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]:
```
'2021-06-12'
```

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: 167 entries, 0 to 166
Data columns (total 15 columns):
 #   Column                           Non-Null Count  Dtype
---  ------                           --------------  -----
 0   date                             167 non-null    datetime64[ns]
 1   dosen_kumulativ                  167 non-null    int64
 2   dosen_differenz_zum_vortag       167 non-null    int64
 3   dosen_erst_differenz_zum_vortag  167 non-null    int64
 4   dosen_zweit_differenz_zum_vortag 167 non-null    int64
 5   dosen_biontech_kumulativ         167 non-null    int64
 6   dosen_moderna_kumulativ          167 non-null    int64
 7   dosen_astrazeneca_kumulativ      167 non-null    int64
 8   personen_erst_kumulativ          167 non-null    int64
 9   personen_voll_kumulativ          167 non-null    int64
 10  dosen_dim_kumulativ              167 non-null    int64
 11  dosen_kbv_kumulativ              167 non-null    int64
 12  dosen_johnson_kumulativ          167 non-null    int64
 13  dosen_erst_kumulativ             167 non-null    int64
 14  dosen_zweit_kumulativ            167 non-null    int64
dtypes: datetime64[ns](1), int64(14)
memory usage: 19.7 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
164	2021-06-09	58022952	1328025	399662	928363	4250787
165	2021-06-10	59139933	1116981	351291	765690	4340211
166	2021-06-11	60105411	965478	316452	649026	441311

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]: 166    60105411
         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]: 166    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: 167 entries, 0 to 166
Data columns (total 17 columns):
 #   Column                            Non-Null Count  Dtype
---  ------                            --------------  -----
 0   date                              167 non-null    datetime64[ns]
 1   dosen_kumulativ                   167 non-null    int64
 2   dosen_differenz_zum_vortag        167 non-null    int64
 3   dosen_erst_differenz_zum_vortag   167 non-null    int64
 4   dosen_zweit_differenz_zum_vortag  167 non-null    int64
 5   dosen_biontech_kumulativ          167 non-null    int64
 6   dosen_moderna_kumulativ           167 non-null    int64
 7   dosen_astrazeneca_kumulativ       167 non-null    int64
 8   personen_erst_kumulativ           167 non-null    int64
 9   personen_voll_kumulativ           167 non-null    int64
 10  dosen_dim_kumulativ               167 non-null    int64
 11  dosen_kbv_kumulativ                 167 non-null    int64
 12  dosen_johnson_kumulativ             167 non-null    int64
 13  dosen_erst_kumulativ                167 non-null    int64
 14  dosen_zweit_kumulativ               167 non-null    int64
 15  partly vaccinated                   167 non-null    float64
 16  fully vaccinated                    167 non-null    float64
dtypes: datetime64[ns](1), float64(2), int64(14)
memory usage: 22.3 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
164	2021-06-09	58022952	1328025	399662	928363	4250787
165	2021-06-10	59139933	1116981	351291	765690	4340211
166	2021-06-11	60105411	965478	316452	649026	4413110

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]:
```
'2021-06-11'
```

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]:

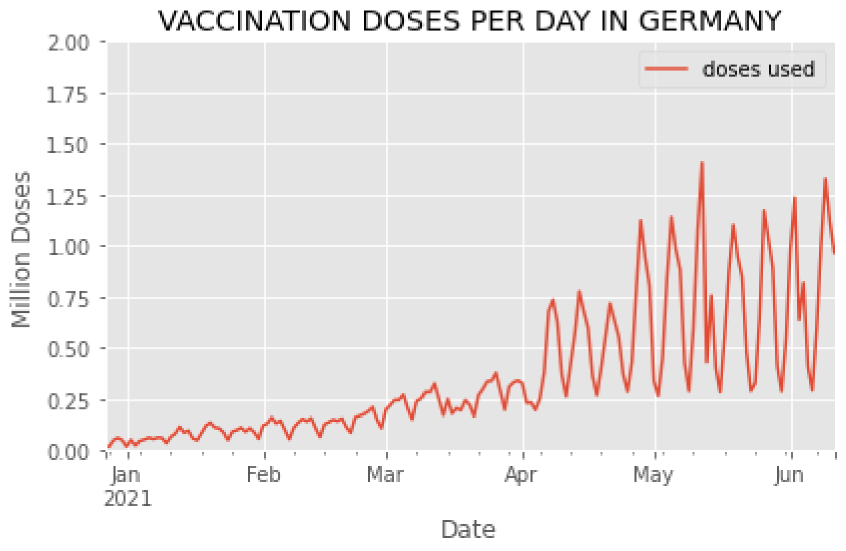
	doses used
date	
2021-06-11	0.965478

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]:
```
1.407423
```

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
164	2021-06-09	1.328025	Wednesday
165	2021-06-10	1.116981	Thursday
166	2021-06-11	0.965478	Friday

```
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
164	1.328025	Wednesday
165	1.116981	Thursday
166	0.965478	Friday

```
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
162	NaN	0.596145	NaN	NaN	NaN	NaN	NaN
163	NaN	NaN	NaN	NaN	NaN	1.007742	NaN
164	NaN	NaN	NaN	NaN	NaN	NaN	1.328025
165	NaN	NaN	NaN	NaN	1.116981	NaN	NaN
166	0.965478	NaN	NaN	NaN	NaN	NaN	NaN

In [34]:

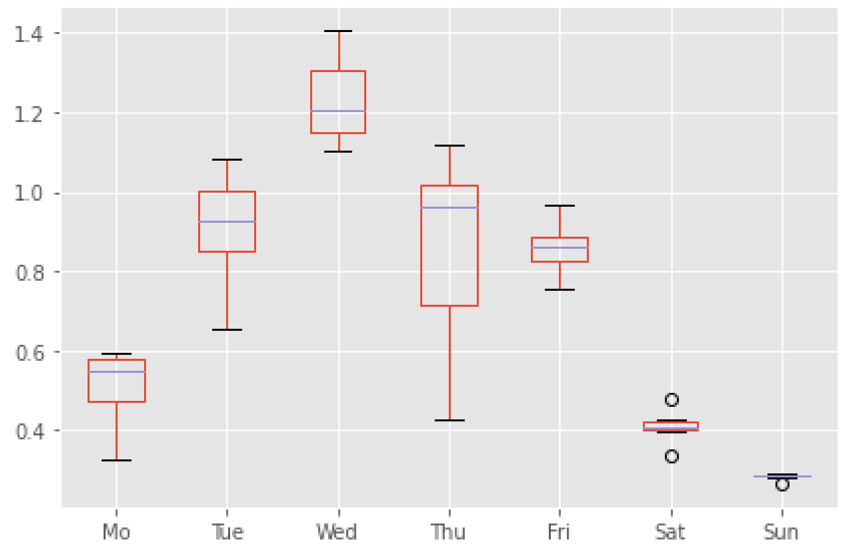
```
# Reorder the columns
pivot_table = pivot_table[['Monday', 'Tuesday', 'Wednesday', 'Thursday', 'Friday', 'Saturday', 'Sunday']]
# Rename the columns
pivot_table.columns=['Mo', 'Tue', 'Wed', 'Thu', 'Fri', 'Sat', 'Sun']
pivot_table.tail()
```

Out[34]:

	Mo	Tue	Wed	Thu	Fri	Sat	Sun
162	0.596145	NaN	NaN	NaN	NaN	NaN	NaN
163	NaN	1.007742	NaN	NaN	NaN	NaN	NaN
164	NaN	NaN	1.328025	NaN	NaN	NaN	NaN
165	NaN	NaN	NaN	1.116981	NaN	NaN	NaN
166	NaN	NaN	NaN	NaN	0.965478	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	
2021-05-17	4.908981
2021-05-24	4.862591
2021-05-31	4.987172
2021-06-07	4.963334
2021-06-14	4.418226

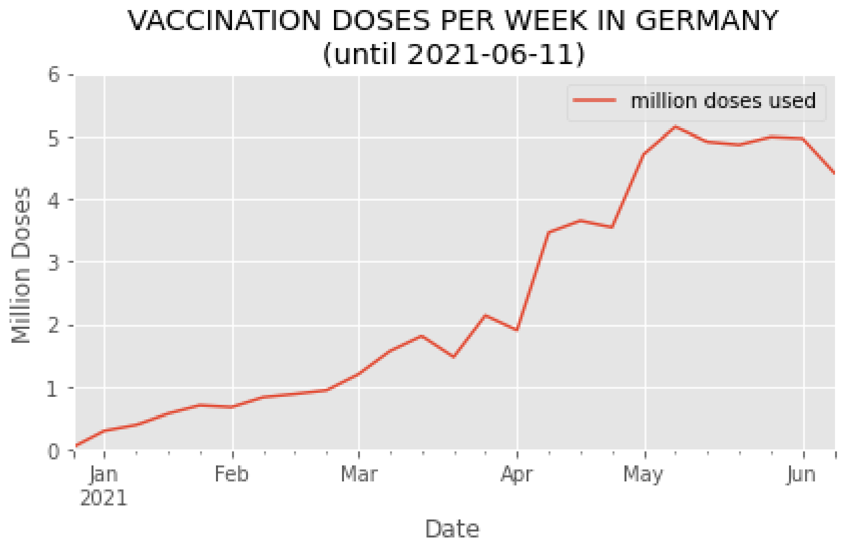
In [38]:
```
# What is the highest number of doses used in a week?
```

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

Out[38]:
```
5.147525
```

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 2021-06-11)'}, 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	3.778156

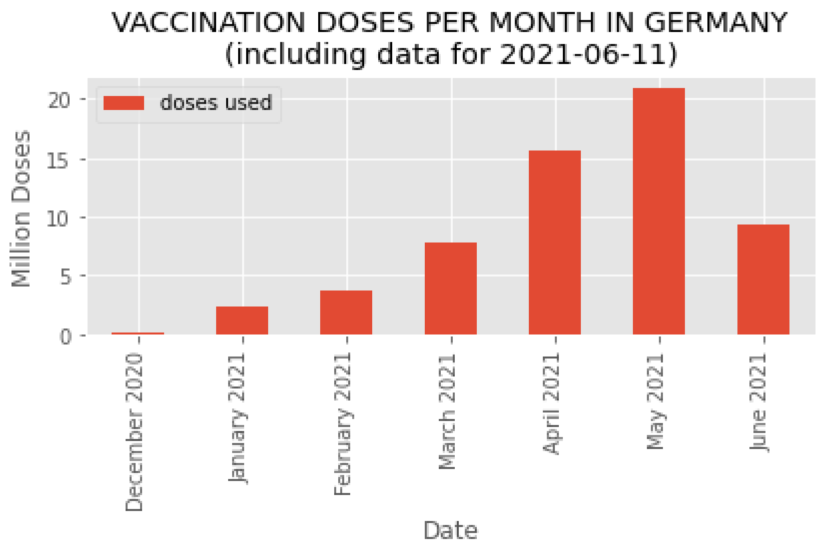
	doses used
date	
2021-03-31	7.856506
2021-04-30	15.555321
2021-05-31	20.960195
2021-06-30	9.381560

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	
January 2021	2.371644
February 2021	3.778156
March 2021	7.856506
April 2021	15.555321
May 2021	20.960195
June 2021	9.381560

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')
```

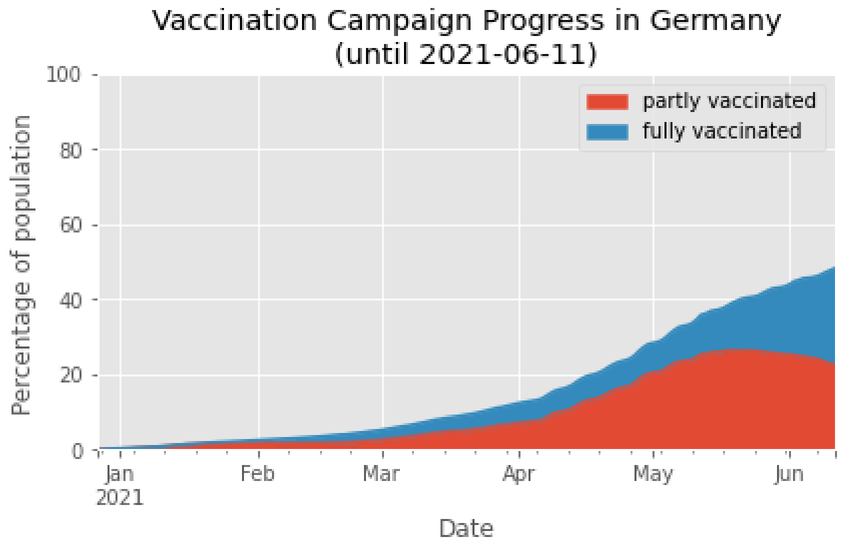
Vaccination Campaign Progress

```
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		
2021-06-09	23.10	23.96
2021-06-10	22.71	24.88
2021-06-11	22.42	25.66

```
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')
```

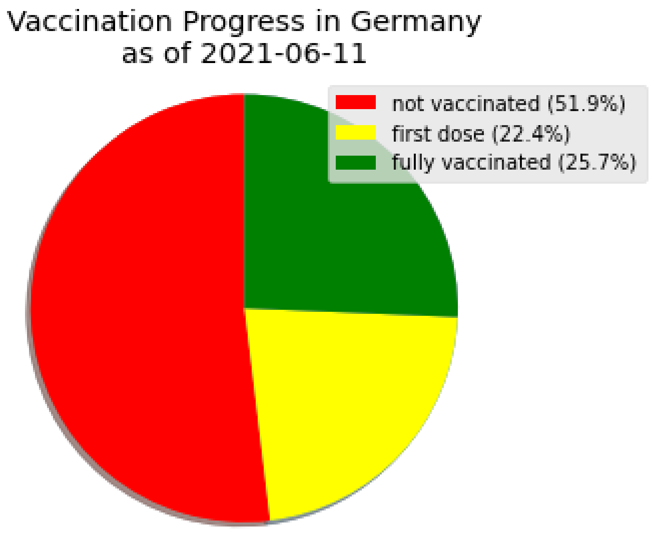
As of Today

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

```
Out[47]: partly vaccinated    22.42
         fully vaccinated     25.66
         Name: 2021-06-11 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()
```



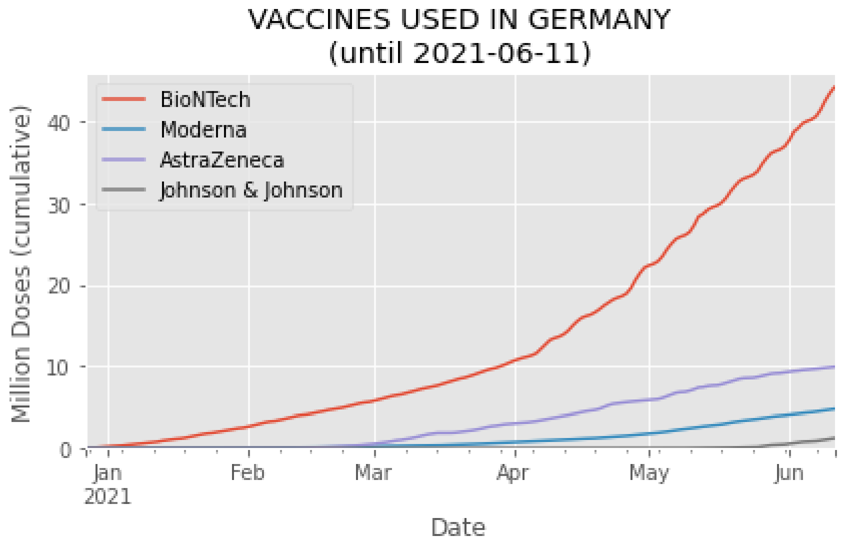
Vaccines in Use

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
2021-06-09	42.507875	4.632128	9.814362	1.068587
2021-06-10	43.402113	4.714156	9.868463	1.155201
2021-06-11	44.131106	4.795533	9.930483	1.248289

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
```

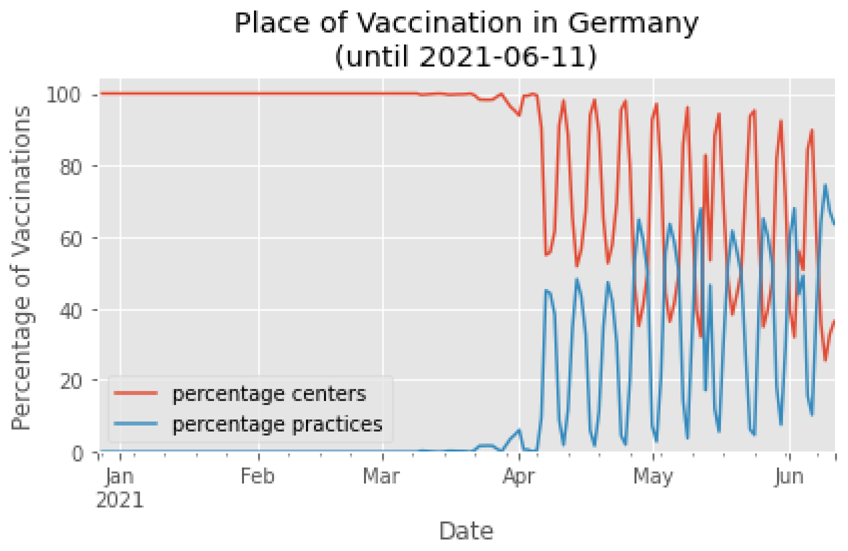
Out[56]:

	vaccination centers	practices	vaccination centers daily	practices daily	percentage practices	percentage centers
date						
2020-12-27	23271	0	NaN	NaN	NaN	NaN
2020-12-28	40908	0	17637.0	0.0	0.00	100.00
2020-12-29	90348	0	49440.0	0.0	0.00	100.00
2020-12-30	152010	0	61662.0	0.0	0.00	100.00
2020-12-31	202029	0	50019.0	0.0	0.00	100.00
...	...	...	...	...	...	...
2021-06-07	38363034	17323248	356861.0	238381.0	40.05	59.95
2021-06-08	38722955	17968865	359921.0	645617.0	64.21	35.79
2021-06-09	39060251	18956810	337296.0	987945.0	74.55	25.45
2021-06-10	39425691	19705530	365440.0	748720.0	67.20	32.80
2021-06-11	39775393	20318630	349702.0	613100.0	63.68	36.32

167 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	3778156.0	0.0
2021-03-31	7790272.0	66234.0
2021-04-30	10226181.0	5329140.0
2021-05-31	11476607.0	9483588.0
2021-06-30	3930504.0	5439668.0

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
```

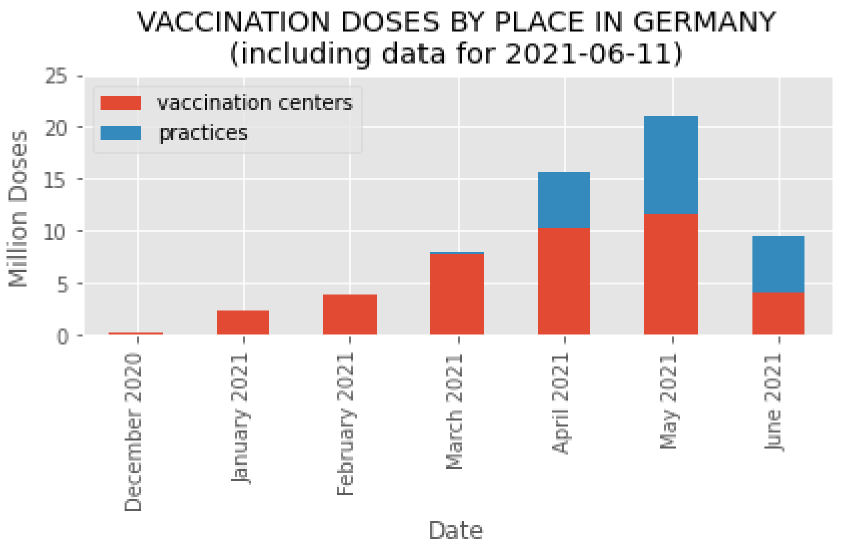
Rename the columns

```
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	2.371644	0.000000
February 2021	3.778156	0.000000
March 2021	7.790272	0.066234
April 2021	10.226181	5.329140
May 2021	11.476607	9.483588
June 2021	3.930504	5.439668

```
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')
```