Covid-19 Vaccination Campaign in Germany

The data used here were provided by Robert Koch Institute and the German federal ministry of Health.

These institutions publish the datasets and some analysis on the page impfdashboard.de.

Setup

Imports

In [1]:
```
# standard library
import datetime
import math
```

In [2]:
```
# third party
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import requests
import seaborn
```

Date this Notebook was run

In [3]:
```
today = datetime.datetime.today().strftime('%Y-%m-%d')
today
```

Out[3]:
```
'2021-08-18'
```

Set Defaults

In [4]:
```
# style like ggplot in R
plt.style.use('ggplot')
```

In [5]:
```
# Avoid cutting off part of the axis labels, see:
# https://stackoverflow.com/questions/6774086/why-is-my-xlabel-cut-off-in-my-matplotlib-plot
plt.rcParams.update({'figure.autolayout': True})
```

```
In [6]: population_germany = 83_200_000
```

Get and Transform Data

```
In [7]: vaccination_data_permalink = 'https://impfdashboard.de/static/data/germany_vaccinations_timeseries_v2.tsv'
        vaccinations = pd.read_csv(
            vaccination_data_permalink,
            sep="\t")
```

Drop unnecessary / misleading columns

Columns with names starting with 'indikation_' will not be analyzed as the data providers stopped updating them.

```
In [8]: cols_to_drop = vaccinations.columns[vaccinations.columns.str.contains('indikation_')]
        vaccinations.drop(columns=cols_to_drop, inplace=True)
```

Some more columns can be dropped, as there is no interest in analyzing differences on a vaccine level - especially since in some cases vaccines were mixed.

```
In [9]: more_cols_to_drop = ['dosen_biontech_erst_kumulativ', 'dosen_biontech_zweit_kumulativ',
                             'dosen_moderna_erst_kumulativ', 'dosen_moderna_zweit_kumulativ',
                             'dosen_astrazeneca_erst_kumulativ', 'dosen_astrazeneca_zweit_kumulativ']
        vaccinations.drop(columns=more_cols_to_drop, inplace=True)
```

Some columns are labeled misleadingly. As stated by the data provider the columns `personen_erst_kumulativ` and `impf_quote_erst` contain people vaccinated with the Johnson & Johnson vaccine. As this requires only one shot. the same persons are included in `personen_voll_kumulativ` . Therefore more columns are dropped and recalculated later.

```
In [10]: vaccinations.drop(columns=['impf_quote_erst', 'impf_quote_voll'], inplace=True)
```

Convert datatype of date column

```
In [11]: vaccinations.iloc[ : , [0]] = vaccinations.iloc[ : , [0]].apply(pd.to_datetime)
```

Show Data

```
In [12]: vaccinations.info()
```

```
<class 'pandas.core.frame.DataFrame'>
```

```
RangeIndex: 234 entries, 0 to 233
Data columns (total 15 columns):
 #   Column                            Non-Null Count  Dtype         
---  ------                            --------------  -----         
 0   date                              234 non-null    datetime64[ns]
 1   dosen_kumulativ                   234 non-null    int64         
 2   dosen_differenz_zum_vortag        234 non-null    int64         
 3   dosen_erst_differenz_zum_vortag   234 non-null    int64         
 4   dosen_zweit_differenz_zum_vortag  234 non-null    int64         
 5   dosen_biontech_kumulativ          234 non-null    int64         
 6   dosen_moderna_kumulativ           234 non-null    int64         
 7   dosen_astrazeneca_kumulativ       234 non-null    int64         
 8   personen_erst_kumulativ           234 non-null    int64         
 9   personen_voll_kumulativ           234 non-null    int64         
 10  dosen_dim_kumulativ               234 non-null    int64         
 11  dosen_kbv_kumulativ               234 non-null    int64         
 12  dosen_johnson_kumulativ           234 non-null    int64         
 13  dosen_erst_kumulativ              234 non-null    int64         
 14  dosen_zweit_kumulativ             234 non-null    int64         
dtypes: datetime64[ns](1), int64(14)
memory usage: 27.5 KB
```

In [13]:
```python
vaccinations.tail(3)
```

Out[13]:

	date	dosen_kumulativ	dosen_differenz_zum_vortag	dosen_erst_differenz_zum_vortag	dosen_zweit_differenz_zum_vortag	dosen_biontech_kumulati
231	2021-08-15	97673447	116441	30137	86304	7344929
232	2021-08-16	97931054	257607	66621	190986	7365927
233	2021-08-17	98274623	343569	92496	251073	7395622

Check Validity

In [14]:
```python
# get the last row / the newest available data
last_row = vaccinations.tail(1)
```

In [15]:
```python
doses_used = last_row['dosen_kumulativ']
doses_used
```

```
Out[15]: 233    98274623
         Name: dosen_kumulativ, dtype: int64
```

```
In [16]: # The number of person having been vaccinated at least once, includes those fully vaccinated
         at_least_once = last_row['personen_erst_kumulativ']
         fully_vaccinated_people = last_row['personen_voll_kumulativ']
         partially_vaccinated_people = at_least_once - fully_vaccinated_people
         # The johnson & Johnson vaccine is the only one used in Germany that only needs a single shot:
         johnson_doses = last_row['dosen_johnson_kumulativ']
```

```
In [17]: # Must be exactly 0
         doses_used - partially_vaccinated_people - (fully_vaccinated_people - johnson_doses) * 2 - johnson_doses ==  0
```

```
Out[17]: 233    True
         dtype: bool
```

Calculate columns

```
In [18]: vaccinations['partly vaccinated'] = round(
             (vaccinations['personen_erst_kumulativ'] - vaccinations['personen_voll_kumulativ']) * 100 / population_germany,
             2)
```

```
In [19]: vaccinations['fully vaccinated'] = round(
             vaccinations['personen_voll_kumulativ'] * 100 / population_germany,
             2)
```

```
In [20]: vaccinations.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 234 entries, 0 to 233
Data columns (total 17 columns):
 #   Column                             Non-Null Count  Dtype
---  ------                             --------------  -----
 0   date                               234 non-null    datetime64[ns]
 1   dosen_kumulativ                    234 non-null    int64
 2   dosen_differenz_zum_vortag         234 non-null    int64
 3   dosen_erst_differenz_zum_vortag    234 non-null    int64
 4   dosen_zweit_differenz_zum_vortag   234 non-null    int64
 5   dosen_biontech_kumulativ           234 non-null    int64
 6   dosen_moderna_kumulativ            234 non-null    int64
 7   dosen_astrazeneca_kumulativ        234 non-null    int64
 8   personen_erst_kumulativ            234 non-null    int64
 9   personen_voll_kumulativ            234 non-null    int64
 10  dosen_dim_kumulativ                234 non-null    int64
 11  dosen_kbv_kumulativ                  234 non-null    int64
 12  dosen_johnson_kumulativ              234 non-null    int64
 13  dosen_erst_kumulativ                 234 non-null    int64
 14  dosen_zweit_kumulativ                234 non-null    int64
 15  partly vaccinated                    234 non-null    float64
 16  fully vaccinated                     234 non-null    float64
dtypes: datetime64[ns](1), float64(2), int64(14)
memory usage: 31.2 KB
```

In [21]:
```
vaccinations.tail(3)
```

Out[21]:

	date	dosen_kumulativ	dosen_differenz_zum_vortag	dosen_erst_differenz_zum_vortag	dosen_zweit_differenz_zum_vortag	dosen_biontech_kumulati
231	2021-08-15	97673447	116441	30137	86304	7344929
232	2021-08-16	97931054	257607	66621	190986	7365927
233	2021-08-17	98274623	343569	92496	251073	7395622

Last Update

Often the data is not updated on weekends, so get the highest date in the dataset.

In [22]:
```
last_update = vaccinations.loc[vaccinations.index[-1], "date"].strftime('%Y-%m-%d')
last_update
```

Out[22]:
```
'2021-08-17'
```

Doses Used

In [23]:
```
doses = vaccinations.loc[ : , ['date', 'dosen_differenz_zum_vortag']]
# Rename columns
doses.columns = ['date', 'doses used']
```

In [24]:
```
# Scale number of doses as millions
doses['doses used'] = doses['doses used'] / 1_000_000
```

Doses Daily

In [25]:
```
doses_daily = doses.set_index('date', inplace=False)
doses_daily.tail(1)
```

Out[25]:

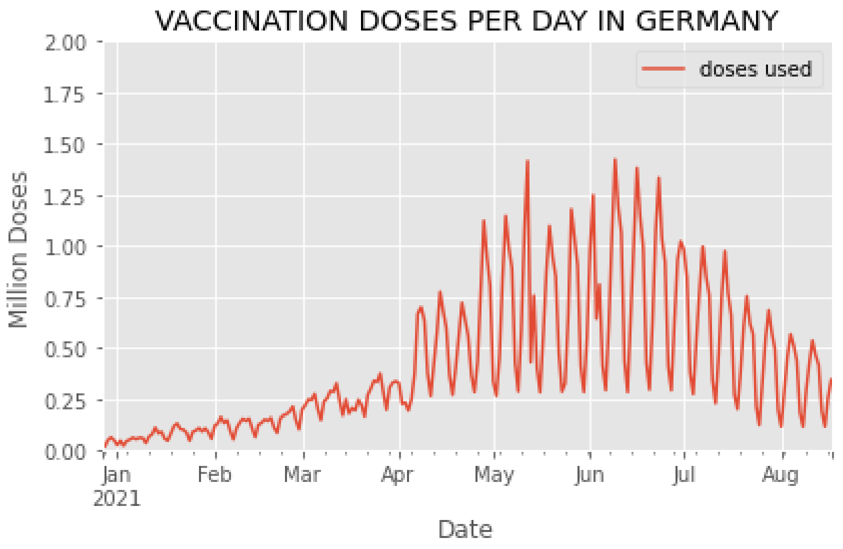
	doses used
date	
2021-08-17	0.343569

In [26]:
```
# What is the highest number of doses used in a day?
max_doses_daily = max(doses_daily['doses used'])
max_doses_daily
```

Out[26]:
```
1.423719
```

In [27]:
```
doses_daily.plot(
    ylim=(0,math.ceil(max_doses_daily)),
    xlabel='Date',
    ylabel='Million Doses',
    title='VACCINATION DOSES PER DAY IN GERMANY')
```

Out[27]:
```
<AxesSubplot:title={'center':'VACCINATION DOSES PER DAY IN GERMANY'}, xlabel='Date', ylabel='Million Doses'>
```



Doses per Weekday (in the last 6 weeks)

In [28]:
```
last_6_weeks = doses.tail(42)
```

In [29]:
```
# Yields a warning, but exactly like the docs prescribe and it works
# https://pandas.pydata.org/docs/getting_started/intro_tutorials/05_add_columns.html
last_6_weeks['weekday'] = last_6_weeks['date'].dt.day_name()
```

```
<ipython-input-29-45013977109e>:3: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stable/user_guide/indexing.html#returning-a
-view-versus-a-copy
  last_6_weeks['weekday'] = last_6_weeks['date'].dt.day_name()
```

In [30]:
```
# check:
last_6_weeks.tail(3)
```

Out[30]:

	date	doses used	weekday
231	2021-08-15	0.116441	Sunday
232	2021-08-16	0.257607	Monday
233	2021-08-17	0.343569	Tuesday

In [31]:
```
# drop the date column
last_6_weeks = last_6_weeks.drop(labels=['date'], axis=1)
```

In [32]:
```
#last_6_weeks.set_index('weekday', inplace=True)
last_6_weeks.tail(3)
```

Out[32]:

	doses used	weekday
231	0.116441	Sunday
232	0.257607	Monday
233	0.343569	Tuesday

In [33]:
```
pivot_table =last_6_weeks.pivot(columns='weekday', values='doses used')
pivot_table.tail()
```

Out[33]:

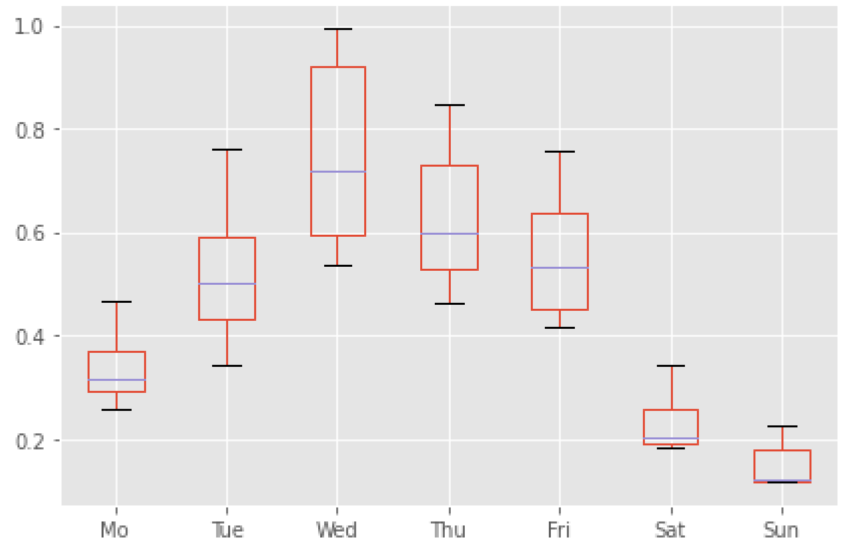
weekday	Friday	Monday	Saturday	Sunday	Thursday	Tuesday	Wednesday
229	0.416032	NaN	NaN	NaN	NaN	NaN	NaN
230	NaN	NaN	0.189281	NaN	NaN	NaN	NaN
231	NaN	NaN	NaN	0.116441	NaN	NaN	NaN
232	NaN	0.257607	NaN	NaN	NaN	NaN	NaN
233	NaN	NaN	NaN	NaN	NaN	0.343569	NaN

In [34]:
```
# Reorder the columns
pivot_table = pivot_table[['Monday', 'Tuesday', 'Wednesday', 'Thursday', 'Friday', 'Saturday', 'Sunday']]
# Rename the columns
pivot_table.columns=['Mo', 'Tue', 'Wed', 'Thu', 'Fri', 'Sat', 'Sun']
pivot_table.tail()
```

Out[34]:

	Mo	Tue	Wed	Thu	Fri	Sat	Sun
229	NaN	NaN	NaN	NaN	0.416032	NaN	NaN
230	NaN	NaN	NaN	NaN	NaN	0.189281	NaN
231	NaN	NaN	NaN	NaN	NaN	NaN	0.116441
232	0.257607	NaN	NaN	NaN	NaN	NaN	NaN
233	NaN	0.343569	NaN	NaN	NaN	NaN	NaN

In [35]:
```
weekday_boxplot = pivot_table.boxplot()
```



In [36]:
```
fig = weekday_boxplot.get_figure()
fig.savefig('img/weekday_boxplot.png')
```

Doses per Week

In [37]:
```
# W-Mon in order to start the week on a Monday, see:
# https://pandas.pydata.org/pandas-docs/stable/user_guide/timeseries.html#anchored-offsets
doses_weekly = doses.groupby(pd.Grouper(key='date',freq='W-Mon')).sum()
doses_weekly.columns = ['million doses used']
doses_weekly.tail()
```

Out[37]:

	million doses used
date	
2021-07-26	3.217374
2021-08-02	2.902226
2021-08-09	2.564355
2021-08-16	2.404726
2021-08-23	0.343569

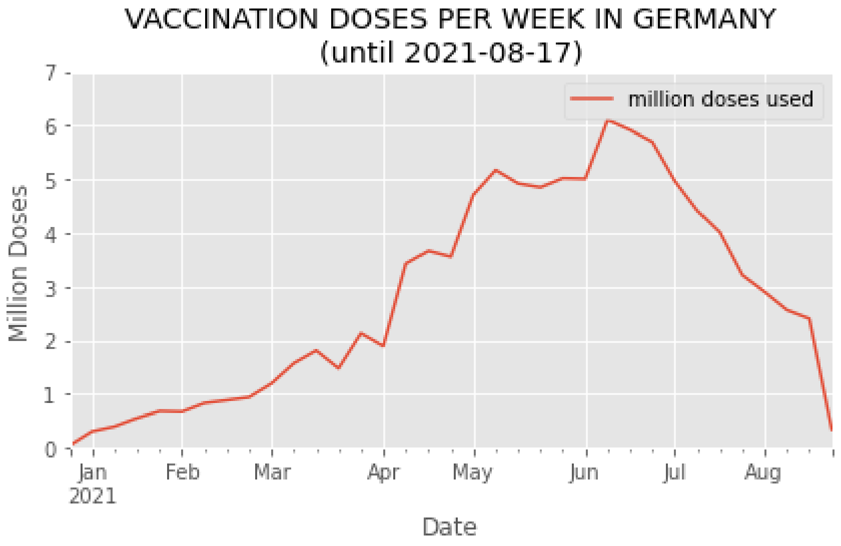
In [38]:
```
# What is the highest number of doses used in a week?
```

```
max_million_doses_weekly = max(doses_weekly['million doses used'])
max_million_doses_weekly
```

Out[38]:
```
6.1052589999999999
```

In [39]:
```
doses_weekly.plot(
    ylim=(0, math.ceil(max_million_doses_weekly)),
    xlabel='Date',
    ylabel='Million Doses',
    title=f"VACCINATION DOSES PER WEEK IN GERMANY\n(until {last_update})")
```

Out[39]:
```
<AxesSubplot:title={'center':'VACCINATION DOSES PER WEEK IN GERMANY\n(until 2021-08-17)'}, xlabel='Date', ylabel='Milli
on Doses'>
```



Doses per Month

In [40]:
```
# M = month end frequency
doses_monthly = doses.groupby(pd.Grouper(key='date',freq='M')).sum()
doses_monthly.tail()
```

Out[40]:

	doses used
date	
2021-04-30	15.536267

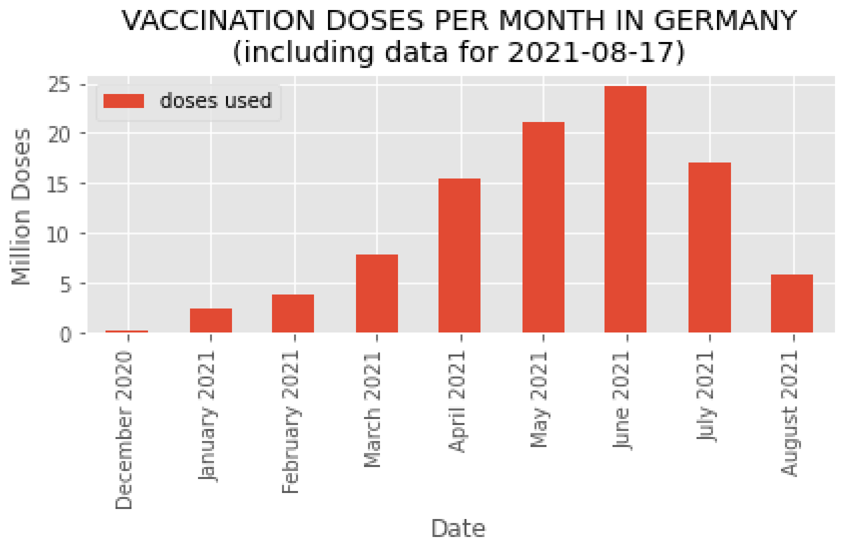
	doses used
date	
2021-05-31	21.023793
2021-06-30	24.685328
2021-07-31	17.159936
2021-08-31	5.720023

In [41]:
```
max_doses_monthly = max(doses_monthly['doses used'])
max_doses_monthly
doses_monthly['month'] = doses_monthly.index.strftime('%B')
doses_monthly['year'] =  doses_monthly.index.strftime('%Y')
doses_monthly['label'] = doses_monthly['month'] + ' ' + doses_monthly['year']
doses_monthly.drop(columns=['month', 'year'], inplace=True)
doses_monthly.set_index('label', inplace=True)
doses_monthly.tail(6)
```

Out[41]:

	doses used
label	
March 2021	7.850834
April 2021	15.536267
May 2021	21.023793
June 2021	24.685328
July 2021	17.159936
August 2021	5.720023

In [42]:
```
monthly_plot = doses_monthly.plot.bar(
    ylim=(0,math.ceil(max_doses_monthly) + 1),
    xlabel='Date',
    ylabel='Million Doses',
    title=f"VACCINATION DOSES PER MONTH IN GERMANY\n(including data for {last_update})")
```



In [43]:
```
fig = monthly_plot.get_figure()
fig.savefig('img/monthly_doses_germany.png')
```

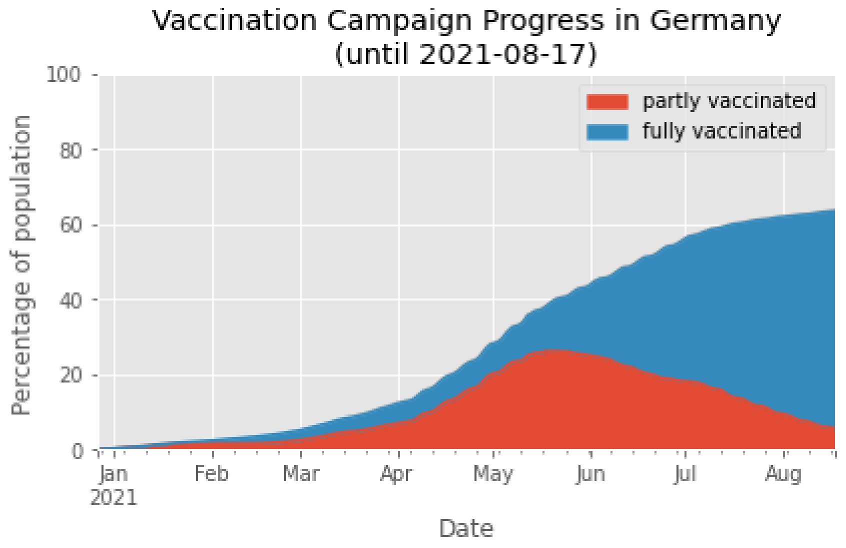
Vaccination Campaign Progress

In [44]:
```
doses_cumulative = vaccinations.loc[ : , ['date', 'partly vaccinated', 'fully vaccinated']]
doses_cumulative.set_index('date', inplace=True)
doses_cumulative.tail(3)
```

Out[44]:

	partly vaccinated	fully vaccinated
date		
2021-08-15	5.95	57.29
2021-08-16	5.82	57.52
2021-08-17	5.64	57.82

In [45]:
```
doses_area_plot = doses_cumulative.plot.area(
    ylim=(0,100),
    xlabel='Date',
    ylabel='Percentage of population',
    title=f"Vaccination Campaign Progress in Germany\n(until {last_update})")
```



```
In [46]: fig = doses_area_plot.get_figure()
         fig.savefig('img/vaccinations_germany_area_plot.png')
```

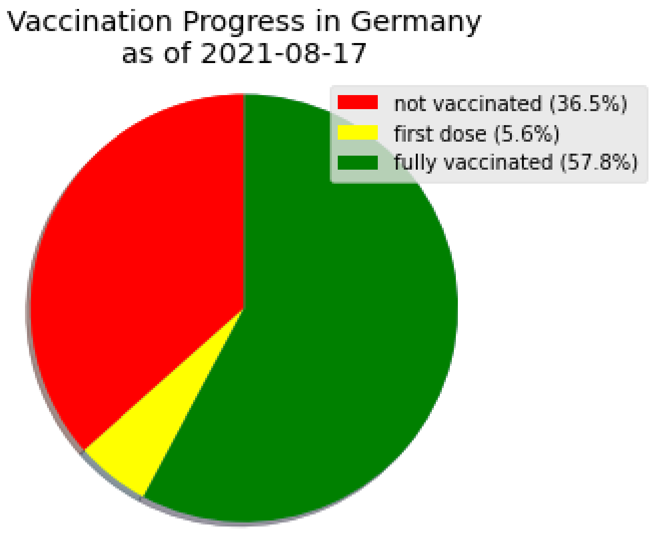
As of Today

```
In [47]: # get the last line of the data
         current_state = doses_cumulative.iloc[-1]
         current_state
```

```
Out[47]: partly vaccinated     5.64
         fully vaccinated     57.82
         Name: 2021-08-17 00:00:00, dtype: float64
```

```
In [48]: percentage_not_vacc = 100 - current_state['partly vaccinated'] - current_state['fully vaccinated']
         labels = [f"not vaccinated ({round(percentage_not_vacc, 1)}%)",
                   f"first dose ({round(current_state['partly vaccinated'], 1)}%)",
                   f"fully vaccinated ({round(current_state['fully vaccinated'], 1)}%)"]
         colors = ['red', 'yellow', 'green']
         sizes = [percentage_not_vacc,
                  current_state['partly vaccinated'],
                  current_state['fully vaccinated']]
         fig1, ax1 = plt.subplots()
         ax1.pie(sizes, shadow=True, startangle=90)
         ax1.axis('equal')  # Equal aspect ratio ensures that pie is drawn as a circle.
         patches, texts = plt.pie(sizes, colors=colors, startangle=90)
```

```
plt.legend(patches, labels, loc="best")
plt.title(f"Vaccination Progress in Germany\nas of {last_update}")
# plt.savefig must be before show()
# BEWARE plt.savefig must be in the same Jupyter code cell that creates the graph!
# See comment by ijoseph here:
# https://stackoverflow.com/questions/9012487/matplotlib-pyplot-savefig-outputs-blank-image
plt.savefig('img/vaccination_in_germany_pie.png', bbox_inches='tight')
plt.show()
```



Vaccines in Use

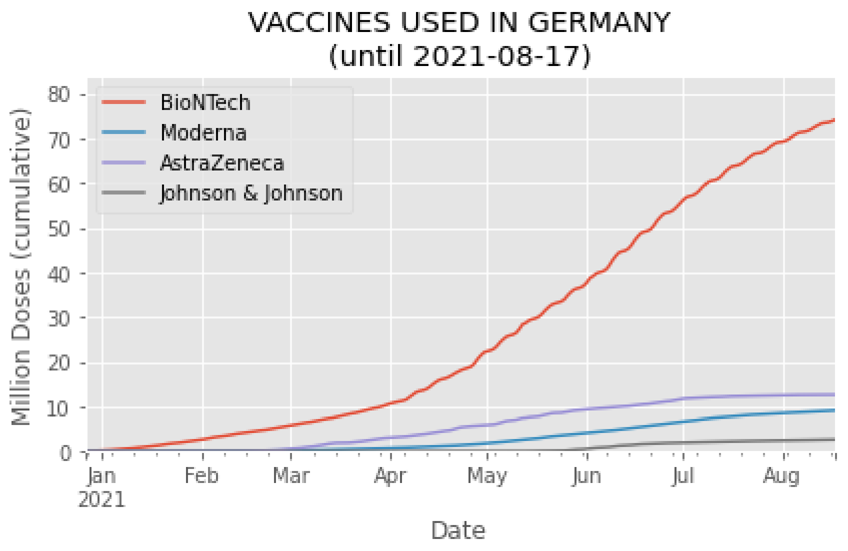
In [49]:
```
vaccine_use = vaccinations.loc[ : , ['date', 'dosen_biontech_kumulativ',
                                     'dosen_moderna_kumulativ',
                                     'dosen_astrazeneca_kumulativ',
                                     'dosen_johnson_kumulativ']]
# Rename columns
vaccine_use.columns = ['date', 'BioNTech', 'Moderna', 'AstraZeneca', 'Johnson & Johnson']
# make 'date' an index
vaccine_use.set_index('date', inplace=True)
# divide columns by 1 million
vaccine_use["BioNTech"] = vaccine_use["BioNTech"] / 1_000_000
vaccine_use["Moderna"] = vaccine_use["Moderna"] / 1_000_000
vaccine_use["AstraZeneca"] = vaccine_use["AstraZeneca"] / 1_000_000
vaccine_use["Johnson & Johnson"] = vaccine_use["Johnson & Johnson"] / 1_000_000
vaccine_use.tail(3)
```

Out[49]:

date	BioNTech	Moderna	AstraZeneca	Johnson & Johnson
2021-08-15	73.449294	9.025107	12.586965	2.612081
2021-08-16	73.659276	9.057455	12.589790	2.624533
2021-08-17	73.956227	9.085183	12.595520	2.637693

In [50]:

```
vaccines_used = vaccine_use.plot(
    # as it is cumulative, the last row must contain the single highest number
    ylim=(0,math.ceil(max(vaccine_use.iloc[-1]))+10),
    xlabel='Date',
    ylabel='Million Doses (cumulative)',
    title=f"VACCINES USED IN GERMANY\n(until {last_update})")
```



In [51]:

```
fig = vaccines_used.get_figure()
fig.savefig('img/vaccines_used_in_germany.png')
```

Vaccination Centers versus Doctor’s Practices

In [52]:

```
by_place = vaccinations.loc[ : , ['date', 'dosen_dim_kumulativ', 'dosen_kbv_kumulativ']]
```

```
by_place.columns = ['date', 'vaccination centers', 'practices']
```

In [53]:
```
by_place['vaccination centers daily'] = by_place['vaccination centers'].diff()
by_place['practices daily'] = by_place['practices'].diff()
```

In [54]:
```
by_place['percentage practices'] =  round(
    by_place['practices daily'] * 100 /
    (by_place['vaccination centers daily'] + by_place['practices daily']), 2)

by_place['percentage centers'] = 100 - by_place['percentage practices']
```

In [55]:
```
# make 'date' an index
by_place.set_index('date', inplace=True)
```

In [56]:
```
by_place
```

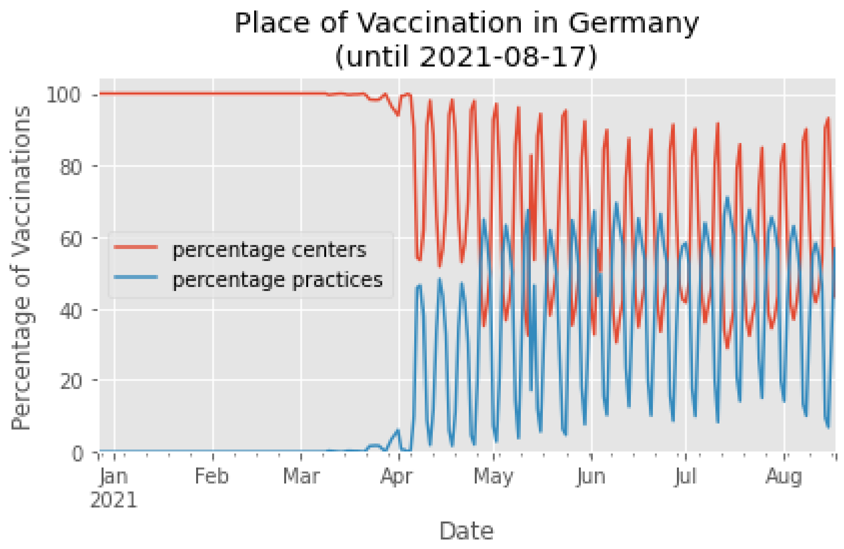
Out[56]:

	vaccination centers	practices	vaccination centers daily	practices daily	percentage practices	percentage centers
date						
2020-12-27	24088	0	NaN	NaN	NaN	NaN
2020-12-28	42079	0	17991.0	0.0	0.00	100.00
2020-12-29	92088	0	50009.0	0.0	0.00	100.00
2020-12-30	155585	0	63497.0	0.0	0.00	100.00
2020-12-31	205276	0	49691.0	0.0	0.00	100.00
...	...	...	...	...	...	...
2021-08-13	57938964	39251353	222054.0	192389.0	46.42	53.58
2021-08-14	58109214	39269532	170250.0	18179.0	9.65	90.35
2021-08-15	58217468	39277544	108254.0	8012.0	6.89	93.11
2021-08-16	58389803	39361152	172335.0	83608.0	32.67	67.33
2021-08-17	58537885	39554693	148082.0	193541.0	56.65	43.35

234 rows × 6 columns

In [57]:
```
share = by_place.loc[ : , ['percentage centers', 'percentage practices']]
```

In [58]:
```
vacc_shares = share.plot(
    # as it is cumulative, the last row must contain the single highest number
    ylim=(0, 105),  # above 100 to see the line
    xlabel='Date',
    ylabel='Percentage of Vaccinations',
    title=f"Place of Vaccination in Germany\n(until {last_update})")
```



In [59]:
```
fig = vacc_shares.get_figure()
fig.savefig('img/vaccinations_germany_by_place.png')
```

Other units of Time

In [60]:
```
by_place_daily = by_place.loc[ : , ['vaccination centers daily', 'practices daily']]
by_place_daily.columns = ['vaccination centers', 'practices']
by_place_daily.reset_index(inplace=True)
```

Monthly

In [61]:
```
by_place_monthly = by_place_daily.groupby(pd.Grouper(key='date',freq='M')).sum()
by_place_monthly.tail()
```

Out[61]:

	vaccination centers	practices
date		

	vaccination centers	practices
date		
2021-04-30	10207127.0	5329140.0
2021-05-31	11540205.0	9483588.0
2021-06-30	11803744.0	12819000.0
2021-07-31	7913038.0	9158395.0
2021-08-31	2990729.0	2698336.0

Scale:

In [62]:
```
by_place_monthly['vaccination centers'] = by_place_monthly['vaccination centers'] / 1_000_000
by_place_monthly['practices'] = by_place_monthly['practices'] / 1_000_000
```

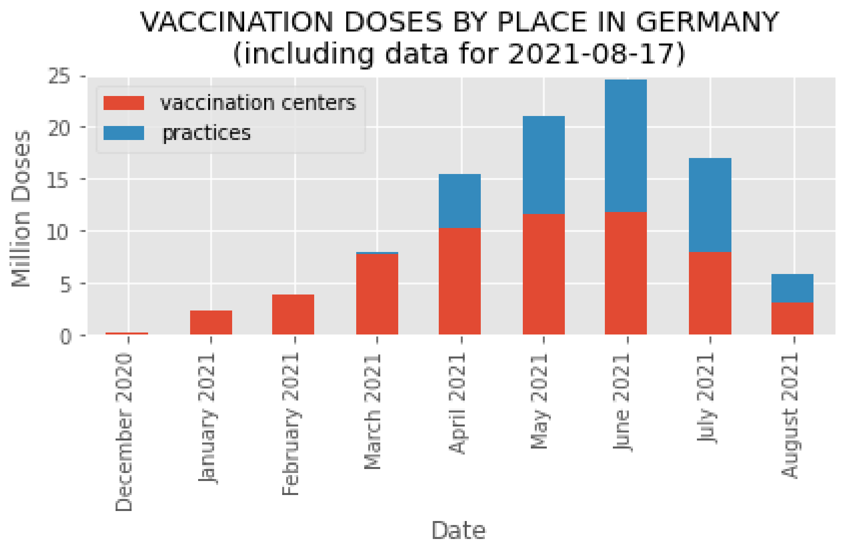
Rename the columns

In [63]:
```
by_place_monthly['month'] = by_place_monthly.index.strftime('%B')
by_place_monthly['year'] =  by_place_monthly.index.strftime('%Y')
by_place_monthly['label'] = by_place_monthly['month'] + ' ' + by_place_monthly['year']
by_place_monthly.drop(columns=['month', 'year'], inplace=True)
by_place_monthly.set_index('label', inplace=True)
by_place_monthly.tail(6)
```

Out[63]:

	vaccination centers	practices
label		
March 2021	7.784600	0.066234
April 2021	10.207127	5.329140
May 2021	11.540205	9.483588
June 2021	11.803744	12.819000
July 2021	7.913038	9.158395
August 2021	2.990729	2.698336

In [64]:
```
monthly_plot = by_place_monthly.plot.bar(
    stacked=True,
    ylim=(0, 25),
    xlabel='Date',
    ylabel='Million Doses',
    title=f"VACCINATION DOSES BY PLACE IN GERMANY\n(including data for {last_update})")
```



```
In [65]: fig = monthly_plot.get_figure()
         fig.savefig('img/monthly_doses_by_place_germany.png')
```