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]:
```
'2021-08-13'
```

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: 229 entries, 0 to 228
Data columns (total 15 columns):
 #   Column                          Non-Null Count  Dtype
---  ------                          --------------  -----
 0   date                            229 non-null    datetime64[ns]
 1   dosen_kumulativ                 229 non-null    int64
 2   dosen_differenz_zum_vortag      229 non-null    int64
 3   dosen_erst_differenz_zum_vortag 229 non-null    int64
 4   dosen_zweit_differenz_zum_vortag 229 non-null   int64
 5   dosen_biontech_kumulativ        229 non-null    int64
 6   dosen_moderna_kumulativ         229 non-null    int64
 7   dosen_astrazeneca_kumulativ     229 non-null    int64
 8   personen_erst_kumulativ         229 non-null    int64
 9   personen_voll_kumulativ         229 non-null    int64
 10  dosen_dim_kumulativ             229 non-null    int64
 11  dosen_kbv_kumulativ             229 non-null    int64
 12  dosen_johnson_kumulativ         229 non-null    int64
 13  dosen_erst_kumulativ            229 non-null    int64
 14  dosen_zweit_kumulativ           229 non-null    int64
dtypes: datetime64[ns](1), int64(14)
memory usage: 27.0 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
226	2021-08-10	95882983	420823	73210	347613	7194243
227	2021-08-11	96410848	527865	101627	426238	7239985
228	2021-08-12	96852861	442013	92060	349953	7278448

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]:
```
228    96852861
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]:
```
228    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: 229 entries, 0 to 228
Data columns (total 17 columns):
 #   Column                            Non-Null Count  Dtype
---  ------                            --------------  -----
 0   date                              229 non-null    datetime64[ns]
 1   dosen_kumulativ                   229 non-null    int64
 2   dosen_differenz_zum_vortag        229 non-null    int64
 3   dosen_erst_differenz_zum_vortag   229 non-null    int64
 4   dosen_zweit_differenz_zum_vortag  229 non-null    int64
 5   dosen_biontech_kumulativ          229 non-null    int64
 6   dosen_moderna_kumulativ           229 non-null    int64
 7   dosen_astrazeneca_kumulativ       229 non-null    int64
 8   personen_erst_kumulativ           229 non-null    int64
 9   personen_voll_kumulativ           229 non-null    int64
 10  dosen_dim_kumulativ               229 non-null    int64
```

```
 11  dosen_kbv_kumulativ              229 non-null    int64
 12  dosen_johnson_kumulativ          229 non-null    int64
 13  dosen_erst_kumulativ             229 non-null    int64
 14  dosen_zweit_kumulativ            229 non-null    int64
 15  partly vaccinated                229 non-null    float64
 16  fully vaccinated                 229 non-null    float64
dtypes: datetime64[ns](1), float64(2), int64(14)
memory usage: 30.5 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
226	2021-08-10	95882983	420823	73210	347613	7194243
227	2021-08-11	96410848	527865	101627	426238	7239985
228	2021-08-12	96852861	442013	92060	349953	7278448

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]:
```
'2021-08-12'
```

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]:

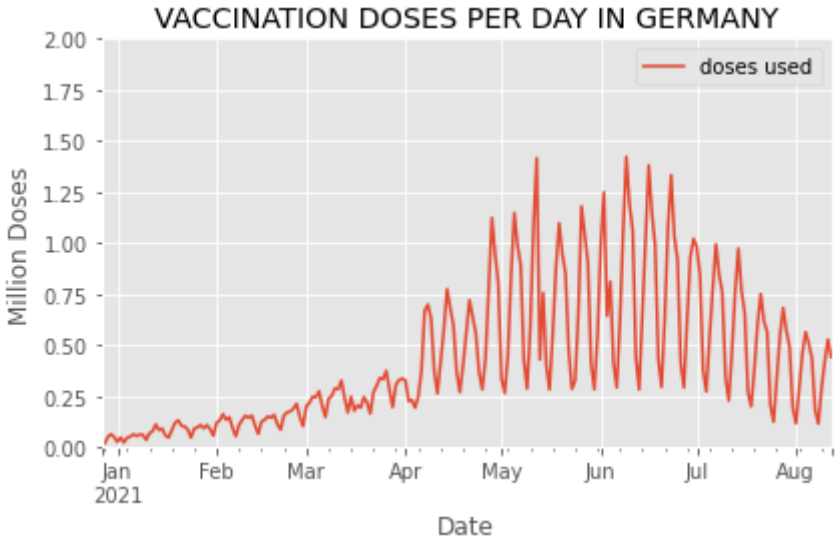
date	doses used
2021-08-12	0.442013

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]:
```
1.422799
```

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
226	2021-08-10	0.420823	Tuesday
227	2021-08-11	0.527865	Wednesday
228	2021-08-12	0.442013	Thursday

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
226	0.420823	Tuesday
227	0.527865	Wednesday
228	0.442013	Thursday

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
224	NaN	NaN	NaN	0.115546	NaN	NaN	NaN
225	NaN	0.289368	NaN	NaN	NaN	NaN	NaN
226	NaN	NaN	NaN	NaN	NaN	0.420823	NaN
227	NaN	NaN	NaN	NaN	NaN	NaN	0.527865
228	NaN	NaN	NaN	NaN	0.442013	NaN	NaN

In [34]:

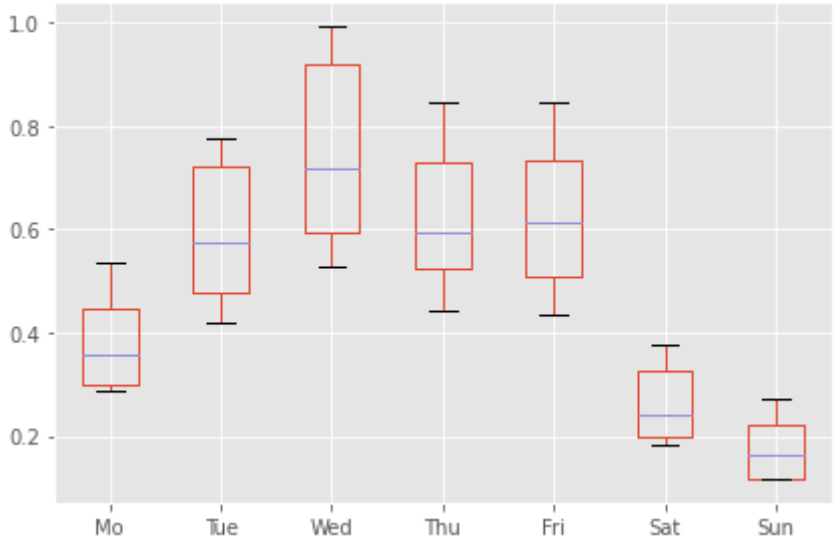
```
# Reorder the columns
pivot_table = pivot_table[['Monday', 'Tuesday', 'Wednesday', 'Thursday', 'Friday', 'Saturday', 'Sunday']]
# Rename the columns
pivot_table.columns=['Mo', 'Tue', 'Wed', 'Thu', 'Fri', 'Sat', 'Sun']
pivot_table.tail()
```

Out[34]:

	Mo	Tue	Wed	Thu	Fri	Sat	Sun
224	NaN	NaN	NaN	NaN	NaN	NaN	0.115546
225	0.289368	NaN	NaN	NaN	NaN	NaN	NaN
226	NaN	0.420823	NaN	NaN	NaN	NaN	NaN
227	NaN	NaN	0.527865	NaN	NaN	NaN	NaN
228	NaN	NaN	NaN	0.442013	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
2021-07-19	4.007234
2021-07-26	3.206011
2021-08-02	2.893289
2021-08-09	2.549785
2021-08-16	1.390701

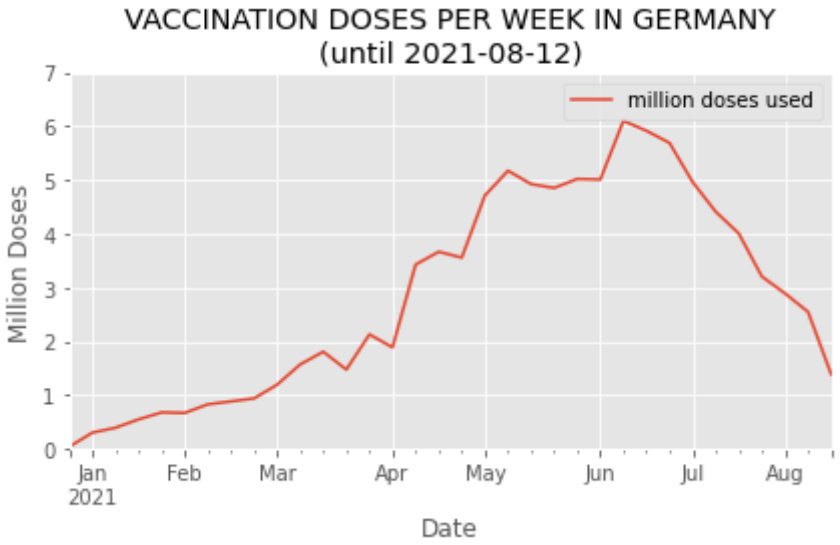
In [38]:
```
# What is the highest number of doses used in a week?
```

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

Out[38]: 6.101500000000001

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 2021-08-12)'}, 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	
2021-04-30	15.537955

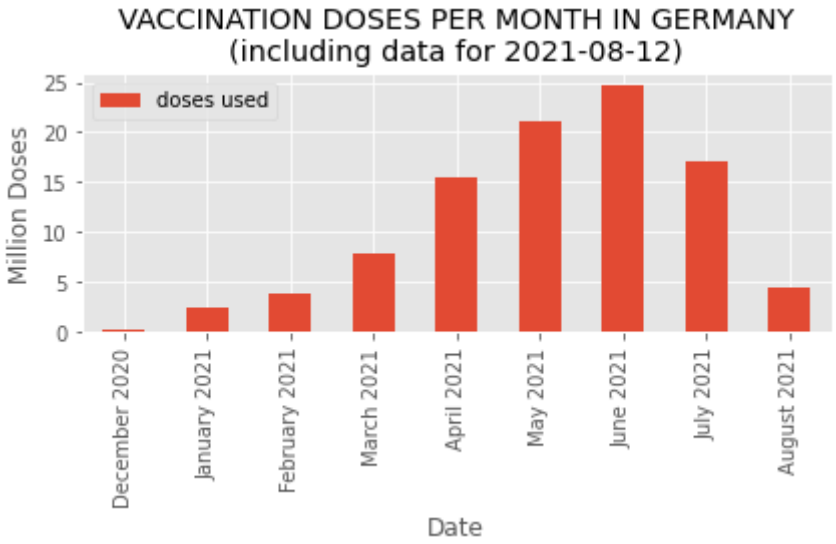
date	doses used
2021-05-31	21.026021
2021-06-30	24.669439
2021-07-31	17.122295
2021-08-31	4.346755

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
March 2021	7.851566
April 2021	15.537955
May 2021	21.026021
June 2021	24.669439
July 2021	17.122295
August 2021	4.346755

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')
```

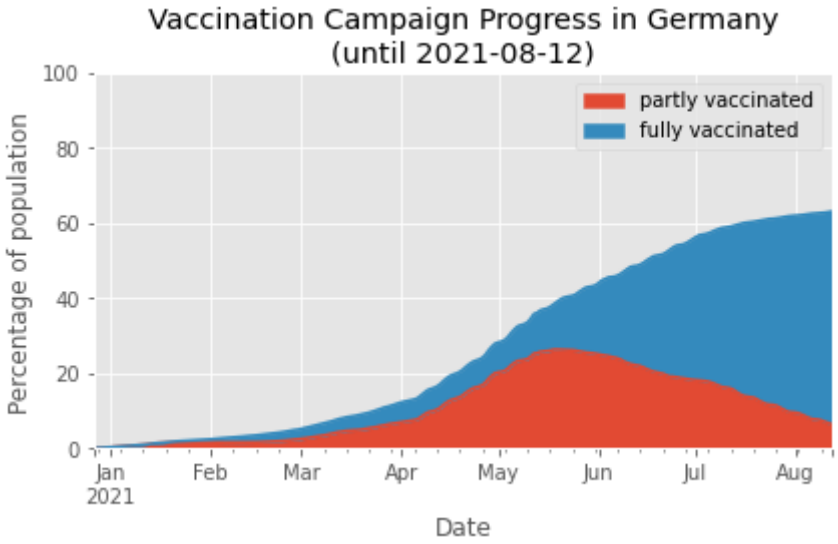
Vaccination Campaign Progress

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
2021-08-10	7.06	55.62
2021-08-11	6.69	56.13
2021-08-12	6.40	56.55

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')
```

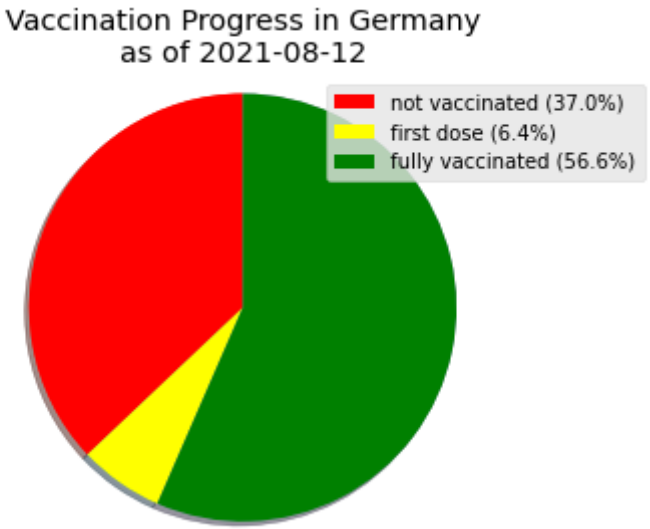
As of Today

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

Out[47]:
```
partly vaccinated     6.40
fully vaccinated     56.55
Name: 2021-08-12 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

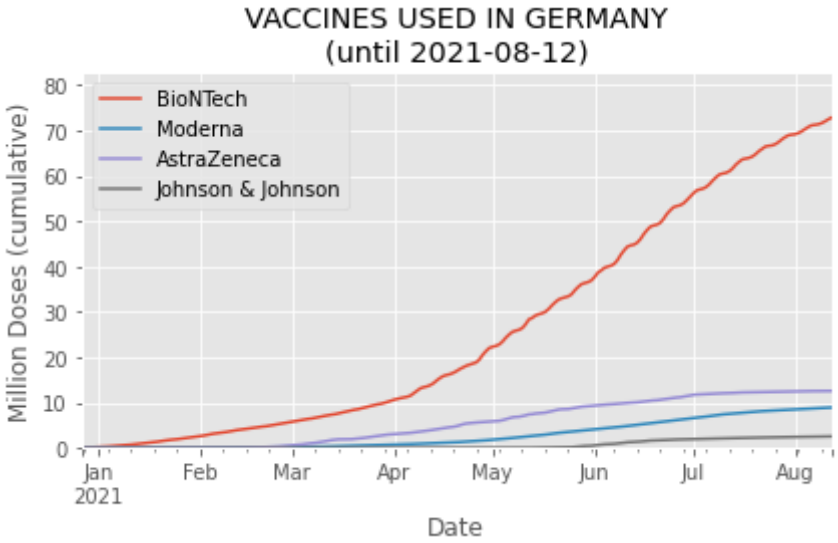
In [49]:

```
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
2021-08-10	71.942433	8.840913	12.562192	2.537445
2021-08-11	72.399851	8.887319	12.571857	2.551821
2021-08-12	72.784481	8.923113	12.578796	2.566471

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]))+10),
    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
```

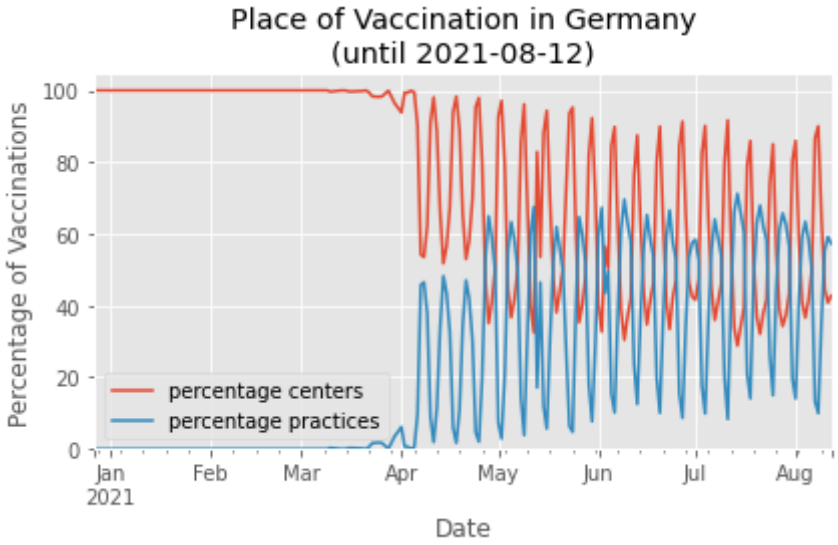
Out[56]:

date	vaccination centers	practices	vaccination centers daily	practices daily	percentage practices	percentage centers
2020-12-27	24089	0	NaN	NaN	NaN	NaN
2020-12-28	42083	0	17994.0	0.0	0.00	100.00
2020-12-29	92098	0	50015.0	0.0	0.00	100.00
2020-12-30	155591	0	63493.0	0.0	0.00	100.00
2020-12-31	205281	0	49690.0	0.0	0.00	100.00
...	...	...	...	...	...	...
2021-08-08	56843392	38163142	103896.0	11513.0	9.98	90.02
2021-08-09	57029644	38264866	186252.0	101724.0	35.32	64.68
2021-08-10	57216295	38496745	186651.0	231879.0	55.40	44.60
2021-08-11	57430420	38807109	214125.0	310364.0	59.17	40.83
2021-08-12	57618078	39058964	187658.0	251855.0	57.30	42.70

229 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
2021-04-30	10208815.0	5329140.0
2021-05-31	11542433.0	9483588.0
2021-06-30	11787855.0	12819000.0
2021-07-31	7875397.0	9158395.0
2021-08-31	2119416.0	2202607.0

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

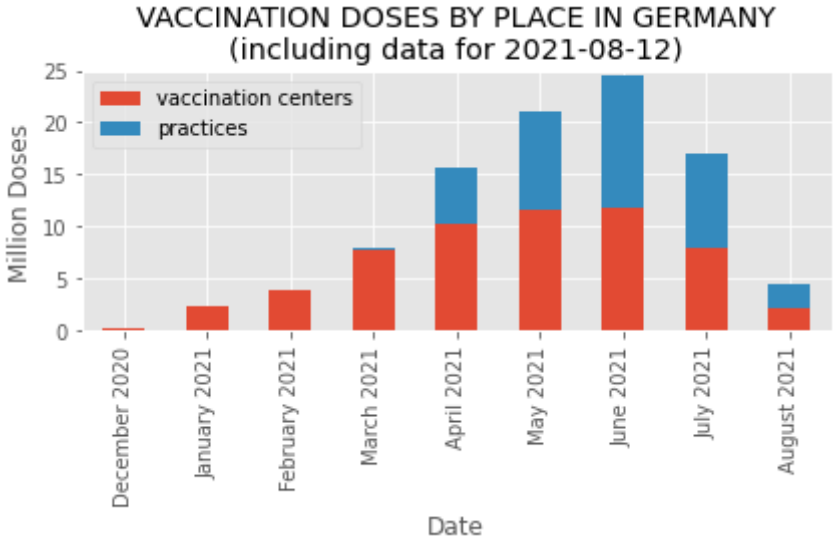
In [63]:
```
by_place_monthly['month'] = by_place_monthly.index.strftime('%B')
by_place_monthly['year'] =  by_place_monthly.index.strftime('%Y')
by_place_monthly['label'] = by_place_monthly['month'] + ' ' + by_place_monthly['year']
by_place_monthly.drop(columns=['month', 'year'], inplace=True)
by_place_monthly.set_index('label',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

Out[63]:

label	vaccination centers	practices
March 2021	7.785332	0.066234
April 2021	10.208815	5.329140
May 2021	11.542433	9.483588
June 2021	11.787855	12.819000
July 2021	7.875397	9.158395
August 2021	2.119416	2.202607

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')
```