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]:
```
'2021-06-07'
```

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: 162 entries, 0 to 161
Data columns (total 15 columns):
 #   Column                          Non-Null Count  Dtype         
---  ------                          --------------  -----         
 0   date                            162 non-null    datetime64[ns]
 1   dosen_kumulativ                 162 non-null    int64         
 2   dosen_differenz_zum_vortag      162 non-null    int64         
 3   dosen_erst_differenz_zum_vortag  162 non-null    int64         
 4   dosen_zweit_differenz_zum_vortag  162 non-null    int64         
 5   dosen_biontech_kumulativ        162 non-null    int64         
 6   dosen_moderna_kumulativ         162 non-null    int64         
 7   dosen_astrazeneca_kumulativ     162 non-null    int64         
 8   personen_erst_kumulativ         162 non-null    int64         
 9   personen_voll_kumulativ         162 non-null    int64         
 10  dosen_dim_kumulativ             162 non-null    int64         
 11  dosen_kbv_kumulativ             162 non-null    int64         
 12  dosen_johnson_kumulativ         162 non-null    int64         
 13  dosen_erst_kumulativ            162 non-null    int64         
 14  dosen_zweit_kumulativ           162 non-null    int64         
dtypes: datetime64[ns](1), int64(14)
memory usage: 19.1 KB
```

In [13]:
```
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
159	2021-06-04	54247601	783545	291705	491840	3966191
160	2021-06-05	54631777	384176	97460	286716	3991619
161	2021-06-06	54905132	273355	60488	212867	4011194

Check Validity

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

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

```
Out[15]: 161    54905132
         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]: 161    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: 162 entries, 0 to 161
Data columns (total 17 columns):
 #   Column                          Non-Null Count  Dtype
---  ------                          --------------  -----
 0   date                            162 non-null    datetime64[ns]
 1   dosen_kumulativ                 162 non-null    int64
 2   dosen_differenz_zum_vortag      162 non-null    int64
 3   dosen_erst_differenz_zum_vortag 162 non-null    int64
 4   dosen_zweit_differenz_zum_vortag 162 non-null   int64
 5   dosen_biontech_kumulativ        162 non-null    int64
 6   dosen_moderna_kumulativ         162 non-null    int64
 7   dosen_astrazeneca_kumulativ     162 non-null    int64
 8   personen_erst_kumulativ         162 non-null    int64
 9   personen_voll_kumulativ         162 non-null    int64
 10  dosen_dim_kumulativ             162 non-null    int64
 11  dosen_kbv_kumulativ               162 non-null    int64
 12  dosen_johnson_kumulativ           162 non-null    int64
 13  dosen_erst_kumulativ              162 non-null    int64
 14  dosen_zweit_kumulativ             162 non-null    int64
 15  partly vaccinated                 162 non-null    float64
 16  fully vaccinated                  162 non-null    float64
dtypes: datetime64[ns](1), float64(2), int64(14)
memory usage: 21.6 KB
```

In [21]:
```python
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
159	2021-06-04	54247601	783545	291705	491840	3966191
160	2021-06-05	54631777	384176	97460	286716	3991619
161	2021-06-06	54905132	273355	60488	212867	4011194

Last Update

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

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

Out[22]:
```
'2021-06-06'
```

Doses Used

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

In [24]:
```python
# 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]:

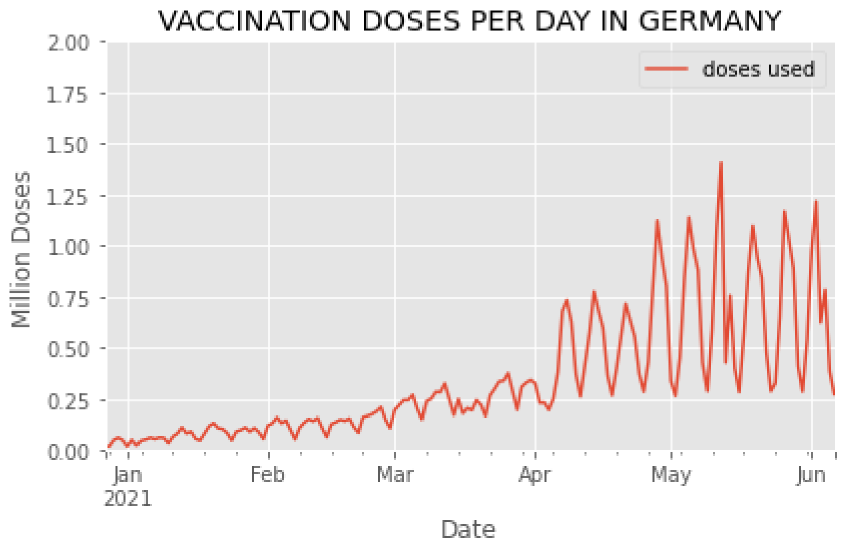
	doses used
date	
2021-06-06	0.273355

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]:
```
1.407901
```

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
159	2021-06-04	0.783545	Friday
160	2021-06-05	0.384176	Saturday
161	2021-06-06	0.273355	Sunday

```
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
159	0.783545	Friday
160	0.384176	Saturday
161	0.273355	Sunday

```
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
157	NaN	NaN	NaN	NaN	NaN	NaN	1.216552
158	NaN	NaN	NaN	NaN	0.622989	NaN	NaN
159	0.783545	NaN	NaN	NaN	NaN	NaN	NaN
160	NaN	NaN	0.384176	NaN	NaN	NaN	NaN
161	NaN	NaN	NaN	0.273355	NaN	NaN	NaN

In [34]:

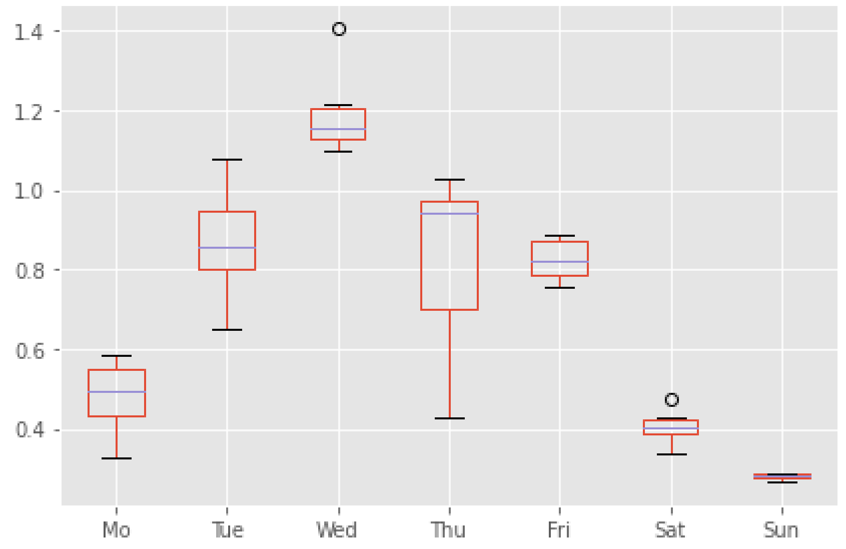
```
# Reorder the columns
pivot_table = pivot_table[['Monday', 'Tuesday', 'Wednesday', 'Thursday', 'Friday', 'Saturday', 'Sunday']]
# Rename the columns
pivot_table.columns=['Mo', 'Tue', 'Wed', 'Thu', 'Fri', 'Sat', 'Sun']
pivot_table.tail()
```

Out[34]:

	Mo	Tue	Wed	Thu	Fri	Sat	Sun
157	NaN	NaN	1.216552	NaN	NaN	NaN	NaN
158	NaN	NaN	NaN	0.622989	NaN	NaN	NaN
159	NaN	NaN	NaN	NaN	0.783545	NaN	NaN
160	NaN	NaN	NaN	NaN	NaN	0.384176	NaN
161	NaN	NaN	NaN	NaN	NaN	NaN	0.273355

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	
2021-05-10	5.144797
2021-05-17	4.905011
2021-05-24	4.844181
2021-05-31	4.963979
2021-06-07	4.253301

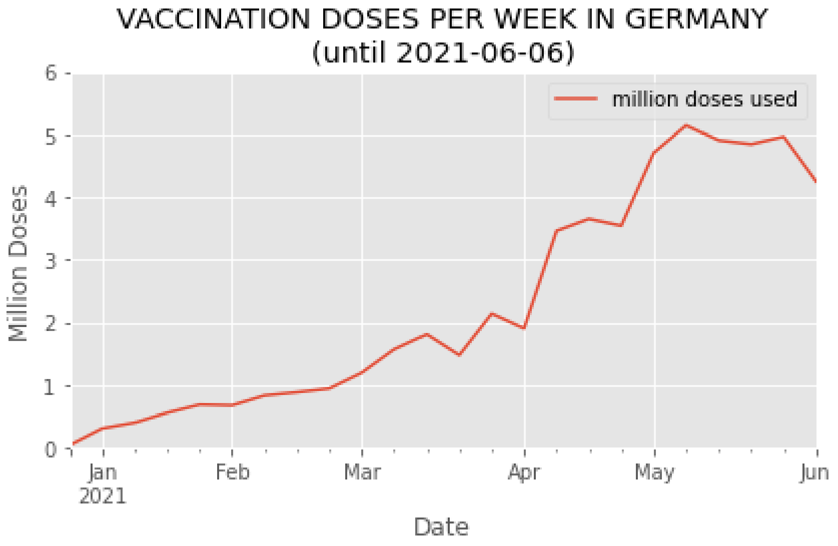
In [38]:
```
# What is the highest number of doses used in a week?
```

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

Out[38]:
```
5.1447970000000005
```

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 2021-06-06)'}, 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	
2021-02-28	3.780708

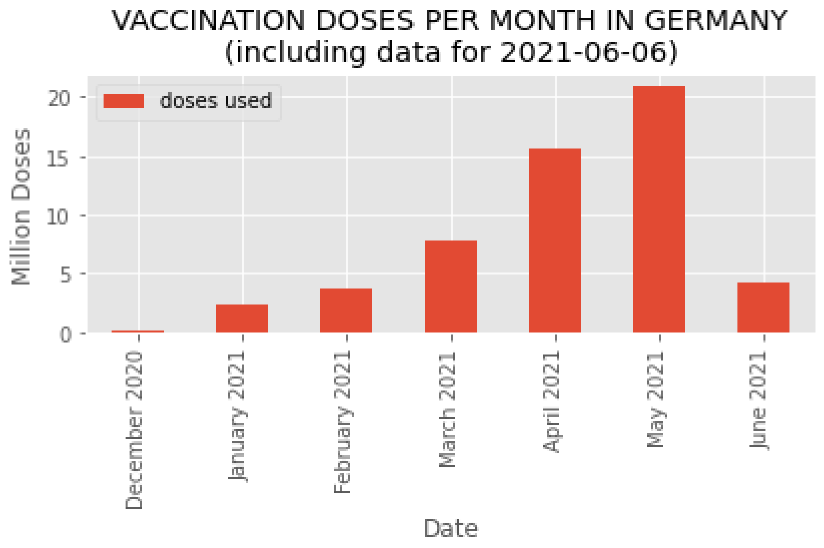
date	doses used
2021-03-31	7.859455
2021-04-30	15.548199
2021-05-31	20.910834
2021-06-30	4.253301

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]:

label	doses used
January 2021	2.345896
February 2021	3.780708
March 2021	7.859455
April 2021	15.548199
May 2021	20.910834
June 2021	4.253301

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')
```

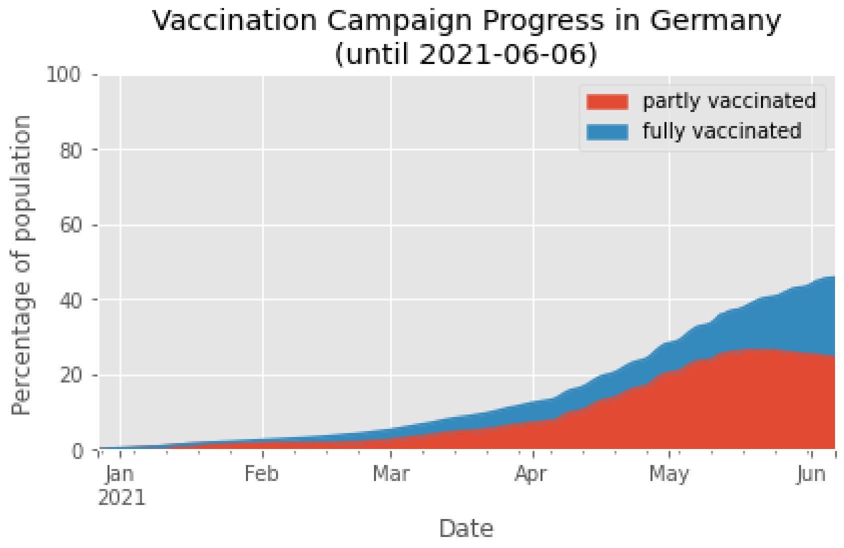
Vaccination Campaign Progress

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		
2021-06-04	24.70	20.73
2021-06-05	24.50	21.07
2021-06-06	24.34	21.33

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')
```

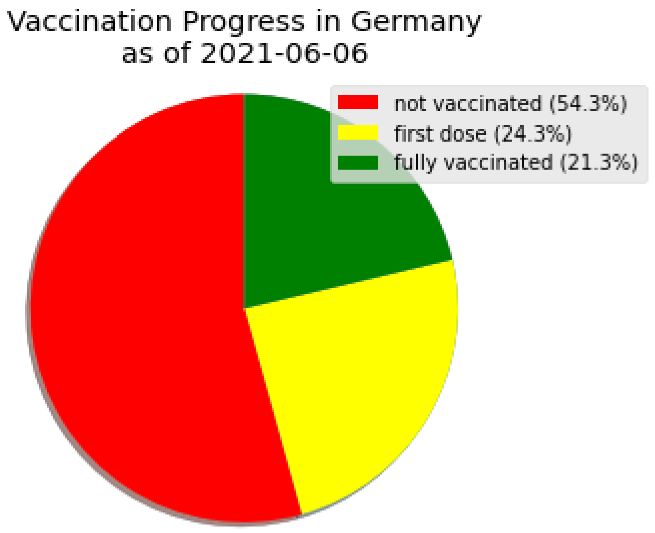
As of Today

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

Out[47]:
```
partly vaccinated    24.34
fully vaccinated     21.33
Name: 2021-06-06 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

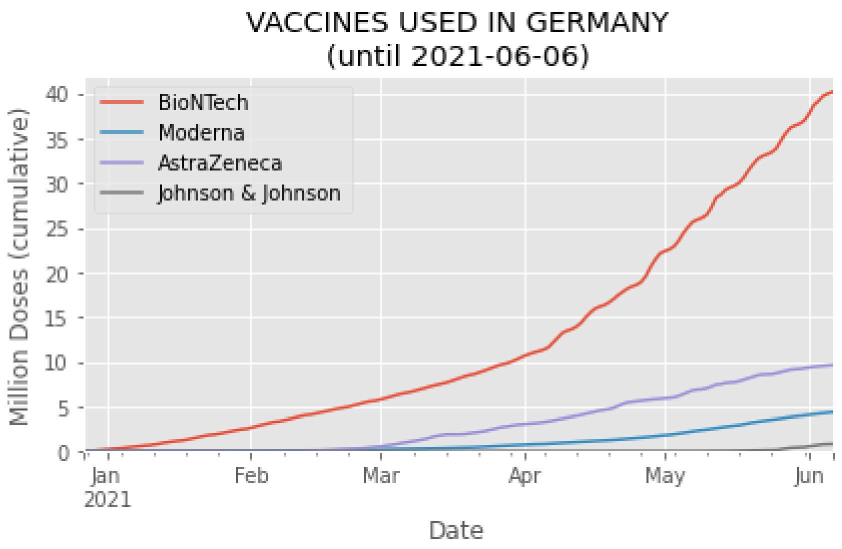
In [49]:

```
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
2021-06-04	39.661915	4.259786	9.534624	0.791276
2021-06-05	39.916197	4.322184	9.576270	0.817126
2021-06-06	40.111941	4.359839	9.602207	0.831145

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]))+1),
    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
```

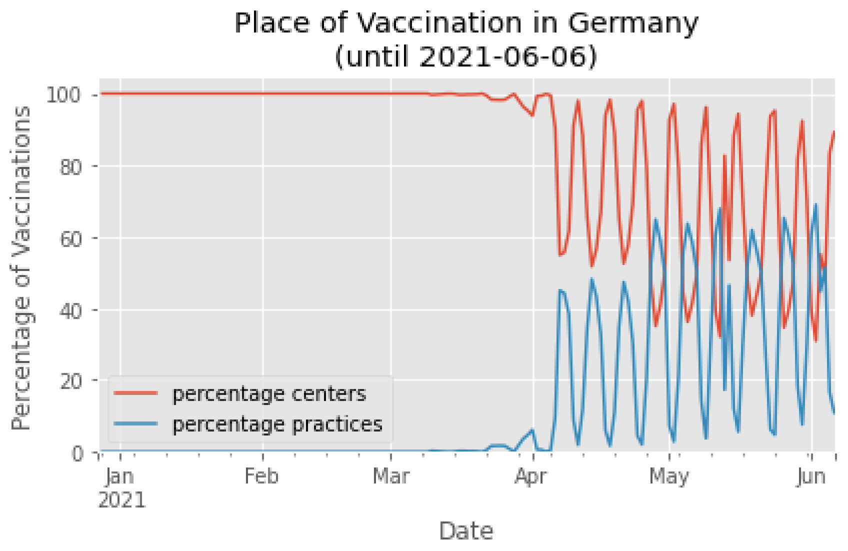
Out[56]:

	vaccination centers	practices	vaccination centers daily	practices daily	percentage practices	percentage centers
date						
2020-12-27	24101	0	NaN	NaN	NaN	NaN
2020-12-28	42657	0	18556.0	0.0	0.00	100.00
2020-12-29	93509	0	50852.0	0.0	0.00	100.00
2020-12-30	156539	0	63030.0	0.0	0.00	100.00
2020-12-31	206739	0	50200.0	0.0	0.00	100.00
...	...	...	...	...	...	...
2021-06-02	36531354	16309713	376274.0	840278.0	69.07	30.93
2021-06-03	36874930	16589126	343576.0	279413.0	44.85	55.15
2021-06-04	37255987	16991614	381057.0	402488.0	51.37	48.63
2021-06-05	37576619	17055158	320632.0	63544.0	16.54	83.46
2021-06-06	37820265	17084867	243646.0	29709.0	10.87	89.13

162 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		
2021-02-28	3780708.0	0.0
2021-03-31	7793221.0	66234.0
2021-04-30	10219059.0	5329140.0
2021-05-31	11427246.0	9483588.0
2021-06-30	2047396.0	2205905.0

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
```

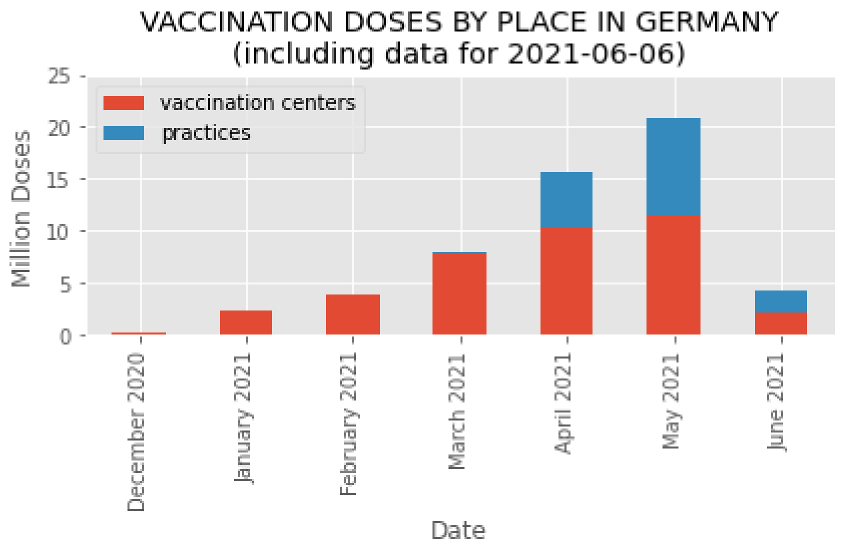
Rename the columns

```
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		
January 2021	2.345896	0.000000
February 2021	3.780708	0.000000
March 2021	7.793221	0.066234
April 2021	10.219059	5.329140
May 2021	11.427246	9.483588
June 2021	2.047396	2.205905

```
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')
```