
  xlim(0,75) +
  facet_wrap(vars(infancy_vac, visit), nrow=2)
```

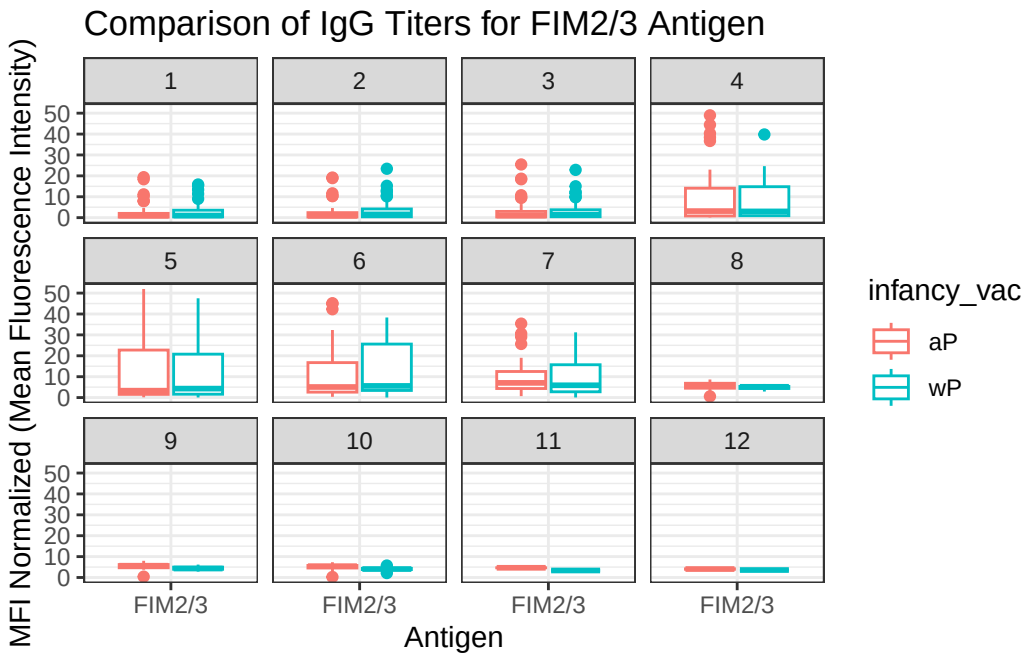
```
Warning: Removed 5 rows containing non-finite outside the scale range
(`stat_boxplot()`).
```




```
# Filter for OVA and PT antigens and create a boxplot
igg %>%
  filter(antigen %in% c("OVA", "PT")) %>%
  ggplot() +
  aes(x = antigen, y = MFI, col = infancy_vac) +  # MFI on y-axis, antigen on x-axis, color l
  geom_boxplot(show.legend = TRUE) +  # Show legend
  facet_wrap(vars(visit)) +  # Facet by visit
  theme_bw() +  # Use a clean theme
  labs(title = "Comparison of IgG Titers for OVA and PT Antigens",
       x = "Antigen",
       y = "MFI (Mean Fluorescence Intensity)")  # Adding axis labels and a title
```




```
# Filter for FIM2/3 antigen and create a boxplot
igg %>%
  filter(antigen == "FIM2/3") %>%
  ggplot() +
  aes(x = antigen, y = MFI_normalised, col = infancy_vac) +  # MFI_normalised on y-axis, anti
  geom_boxplot(show.legend = TRUE) +  # Show legend
  facet_wrap(vars(visit)) +  # Facet by visit
  theme_bw() +  # Use a clean theme
  labs(title = "Comparison of IgG Titers for FIM2/3 Antigen",
       x = "Antigen",
       y = "MFI Normalized (Mean Fluorescence Intensity)")  # Adding axis labels and a title
```



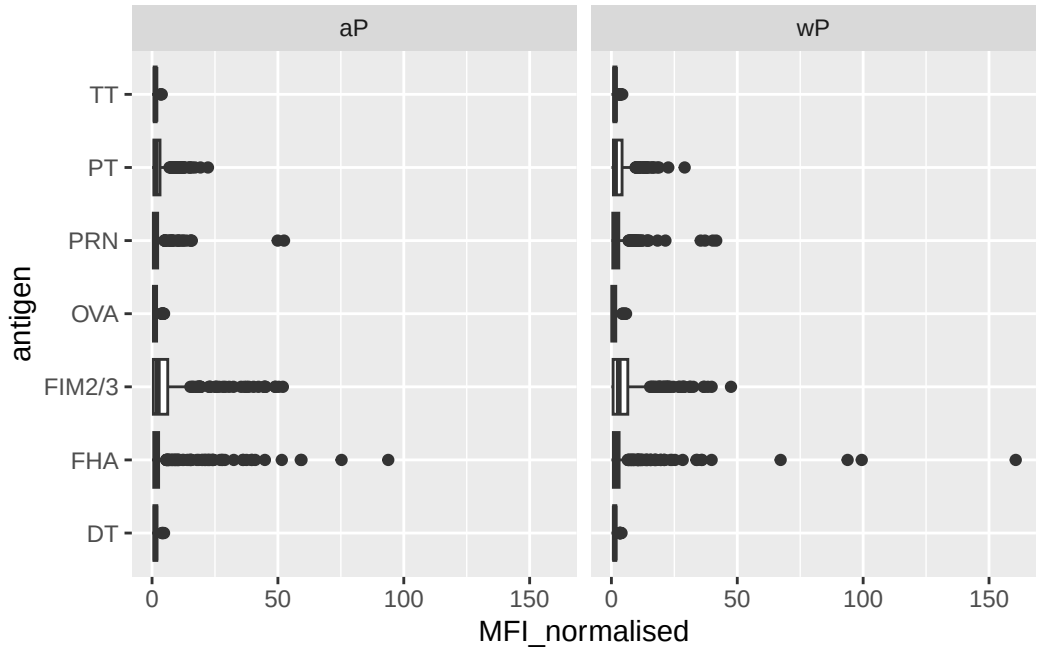
PT shows a clear rise and peak in antibody levels over time, especially at visit 5, then declines, indicating an immune response. OVA remains stable, insignificant immune reaction.

wP shows a more pronounced immune response to PT, with higher antibody levels at earlier visits compared to aP, which shows a more gradual response.

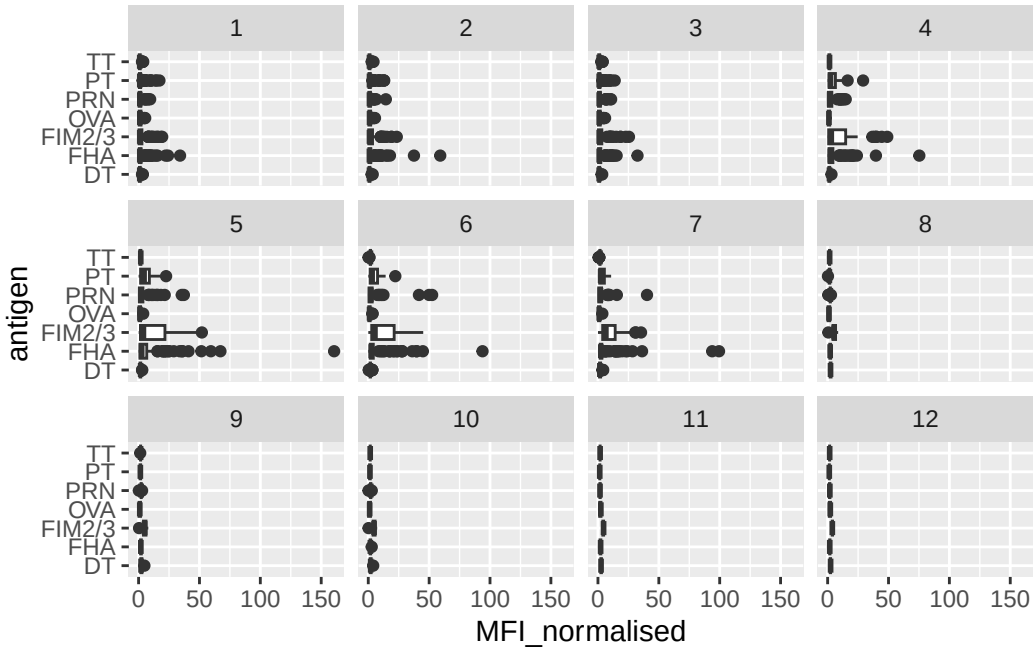
```
table(abdata$visit)
```

```
   1    2    3    4    5    6    7    8    9   10   11   12
8280 8280 8420 6565 6565 6210 5810  815  735  686  105  105
```

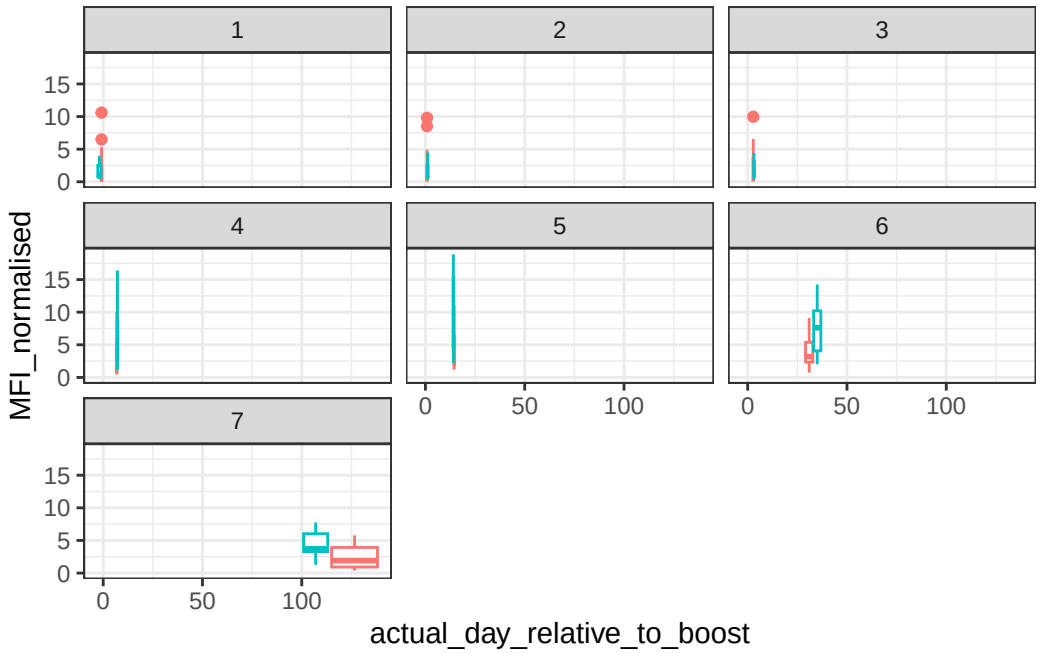
```
ggplot(igg) +
  aes(MFI_normalised, antigen) +
  geom_boxplot() +
  facet_wrap(~infancy_vac)
```




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

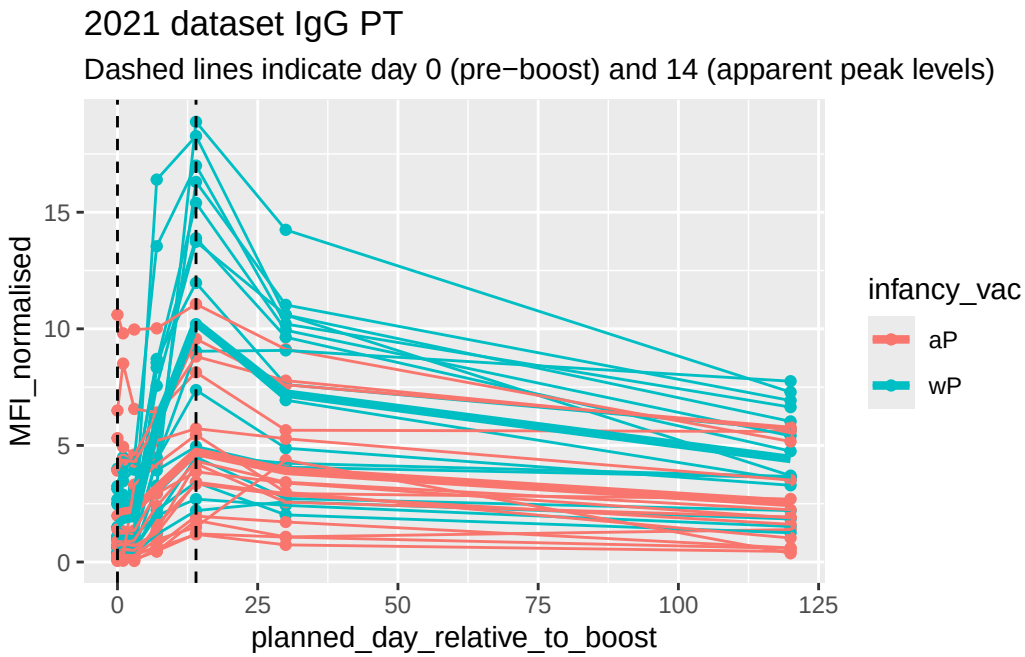



```
igg_pt <- filter(igg, antigen == "PT", dataset == "2021_dataset")
#igg_pt <- filter(igg, antigen == "PT")
ggplot(igg_pt) +
  aes(actual_day_relative_to_boost, MFI_normalised, col = infancy_vac) +
  geom_boxplot(show.legend = FALSE) +
  facet_wrap(vars(visit)) +
  theme_bw()
```

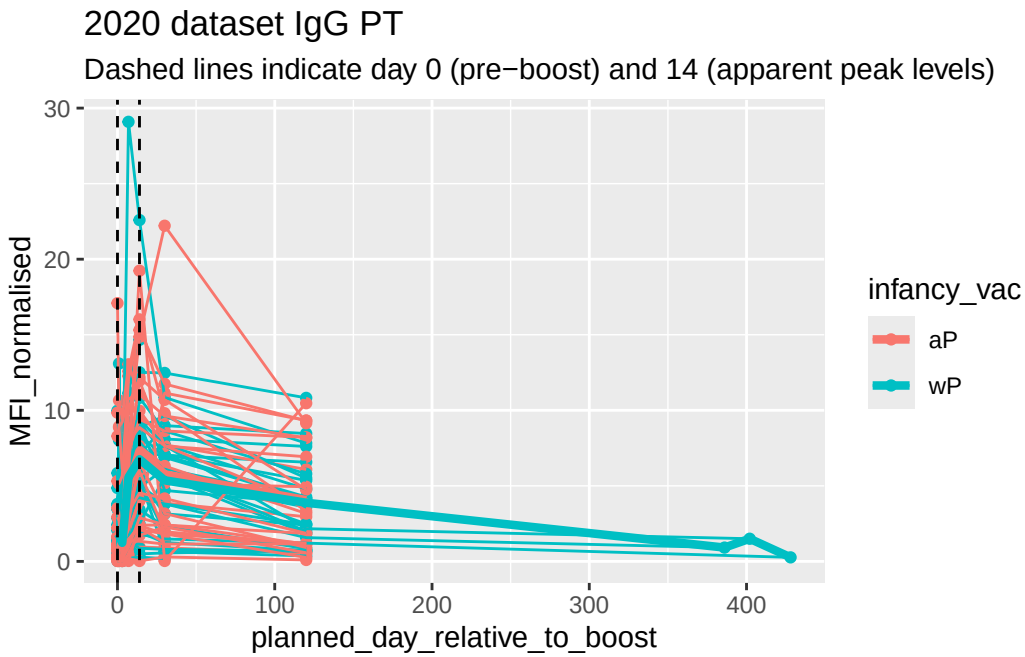



```
filter(igg, antigen == "PT", dataset == "2021_dataset") |>
ggplot() +
   aes(planned_day_relative_to_boost, MFI_normalised, col = infancy_vac, group = subject_id)
   geom_point() +
   geom_line() +
   stat_summary(fun = mean, geom = "line", size = 1.5, aes(group = infancy_vac)) +  # Mean tr
  geom_vline(xintercept = 0, linetype = "dashed") +
  geom_vline(xintercept = 14, linetype = "dashed") +
   labs(title="2021 dataset IgG PT",
       subtitle = "Dashed lines indicate day 0 (pre-boost) and 14 (apparent peak levels)")
```

```
Warning: Using `size` aesthetic for lines was deprecated in ggplot2 3.4.0.
i Please use `linewidth` instead.
```




```
filter(igg, antigen == "PT", dataset == "2020_dataset") |>
ggplot() +
   aes(planned_day_relative_to_boost, MFI_normalised, col = infancy_vac, group = subject_id)
   geom_point() +
   geom_line() +
  stat_summary(fun = mean, geom = "line", size = 1.5, aes(group = infancy_vac)) +  # Mean tr
  geom_vline(xintercept = 0, linetype = "dashed") +
  geom_vline(xintercept = 14, linetype = "dashed") +
   labs(title="2020 dataset IgG PT",
       subtitle = "Dashed lines indicate day 0 (pre-boost) and 14 (apparent peak levels)")
```



The planned day relative to boost for wP is stretched to 400 days, meaning immunity from wP lasts longer

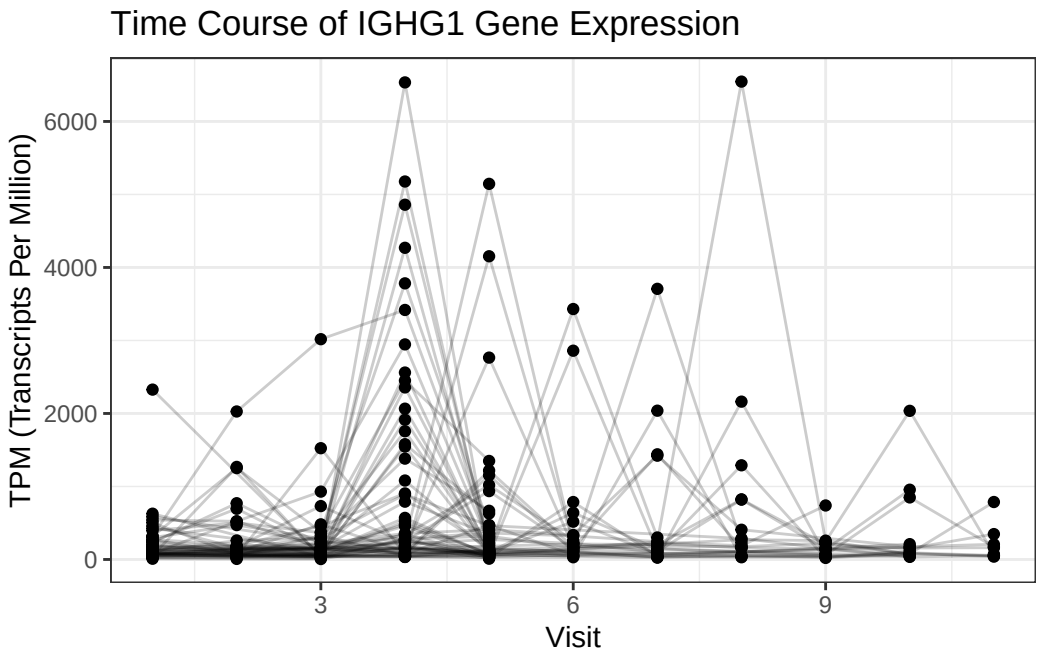
```
url <- "https://www.cmi-pb.org/api/v2/rnaseq?versioned_ensembl_gene_id=eq.ENSG00000211896.7"

rna <- read_json(url, simplifyVector = TRUE)
```

```
#meta <- inner_join(specimen, subject)
ssrna <- inner_join(rna, meta)
```

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

```
ggplot(ssrna) +
  aes(x = visit, y = tpm, group = subject_id) +
  geom_point() +
  geom_line(alpha = 0.2) +
  labs(title = "Time Course of IGHG1 Gene Expression",
       x = "Visit",
       y = "TPM (Transcripts Per Million)") +
  theme_bw()
```



Based on the line plot, the gene expression reaches its maximum level around visit 4. This suggests that the gene is most actively transcribed and translated at this point in time.

Gene expression doesn't directly correlate with antibody levels. There's a time lag between gene expression and antibody production, influenced by various factors like protein processing and transport