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]:
```
'2021-06-08'
```

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: 163 entries, 0 to 162
Data columns (total 15 columns):
 #   Column                          Non-Null Count  Dtype
---  ------                          --------------  -----
 0   date                            163 non-null    datetime64[ns]
 1   dosen_kumulativ                 163 non-null    int64
 2   dosen_differenz_zum_vortag      163 non-null    int64
 3   dosen_erst_differenz_zum_vortag 163 non-null    int64
 4   dosen_zweit_differenz_zum_vortag 163 non-null   int64
 5   dosen_biontech_kumulativ        163 non-null    int64
 6   dosen_moderna_kumulativ         163 non-null    int64
 7   dosen_astrazeneca_kumulativ     163 non-null    int64
 8   personen_erst_kumulativ         163 non-null    int64
 9   personen_voll_kumulativ         163 non-null    int64
 10  dosen_dim_kumulativ             163 non-null    int64
 11  dosen_kbv_kumulativ             163 non-null    int64
 12  dosen_johnson_kumulativ         163 non-null    int64
 13  dosen_erst_kumulativ            163 non-null    int64
 14  dosen_zweit_kumulativ           163 non-null    int64
dtypes: datetime64[ns](1), int64(14)
memory usage: 19.2 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
160	2021-06-05	54692042	395675	98058	297617	3995306
161	2021-06-06	54968963	276921	61048	215873	4015039
162	2021-06-07	55546616	577653	187101	390552	4053388

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]:
```
162    55546616
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]:
```
162    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: 163 entries, 0 to 162
Data columns (total 17 columns):
 #   Column                            Non-Null Count  Dtype
---  ------                            --------------  -----
 0   date                              163 non-null    datetime64[ns]
 1   dosen_kumulativ                   163 non-null    int64
 2   dosen_differenz_zum_vortag        163 non-null    int64
 3   dosen_erst_differenz_zum_vortag   163 non-null    int64
 4   dosen_zweit_differenz_zum_vortag  163 non-null    int64
 5   dosen_biontech_kumulativ          163 non-null    int64
 6   dosen_moderna_kumulativ           163 non-null    int64
 7   dosen_astrazeneca_kumulativ       163 non-null    int64
 8   personen_erst_kumulativ           163 non-null    int64
 9   personen_voll_kumulativ           163 non-null    int64
 10  dosen_dim_kumulativ               163 non-null    int64
```

```
 11  dosen_kbv_kumulativ              163 non-null    int64
 12  dosen_johnson_kumulativ          163 non-null    int64
 13  dosen_erst_kumulativ             163 non-null    int64
 14  dosen_zweit_kumulativ            163 non-null    int64
 15  partly vaccinated                163 non-null    float64
 16  fully vaccinated                 163 non-null    float64
dtypes: datetime64[ns](1), float64(2), int64(14)
memory usage: 21.8 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
160	2021-06-05	54692042	395675	98058	297617	3995306
161	2021-06-06	54968963	276921	61048	215873	4015039
162	2021-06-07	55546616	577653	187101	390552	4053388

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

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]:

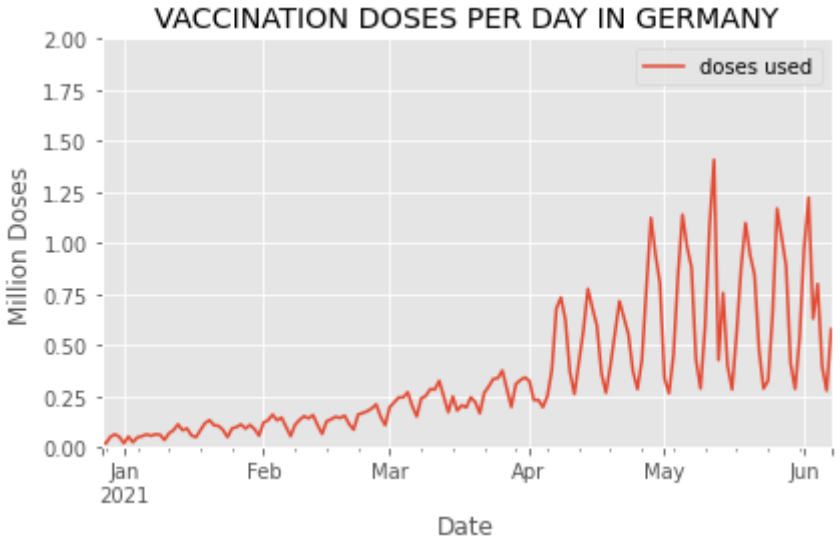
date	doses used
2021-06-07	0.577653

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]:
```
1.408337
```

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
160	2021-06-05	0.395675	Saturday
161	2021-06-06	0.276921	Sunday
162	2021-06-07	0.577653	Monday

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
160	0.395675	Saturday
161	0.276921	Sunday
162	0.577653	Monday

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
158	NaN	NaN	NaN	NaN	0.629811	NaN	NaN
159	0.799952	NaN	NaN	NaN	NaN	NaN	NaN
160	NaN	NaN	0.395675	NaN	NaN	NaN	NaN
161	NaN	NaN	NaN	0.276921	NaN	NaN	NaN
162	NaN	0.577653	NaN	NaN	NaN	NaN	NaN

In [34]:

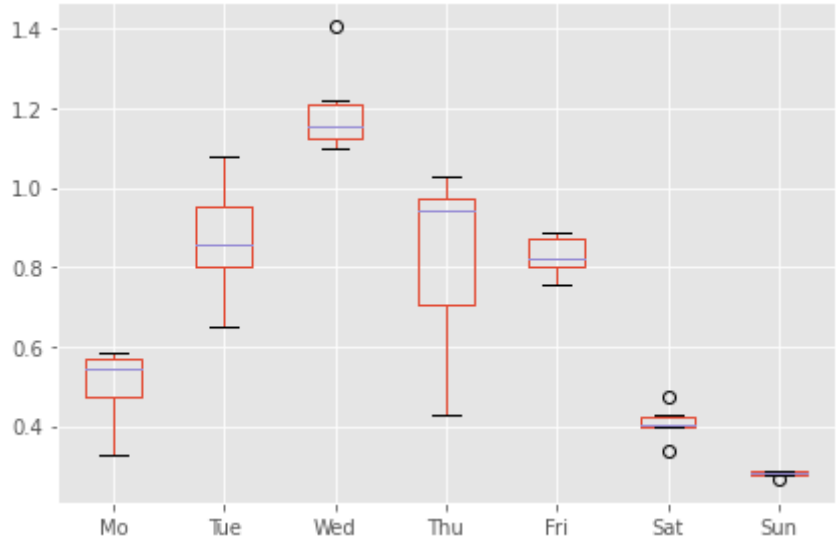
```
# Reorder the columns
pivot_table = pivot_table[['Monday', 'Tuesday', 'Wednesday', 'Thursday', 'Friday', 'Saturday', 'Sunday']]
# Rename the columns
pivot_table.columns=['Mo', 'Tue', 'Wed', 'Thu', 'Fri', 'Sat', 'Sun']
pivot_table.tail()
```

Out[34]:

	Mo	Tue	Wed	Thu	Fri	Sat	Sun
158	NaN	NaN	NaN	0.629811	NaN	NaN	NaN
159	NaN	NaN	NaN	NaN	0.799952	NaN	NaN
160	NaN	NaN	NaN	NaN	NaN	0.395675	NaN
161	NaN	NaN	NaN	NaN	NaN	NaN	0.276921
162	0.577653	NaN	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]:

date	million doses used
2021-05-10	5.145560
2021-05-17	4.907908
2021-05-24	4.848595
2021-05-31	4.968940
2021-06-07	4.878034

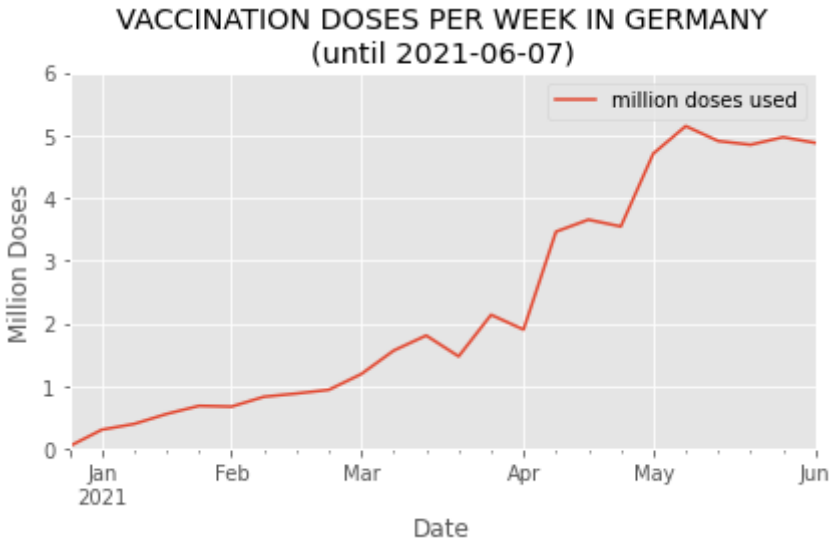
In [38]:
```
# What is the highest number of doses used in a week?
```

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

Out[38]: 5.14556

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 2021-06-07)'}, xlabel='Date', ylabel='Million 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	3.780878

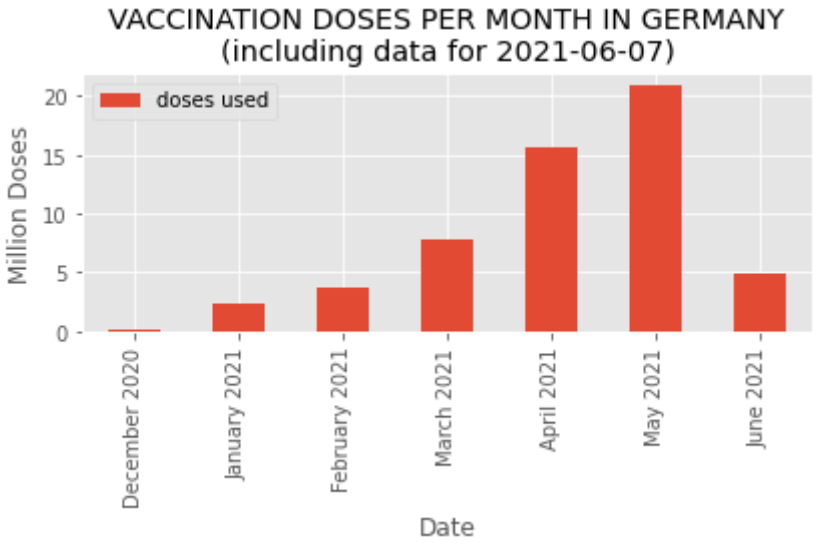
date	doses used
2021-03-31	7.859774
2021-04-30	15.551012
2021-05-31	20.924259
2021-06-30	4.878034

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	2.345921
February 2021	3.780878
March 2021	7.859774
April 2021	15.551012
May 2021	20.924259
June 2021	4.878034

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')
```

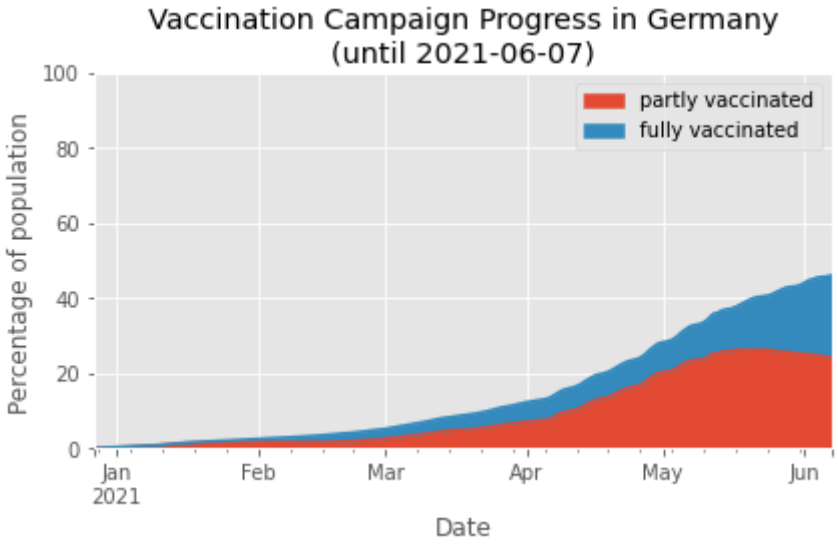
Vaccination Campaign Progress

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
2021-06-05	24.46	21.13
2021-06-06	24.29	21.39
2021-06-07	24.11	21.86

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')
```

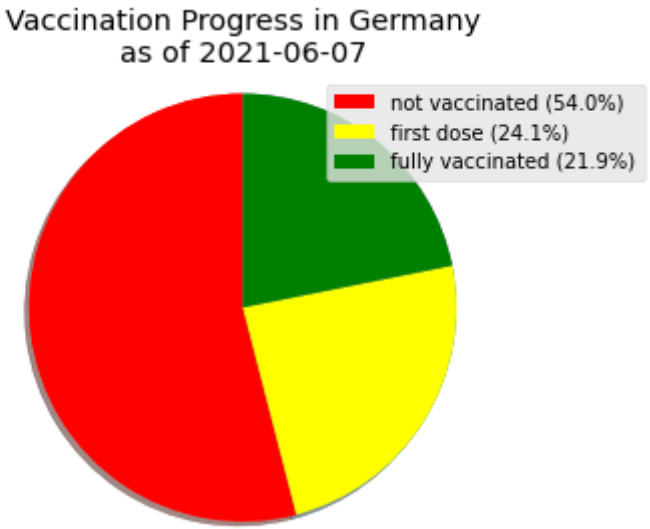
As of Today

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

Out[47]:
```
partly vaccinated    24.11
fully vaccinated     21.86
Name: 2021-06-07 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

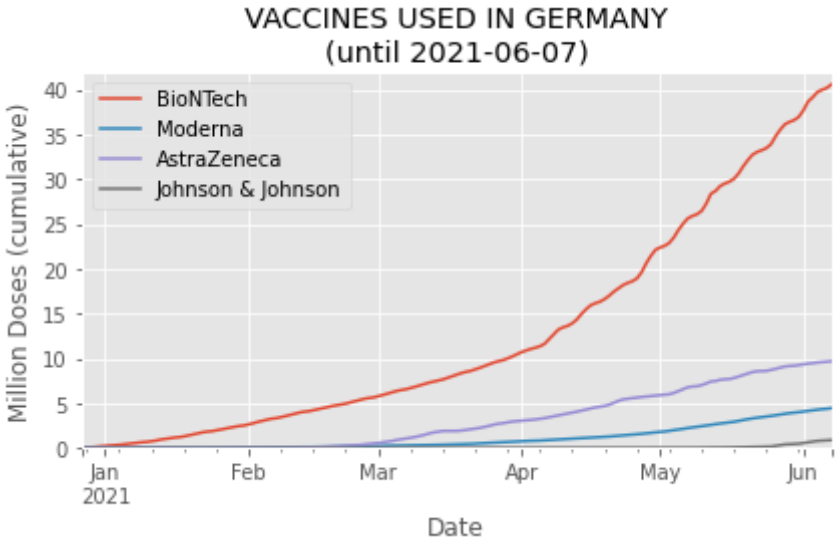
In [49]:

```
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
2021-06-05	39.953063	4.337954	9.583187	0.817838
2021-06-06	40.150398	4.376691	9.610014	0.831860
2021-06-07	40.533884	4.448414	9.678596	0.885722

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
```

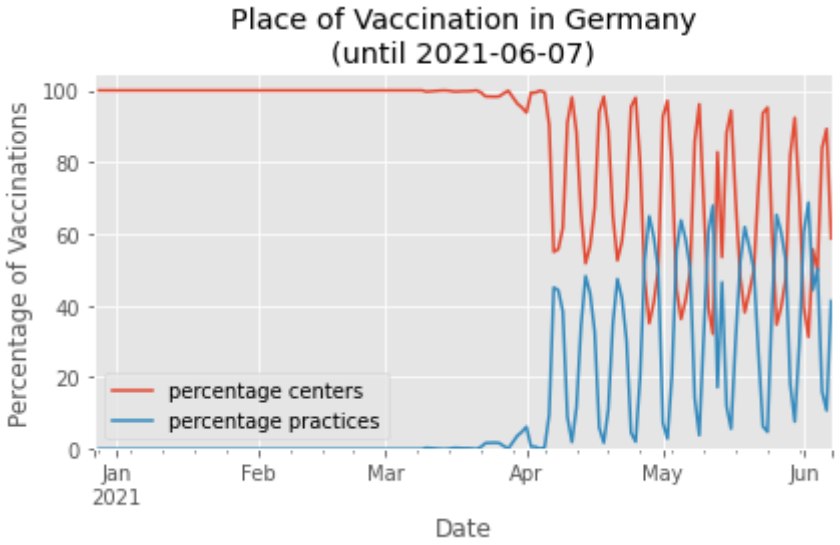
Out[56]:

date	vaccination centers	practices	vaccination centers daily	practices daily	percentage practices	percentage centers
2020-12-27	24102	0	NaN	NaN	NaN	NaN
2020-12-28	42658	0	18556.0	0.0	0.00	100.00
2020-12-29	93509	0	50851.0	0.0	0.00	100.00
2020-12-30	156539	0	63030.0	0.0	0.00	100.00
2020-12-31	206738	0	50199.0	0.0	0.00	100.00
...	...	...	...	...	...	...
2021-06-03	36907289	16589126	350398.0	279413.0	44.36	55.64
2021-06-04	37304753	16991614	397464.0	402488.0	50.31	49.69
2021-06-05	37636884	17055158	332131.0	63544.0	16.06	83.94
2021-06-06	37884096	17084867	247212.0	29709.0	10.73	89.27
2021-06-07	38223368	17323248	339272.0	238381.0	41.27	58.73

163 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]:

date	vaccination centers	practices

date	vaccination centers	practices
2021-02-28	3780878.0	0.0
2021-03-31	7793540.0	66234.0
2021-04-30	10221872.0	5329140.0
2021-05-31	11440671.0	9483588.0
2021-06-30	2433748.0	2444286.0

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

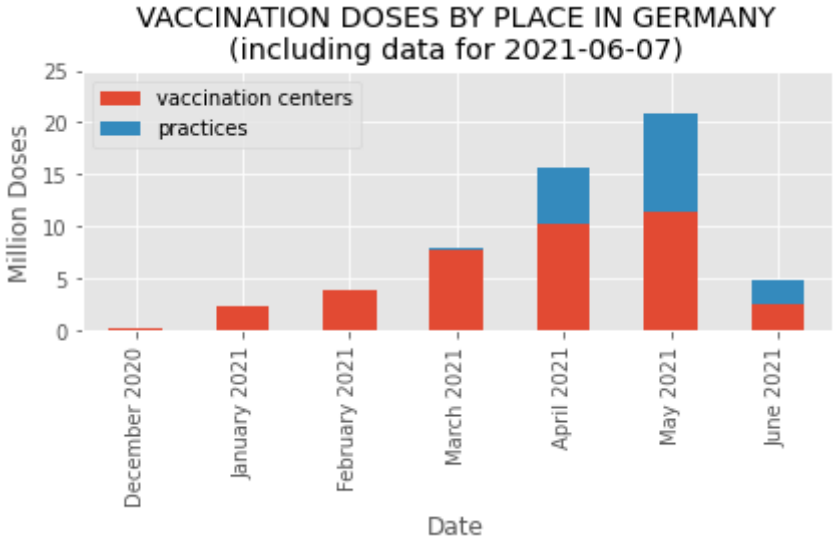
In [63]:
```
by_place_monthly['month'] = by_place_monthly.index.strftime('%B')
by_place_monthly['year'] =  by_place_monthly.index.strftime('%Y')
by_place_monthly['label'] = by_place_monthly['month'] + ' ' + by_place_monthly['year']
by_place_monthly.drop(columns=['month', 'year'], inplace=True)
by_place_monthly.set_index('label',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

Out[63]:

label	vaccination centers	practices
January 2021	2.345921	0.000000
February 2021	3.780878	0.000000
March 2021	7.793540	0.066234
April 2021	10.221872	5.329140
May 2021	11.440671	9.483588
June 2021	2.433748	2.444286

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')
```