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]:
```
'2021-05-26'
```

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: 150 entries, 0 to 149
Data columns (total 13 columns):
 #   Column                          Non-Null Count  Dtype
---  ------                          --------------  -----
 0   date                            150 non-null    datetime64[ns]
 1   dosen_kumulativ                 150 non-null    int64
 2   dosen_differenz_zum_vortag      150 non-null    int64
 3   dosen_erst_differenz_zum_vortag 150 non-null    int64
 4   dosen_zweit_differenz_zum_vortag 150 non-null   int64
 5   dosen_biontech_kumulativ        150 non-null    int64
 6   dosen_moderna_kumulativ         150 non-null    int64
 7   dosen_astrazeneca_kumulativ     150 non-null    int64
 8   personen_erst_kumulativ         150 non-null    int64
 9   personen_voll_kumulativ         150 non-null    int64
 10  dosen_dim_kumulativ             150 non-null    int64
 11  dosen_kbv_kumulativ             150 non-null    int64
 12  dosen_johnson_kumulativ         150 non-null    int64
dtypes: datetime64[ns](1), int64(12)
memory usage: 15.4 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
147	2021-05-23	45171412	266094	119409	146685	330847(
148	2021-05-24	45468149	296737	133522	163215	332954:
149	2021-05-25	46063274	595125	255374	339751	336978:

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]:
```
149    46063274
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]:
```
149    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: 150 entries, 0 to 149
Data columns (total 15 columns):
 #   Column                           Non-Null Count  Dtype
---  ------                           --------------  -----
 0   date                             150 non-null    datetime64[ns]
 1   dosen_kumulativ                  150 non-null    int64
 2   dosen_differenz_zum_vortag       150 non-null    int64
 3   dosen_erst_differenz_zum_vortag  150 non-null    int64
 4   dosen_zweit_differenz_zum_vortag 150 non-null    int64
 5   dosen_biontech_kumulativ         150 non-null    int64
 6   dosen_moderna_kumulativ          150 non-null    int64
 7   dosen_astrazeneca_kumulativ      150 non-null    int64
 8   personen_erst_kumulativ          150 non-null    int64
 9   personen_voll_kumulativ          150 non-null    int64
 10  dosen_dim_kumulativ              150 non-null    int64
 11  dosen_kbv_kumulativ              150 non-null    int64
 12  dosen_johnson_kumulativ          150 non-null    int64
 13  partly vaccinated                150 non-null    float64
```

```
 14  fully vaccinated                  150 non-null    float64
dtypes: datetime64[ns](1), float64(2), int64(12)
memory usage: 17.7 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
147	2021-05-23	45171412	266094	119409	146685	330847(
148	2021-05-24	45468149	296737	133522	163215	3329542
149	2021-05-25	46063274	595125	255374	339751	3369783

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]:
```
'2021-05-25'
```

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]:

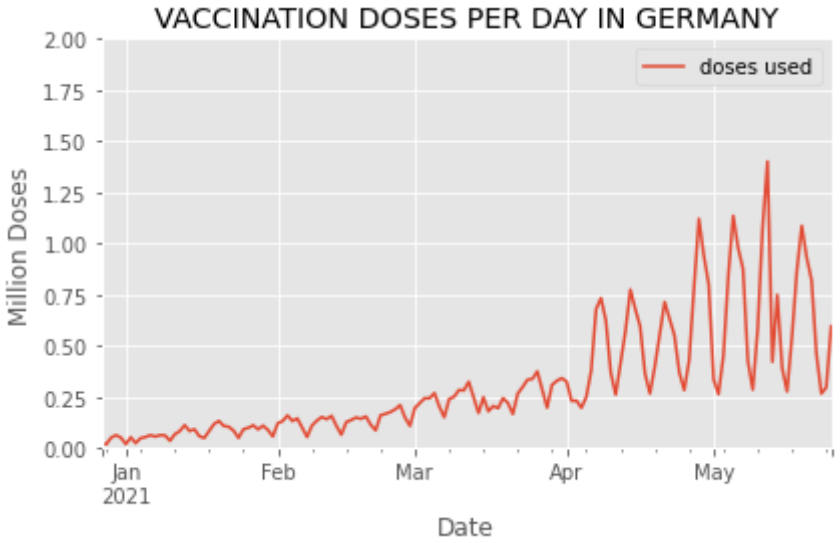
date	doses used
2021-05-25	0.595125

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]: 1.401177

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
147	2021-05-23	0.266094	Sunday
148	2021-05-24	0.296737	Monday
149	2021-05-25	0.595125	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
147	0.266094	Sunday
148	0.296737	Monday
149	0.595125	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
145	0.820362	NaN	NaN	NaN	NaN	NaN	NaN
146	NaN	NaN	0.457894	NaN	NaN	NaN	NaN

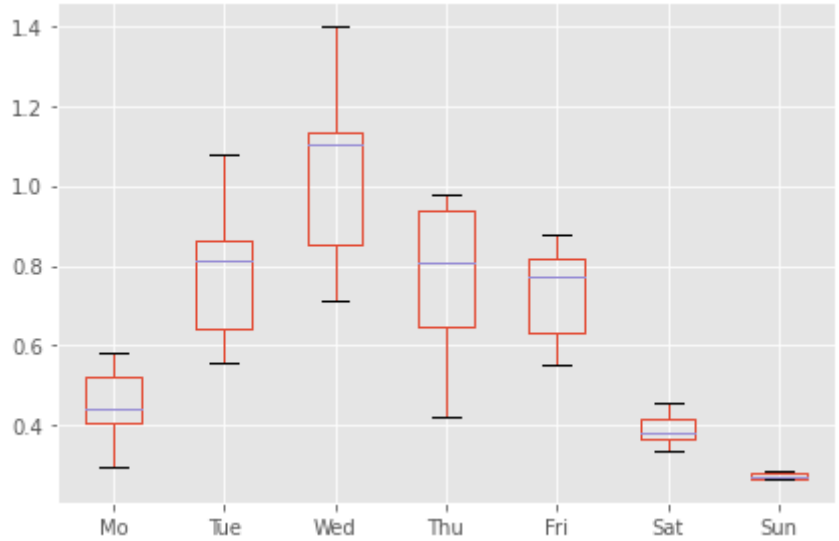
weekday	Friday	Monday	Saturday	Sunday	Thursday	Tuesday	Wednesday
147	NaN	NaN	NaN	0.266094	NaN	NaN	NaN
148	NaN	0.296737	NaN	NaN	NaN	NaN	NaN
149	NaN	NaN	NaN	NaN	NaN	0.595125	NaN

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
145	NaN	NaN	NaN	NaN	0.820362	NaN	NaN
146	NaN	NaN	NaN	NaN	NaN	0.457894	NaN
147	NaN	NaN	NaN	NaN	NaN	NaN	0.266094
148	0.296737	NaN	NaN	NaN	NaN	NaN	NaN
149	NaN	0.595125	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
2021-05-03	4.695279
2021-05-10	5.124669
2021-05-17	4.860584
2021-05-24	4.726880
2021-05-31	0.595125

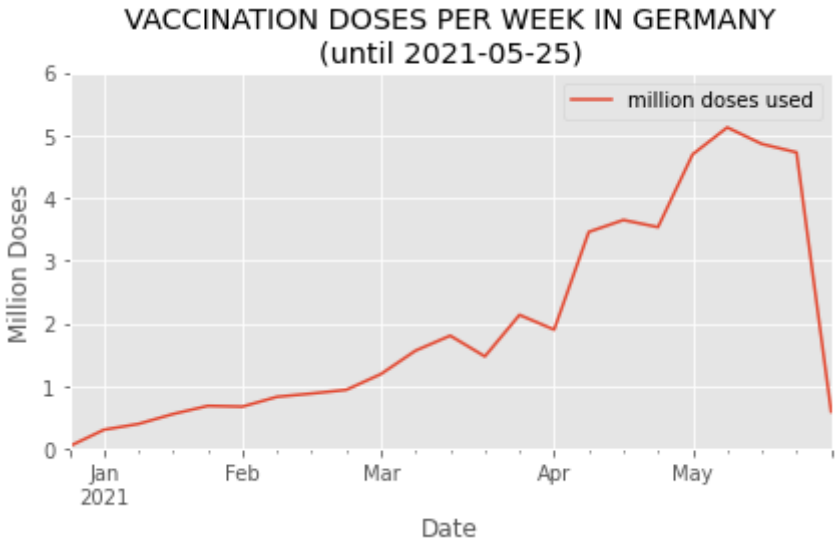
In [38]:
```
# What is the highest number of doses used in a week?
```

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

Out[38]: 5.124669

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 2021-05-25)'}, 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	
2021-01-31	2.344799

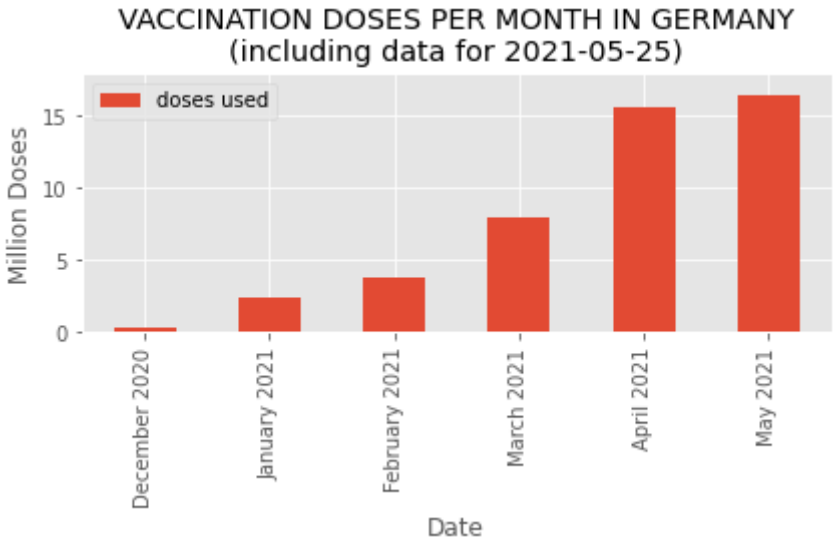
date	doses used
2021-02-28	3.779610
2021-03-31	7.853548
2021-04-30	15.522279
2021-05-31	16.356378

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
December 2020	0.206660
January 2021	2.344799
February 2021	3.779610
March 2021	7.853548
April 2021	15.522279
May 2021	16.356378

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')
```

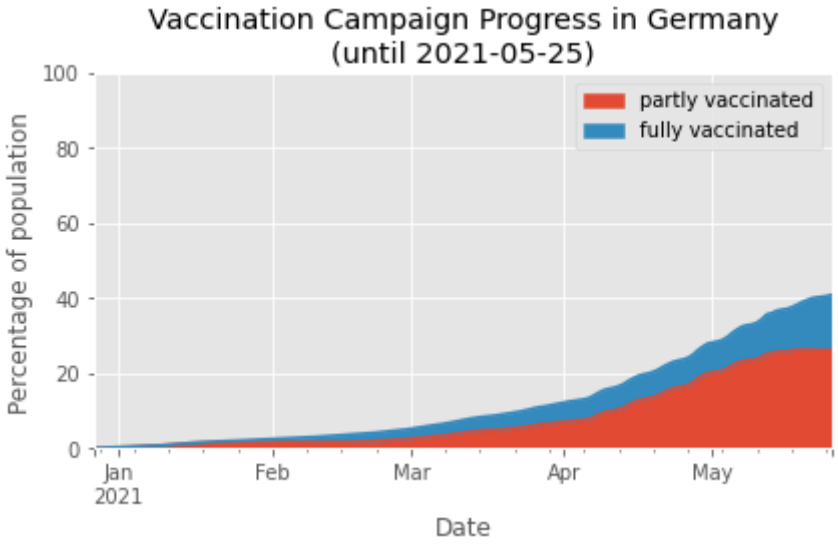
Vaccination Campaign Progress

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
2021-05-23	26.15	14.15
2021-05-24	26.12	14.34
2021-05-25	26.04	14.75

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')
```

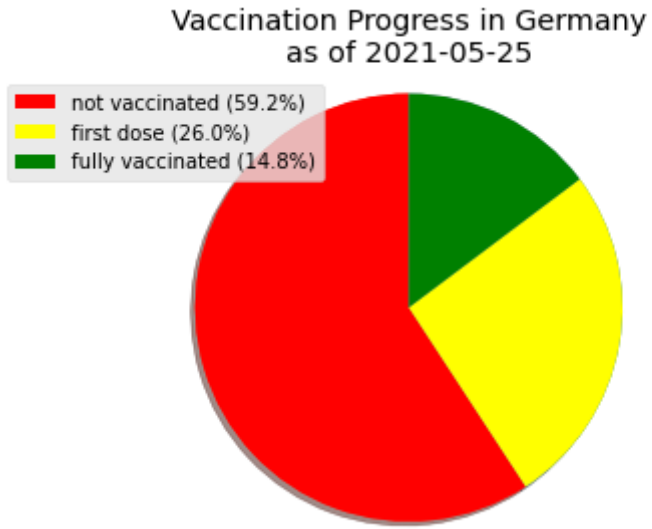
As of Today

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

Out[47]:
```
partly vaccinated    26.04
fully vaccinated     14.75
Name: 2021-05-25 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

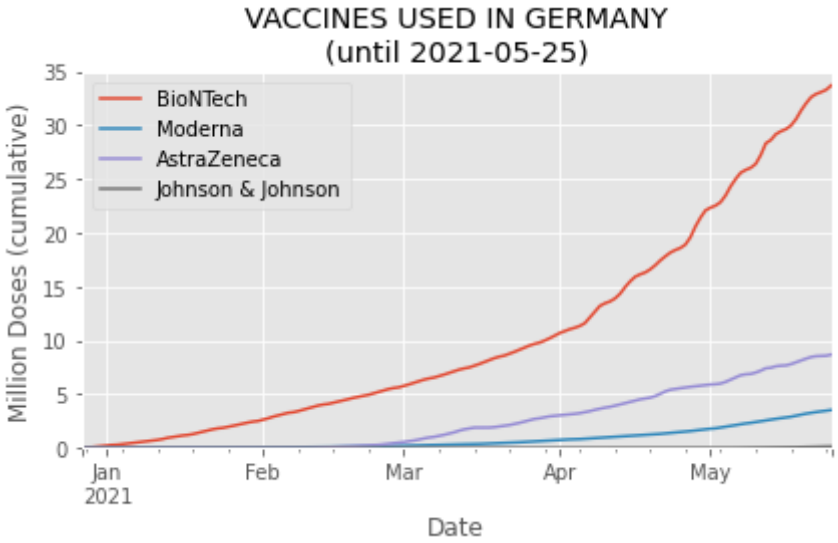
In [49]:

```
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
2021-05-23	33.084708	3.400451	8.560866	0.125387
2021-05-24	33.295425	3.460030	8.581665	0.131029
2021-05-25	33.697833	3.531823	8.681336	0.152282

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
```

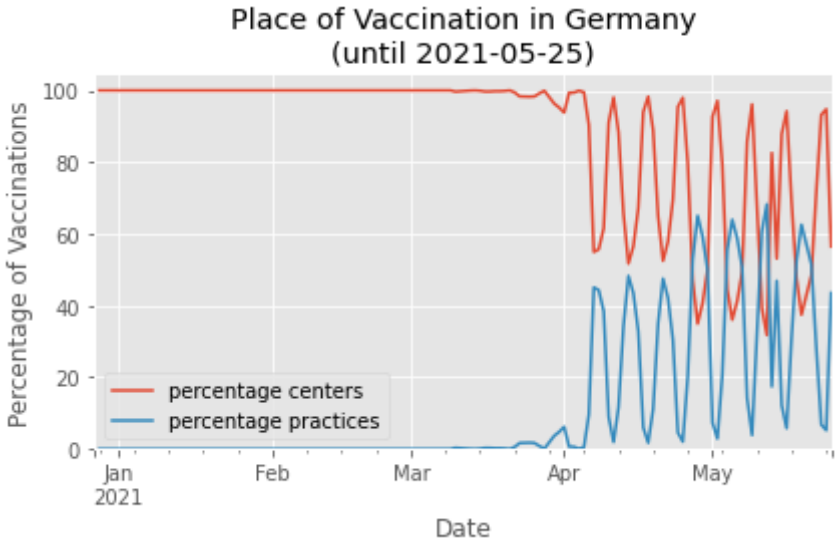
Out[56]:

date	vaccination centers	practices	vaccination centers daily	practices daily	percentage practices	percentage centers
2020-12-27	24087	0	NaN	NaN	NaN	NaN
2020-12-28	42647	0	18560.0	0.0	0.00	100.00
2020-12-29	93467	0	50820.0	0.0	0.00	100.00
2020-12-30	156472	0	63005.0	0.0	0.00	100.00
2020-12-31	206660	0	50188.0	0.0	0.00	100.00
...	...	...	...	...	...	...
2021-05-21	32097190	12350234	397642.0	422720.0	51.53	48.47
2021-05-22	32426154	12479164	328964.0	128930.0	28.16	71.84
2021-05-23	32674127	12497285	247973.0	18121.0	6.81	93.19
2021-05-24	32955339	12512810	281212.0	15525.0	5.23	94.77
2021-05-25	33291521	12771753	336182.0	258943.0	43.51	56.49

150 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
2021-01-31	2344799.0	0.0
2021-02-28	3779610.0	0.0
2021-03-31	7787314.0	66234.0
2021-04-30	10193139.0	5329140.0
2021-05-31	8979999.0	7376379.0

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

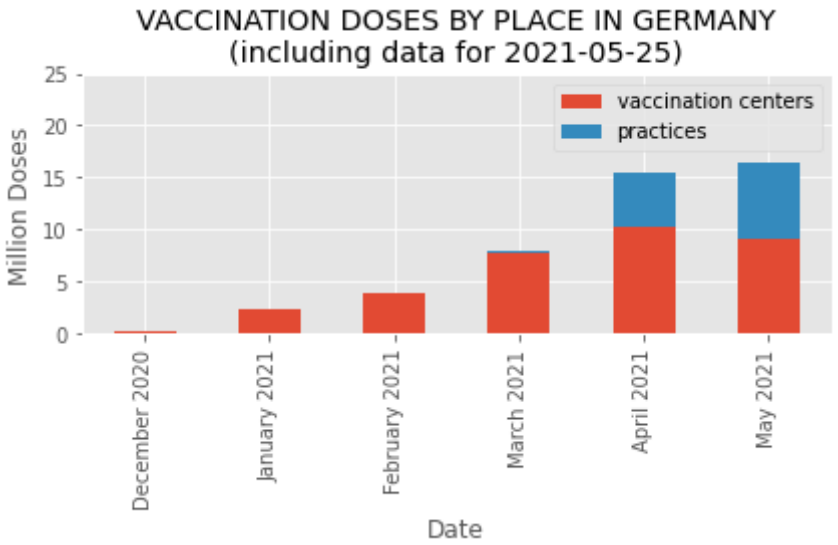
In [63]:
```
by_place_monthly['month'] = by_place_monthly.index.strftime('%B')
by_place_monthly['year'] =  by_place_monthly.index.strftime('%Y')
by_place_monthly['label'] = by_place_monthly['month'] + ' ' + by_place_monthly['year']
by_place_monthly.drop(columns=['month', 'year'], inplace=True)
by_place_monthly.set_index('label',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

Out[63]:

label	vaccination centers	practices
December 2020	0.182573	0.000000
January 2021	2.344799	0.000000
February 2021	3.779610	0.000000
March 2021	7.787314	0.066234
April 2021	10.193139	5.329140
May 2021	8.979999	7.376379

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')
```