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]:
```
'2021-06-02'
```

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: 157 entries, 0 to 156
Data columns (total 13 columns):
 #   Column                          Non-Null Count  Dtype         
---  ------                          --------------  -----         
 0   date                            157 non-null    datetime64[ns]
 1   dosen_kumulativ                 157 non-null    int64         
 2   dosen_differenz_zum_vortag      157 non-null    int64         
 3   dosen_erst_differenz_zum_vortag  157 non-null    int64         
 4   dosen_zweit_differenz_zum_vortag 157 non-null    int64         
 5   dosen_biontech_kumulativ        157 non-null    int64         
 6   dosen_moderna_kumulativ         157 non-null    int64         
 7   dosen_astrazeneca_kumulativ     157 non-null    int64         
 8   personen_erst_kumulativ         157 non-null    int64         
 9   personen_voll_kumulativ         157 non-null    int64         
 10  dosen_dim_kumulativ             157 non-null    int64         
 11  dosen_kbv_kumulativ             157 non-null    int64         
 12  dosen_johnson_kumulativ         157 non-null    int64         
dtypes: datetime64[ns](1), int64(12)
memory usage: 16.1 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
154	2021-05-30	50070400	282753	101219	181534	3654065
155	2021-05-31	50593755	523355	175404	347951	3689378
156	2021-06-01	51540953	947198	394790	552408	3760495

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]:
```
156    51540953
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]: 156    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: 157 entries, 0 to 156
Data columns (total 15 columns):
 #   Column                          Non-Null Count  Dtype
---  ------                          --------------  -----
 0   date                            157 non-null    datetime64[ns]
 1   dosen_kumulativ                 157 non-null    int64
 2   dosen_differenz_zum_vortag      157 non-null    int64
 3   dosen_erst_differenz_zum_vortag  157 non-null    int64
 4   dosen_zweit_differenz_zum_vortag 157 non-null    int64
 5   dosen_biontech_kumulativ        157 non-null    int64
 6   dosen_moderna_kumulativ         157 non-null    int64
 7   dosen_astrazeneca_kumulativ     157 non-null    int64
 8   personen_erst_kumulativ         157 non-null    int64
 9   personen_voll_kumulativ         157 non-null    int64
 10  dosen_dim_kumulativ             157 non-null    int64
 11  dosen_kbv_kumulativ             157 non-null    int64
 12  dosen_johnson_kumulativ         157 non-null    int64
 13  partly vaccinated               157 non-null    float64
 14  fully vaccinated                    157 non-null    float64
dtypes: datetime64[ns](1), float64(2), int64(12)
memory usage: 18.5 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
154	2021-05-30	50070400	282753	101219	181534	3654065
155	2021-05-31	50593755	523355	175404	347951	3689378
156	2021-06-01	51540953	947198	394790	552408	3760495

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]:
```
'2021-06-01'
```

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]:

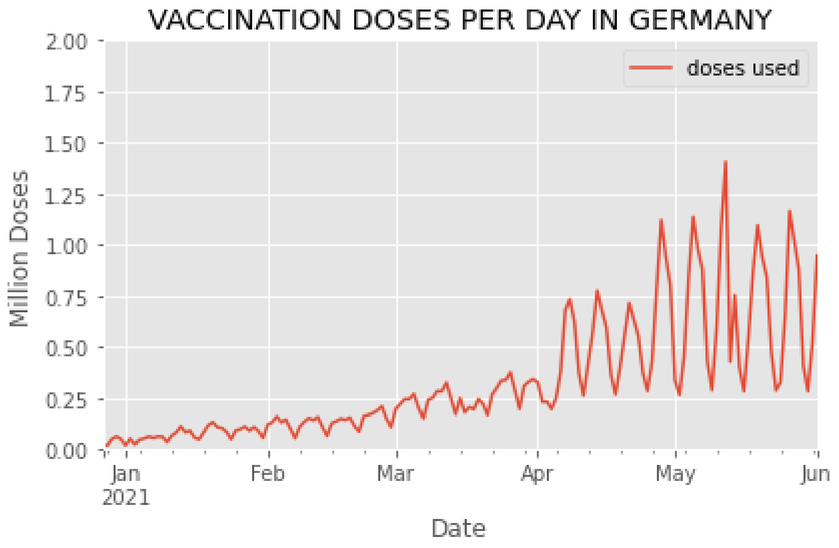
	doses used
date	
2021-06-01	0.947198

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]:
```
1.406756
```

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
154	2021-05-30	0.282753	Sunday
155	2021-05-31	0.523355	Monday
156	2021-06-01	0.947198	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
154	0.282753	Sunday
155	0.523355	Monday
156	0.947198	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
152	0.879533	NaN	NaN	NaN	NaN	NaN	NaN
153	NaN	NaN	0.405897	NaN	NaN	NaN	NaN

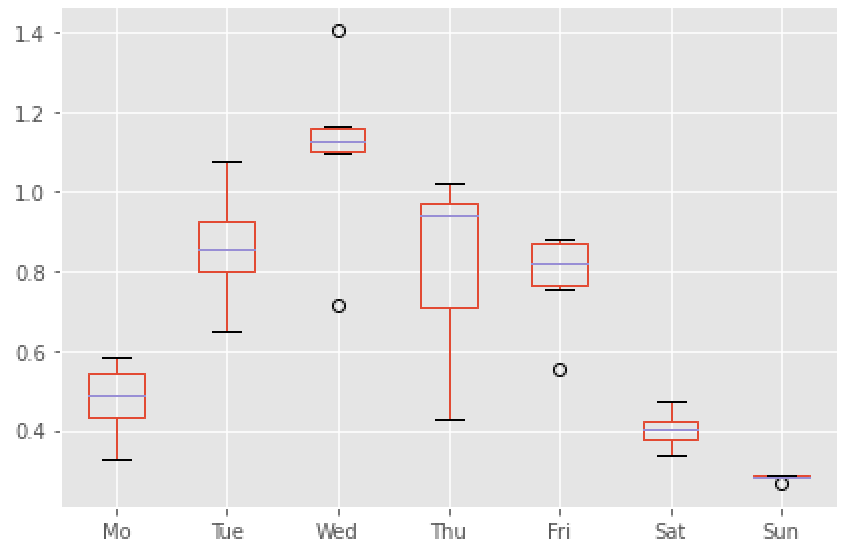
weekday	Friday	Monday	Saturday	Sunday	Thursday	Tuesday	Wednesday
154	NaN	NaN	NaN	0.282753	NaN	NaN	NaN
155	NaN	0.523355	NaN	NaN	NaN	NaN	NaN
156	NaN	NaN	NaN	NaN	NaN	0.947198	NaN

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
152	NaN	NaN	NaN	NaN	0.879533	NaN	NaN
153	NaN	NaN	NaN	NaN	NaN	0.405897	NaN
154	NaN	NaN	NaN	NaN	NaN	NaN	0.282753
155	0.523355	NaN	NaN	NaN	NaN	NaN	NaN
156	NaN	0.947198	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	
2021-05-10	5.140517
2021-05-17	4.899246
2021-05-24	4.837316
2021-05-31	4.931307
2021-06-07	0.947198

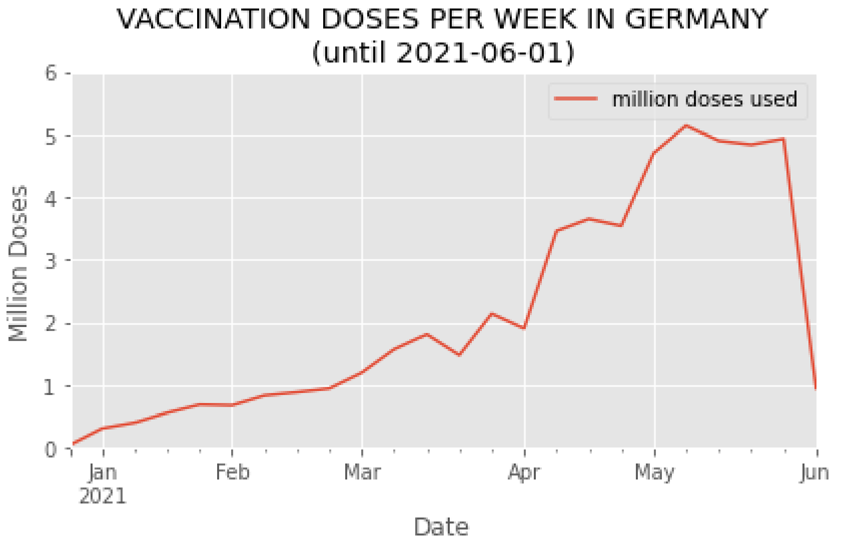
In [38]:
```
# What is the highest number of doses used in a week?
```

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

```
Out[38]: 5.140517000000001
```

```
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 2021-06-01)'}, 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	3.780711

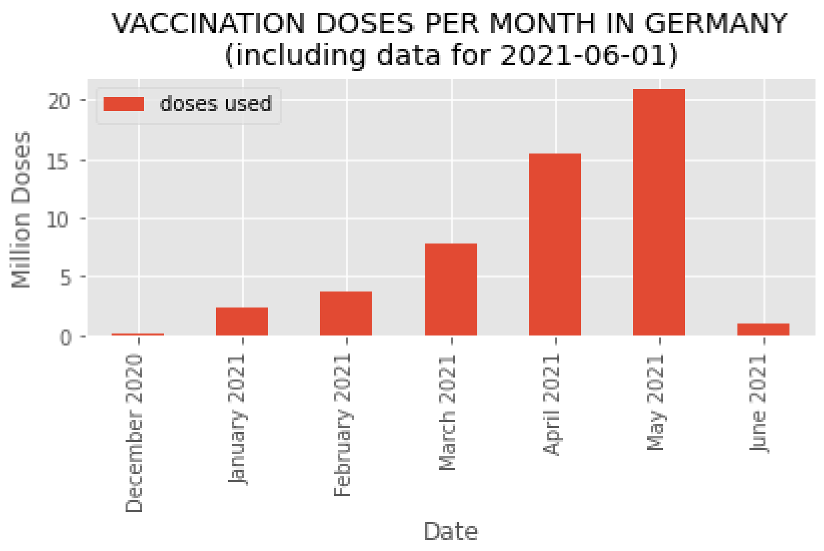
date	doses used
2021-03-31	7.858322
2021-04-30	15.542096
2021-05-31	20.860059
2021-06-30	0.947198

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	2.345831
February 2021	3.780711
March 2021	7.858322
April 2021	15.542096
May 2021	20.860059
June 2021	0.947198

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')
```

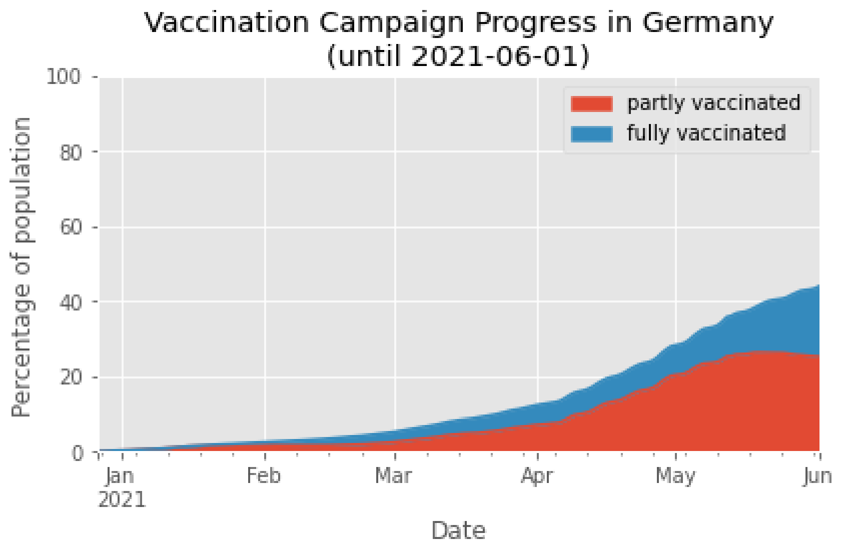
Vaccination Campaign Progress

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

Out[44]:

date	partly vaccinated	fully vaccinated
2021-05-30	25.36	17.67
2021-05-31	25.20	18.09
2021-06-01	25.11	18.75

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')
```

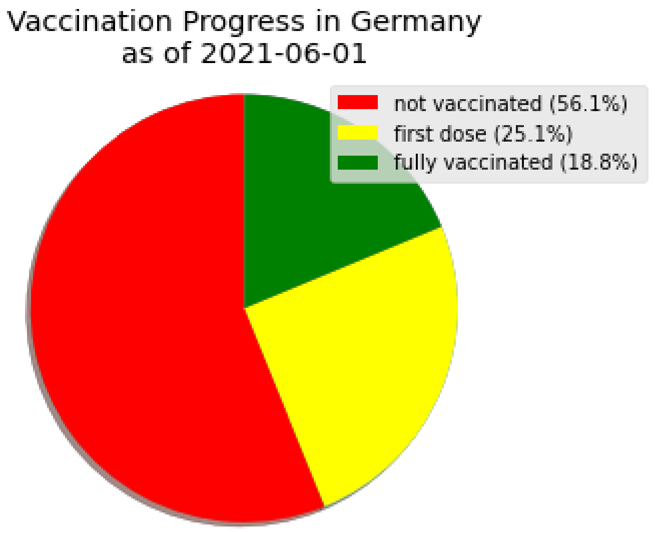
As of Today

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

```
Out[47]: partly vaccinated    25.11
         fully vaccinated     18.75
         Name: 2021-06-01 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()
```



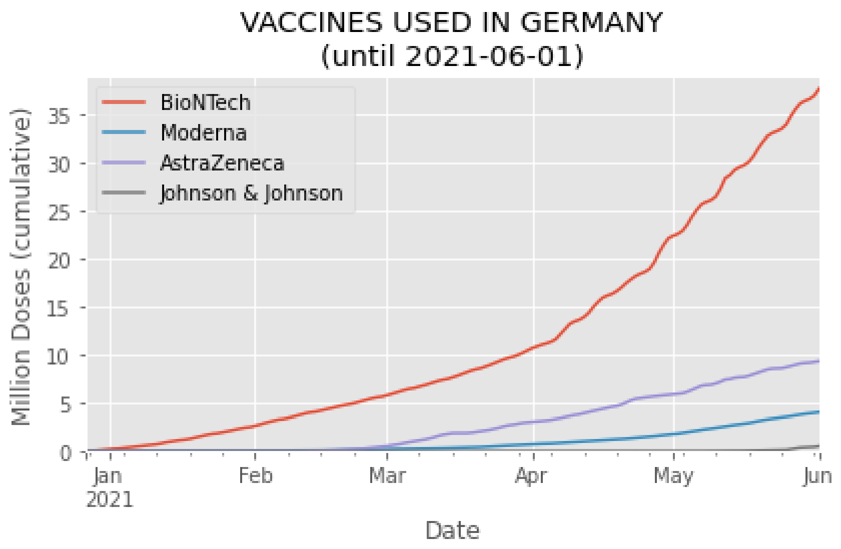
Vaccines in Use

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
2021-05-30	36.540654	3.923414	9.171682	0.434650
2021-05-31	36.893789	3.985877	9.237760	0.476329
2021-06-01	37.604950	4.052929	9.323478	0.559596

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
```

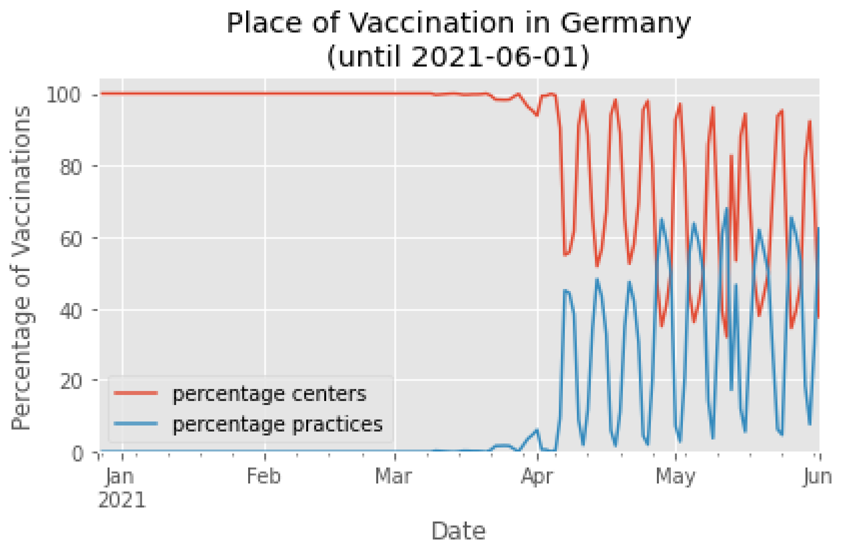
Out[56]:

date	vaccination centers	practices	vaccination centers daily	practices daily	percentage practices	percentage centers
2020-12-27	24099	0	NaN	NaN	NaN	NaN
2020-12-28	42655	0	18556.0	0.0	0.00	100.00
2020-12-29	93507	0	50852.0	0.0	0.00	100.00
2020-12-30	156533	0	63026.0	0.0	0.00	100.00
2020-12-31	206736	0	50203.0	0.0	0.00	100.00
...	...	...	...	...	...	...
2021-05-28	34756784	14624966	411572.0	467961.0	53.21	46.79
2021-05-29	35088272	14699375	331488.0	74409.0	18.33	81.67
2021-05-30	35349207	14721193	260935.0	21818.0	7.72	92.28
2021-05-31	35714793	14878962	365586.0	157769.0	30.15	69.85
2021-06-01	36071518	15469435	356725.0	590473.0	62.34	37.66

157 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	3780711.0	0.0
2021-03-31	7792088.0	66234.0
2021-04-30	10212956.0	5329140.0
2021-05-31	11376471.0	9483588.0
2021-06-30	356725.0	590473.0

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
```

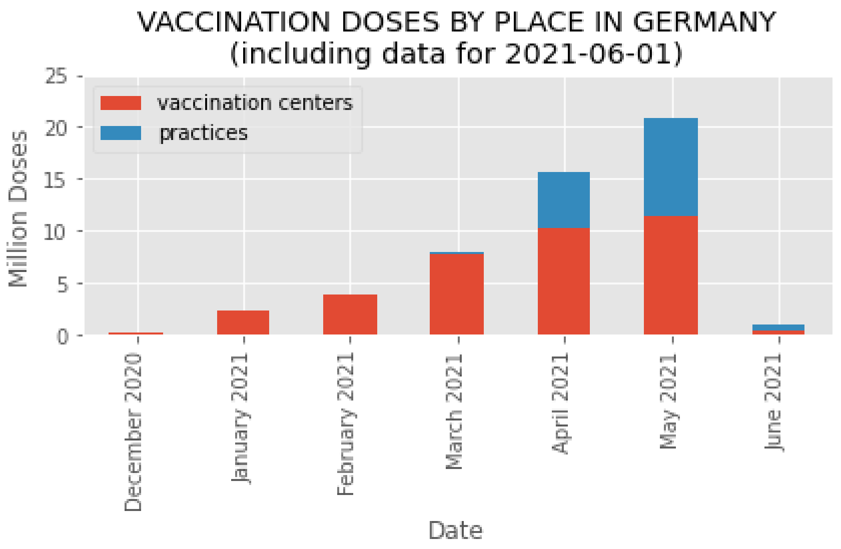
Rename the columns

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	2.345831	0.000000
February 2021	3.780711	0.000000
March 2021	7.792088	0.066234
April 2021	10.212956	5.329140
May 2021	11.376471	9.483588
June 2021	0.356725	0.590473

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')
```