# 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
```

### Date this Notebook was run

In [3]:
```
today = datetime.datetime.today().strftime('%Y-%m-%d')
today
```

Out[3]:
```
'2021-04-26'
```

### 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})
```

# Get and Transform Data

In [6]:
```
vaccination_data_permalink = 'https://impfdashboard.de/static/data/germany_vaccinations_timeseries_v2.tsv'
vaccinations = pd.read_csv(
    vaccination_data_permalink,
    sep="\t")
```

## Drop unnecessary columns

Columns with names starting with 'indikation_' will not be analyzed as the data providers stopped updating them.

In [7]:
```
# No analysis of indication planned:
cols_to_drop = vaccinations.columns[vaccinations.columns.str.contains('indikation_')]
vaccinations.drop(columns=cols_to_drop, inplace=True)
```

In [8]:
```
# Convert datatype of date column
vaccinations.iloc[ : , [0]] = vaccinations.iloc[ : , [0]].apply(pd.to_datetime)
```

## Show Data

In [9]:
```
vaccinations.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 120 entries, 0 to 119
Data columns (total 14 columns):
 #   Column                           Non-Null Count  Dtype         
---  ------                           --------------  -----         
 0   date                             120 non-null    datetime64[ns]
 1   dosen_kumulativ                  120 non-null    int64         
 2   dosen_differenz_zum_vortag       120 non-null    int64         
 3   dosen_erst_differenz_zum_vortag  120 non-null    int64         
 4   dosen_zweit_differenz_zum_vortag 120 non-null    int64         
 5   dosen_biontech_kumulativ         120 non-null    int64         
 6   dosen_moderna_kumulativ          120 non-null    int64         
 7   dosen_astrazeneca_kumulativ      120 non-null    int64         
 8   personen_erst_kumulativ          120 non-null    int64         
 9   personen_voll_kumulativ          120 non-null    int64         
 10  impf_quote_erst                  120 non-null    float64       
 11  impf_quote_voll                  120 non-null    float64       
 12  dosen_dim_kumulativ              120 non-null    int64         
 13  dosen_kbv_kumulativ              120 non-null    int64         
```

```
dtypes: datetime64[ns](1), float64(2), int64(11)
memory usage: 13.2 KB
```

In [10]:
```
vaccinations.tail(3)
```

Out[10]:

| | date | dosen_kumulativ | dosen_differenz_zum_vortag | dosen_erst_differenz_zum_vortag | dosen_zweit_differenz_zum_vortag | dosen_biontech_kumulati |
|---|---|---|---|---|---|---|
| **117** | 2021-04-23 | 24836908 | 525155 | 462564 | 62591 | 1809310 |
| **118** | 2021-04-24 | 25180157 | 343249 | 288573 | 54676 | 1832080 |
| **119** | 2021-04-25 | 25446941 | 266784 | 220229 | 46555 | 1850188 |

## Last Update

Often the data is not updated on weekends, so get the highest date in the dataset.

In [11]:
```
last_update = vaccinations.loc[vaccinations.index[-1], "date"].strftime('%Y-%m-%d')
last_update
```

Out[11]:
```
'2021-04-25'
```

# Doses Used

In [12]:
```
doses = vaccinations.loc[ : , ['date', 'dosen_differenz_zum_vortag']]
# Rename columns
doses.columns = ['date', 'doses used']
```

In [13]:
```
# Scale number of doses as millions
doses['doses used'] = doses['doses used'] / 1_000_000
```

## Doses Daily

In [14]:
```
doses_daily = doses.set_index('date', inplace=False)
doses_daily.tail(1)
```

Out[14]:

| | doses used |
|---|---|

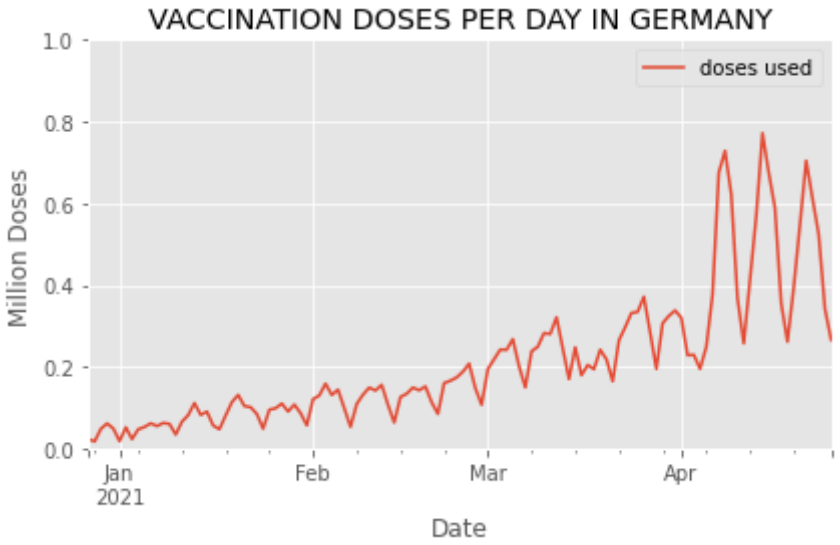
| | date | doses used |
|---|---|---|
| | **date** | |
| **2021-04-25** | 0.266784 | |

In [15]:
```
# What is the highest number of doses used in a day?
max_doses_daily = max(doses_daily['doses used'])
max_doses_daily
```

Out[15]: 0.772206

In [16]:
```
doses_daily.plot(
    ylim=(0,math.ceil(max_doses_daily)),
    xlabel='Date',
    ylabel='Million Doses',
    title='VACCINATION DOSES PER DAY IN GERMANY')
```

Out[16]: <AxesSubplot:title={'center':'VACCINATION DOSES PER DAY IN GERMANY'}, xlabel='Date', ylabel='Million Doses'>




## Doses per Weekday (in the last 6 weeks)

In [17]:
```
last_6_weeks = doses.tail(42)
```

In [18]:
```
# 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-18-45013977109e>: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 [19]:
```
# check:
last_6_weeks.tail(3)
```

Out[19]:

| | date | doses used | weekday |
|---|---|---|---|
| **117** | 2021-04-23 | 0.525155 | Friday |
| **118** | 2021-04-24 | 0.343249 | Saturday |
| **119** | 2021-04-25 | 0.266784 | Sunday |

In [20]:
```
# drop the date column
last_6_weeks = last_6_weeks.drop(labels=['date'], axis=1)
```

In [21]:
```
#last_6_weeks.set_index('weekday', inplace=True)
last_6_weeks.tail(3)
```

Out[21]:

| | doses used | weekday |
|---|---|---|
| **117** | 0.525155 | Friday |
| **118** | 0.343249 | Saturday |
| **119** | 0.266784 | Sunday |

In [22]:
```
pivot_table =last_6_weeks.pivot(columns='weekday', values='doses used')
pivot_table.tail()
```

Out[22]:

| weekday | Friday | Monday | Saturday | Sunday | Thursday | Tuesday | Wednesday |
|---|---|---|---|---|---|---|---|
| **115** | NaN | NaN | NaN | NaN | NaN | NaN | 0.704776 |
| **116** | NaN | NaN | NaN | NaN | 0.613668 | NaN | NaN |

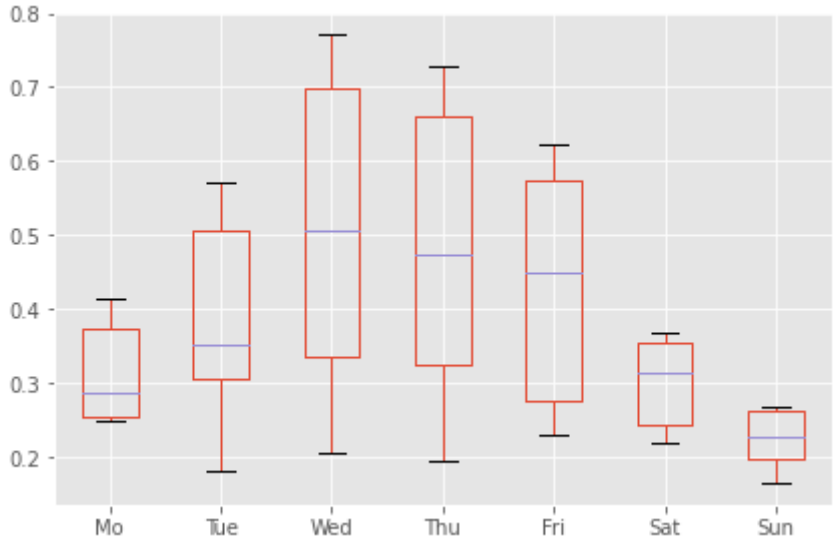
| weekday | Friday | Monday | Saturday | Sunday | Thursday | Tuesday | Wednesday |
|---|---|---|---|---|---|---|---|
| **117** | 0.525155 | NaN | NaN | NaN | NaN | NaN | NaN |
| **118** | NaN | NaN | 0.343249 | NaN | NaN | NaN | NaN |
| **119** | NaN | NaN | NaN | 0.266784 | NaN | NaN | NaN |

In [23]:
```
# 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[23]:

| | Mo | Tue | Wed | Thu | Fri | Sat | Sun |
|---|---|---|---|---|---|---|---|
| **115** | NaN | NaN | 0.704776 | NaN | NaN | NaN | NaN |
| **116** | NaN | NaN | NaN | 0.613668 | NaN | NaN | NaN |
| **117** | NaN | NaN | NaN | NaN | 0.525155 | NaN | NaN |
| **118** | NaN | NaN | NaN | NaN | NaN | 0.343249 | NaN |
| **119** | NaN | NaN | NaN | NaN | NaN | NaN | 0.266784 |

In [24]:
```
weekday_boxplot = pivot_table.boxplot()
```




In [25]:
```
fig = weekday_boxplot.get_figure()
fig.savefig('img/weekday_boxplot.png')
```

## Doses per Week

In [26]:
```
# 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[26]:

| date | million doses used |
|---|---|
| **2021-03-29** | 2.126160 |
| **2021-04-05** | 1.890022 |
| **2021-04-12** | 3.444497 |
| **2021-04-19** | 3.619760 |
| **2021-04-26** | 3.001861 |

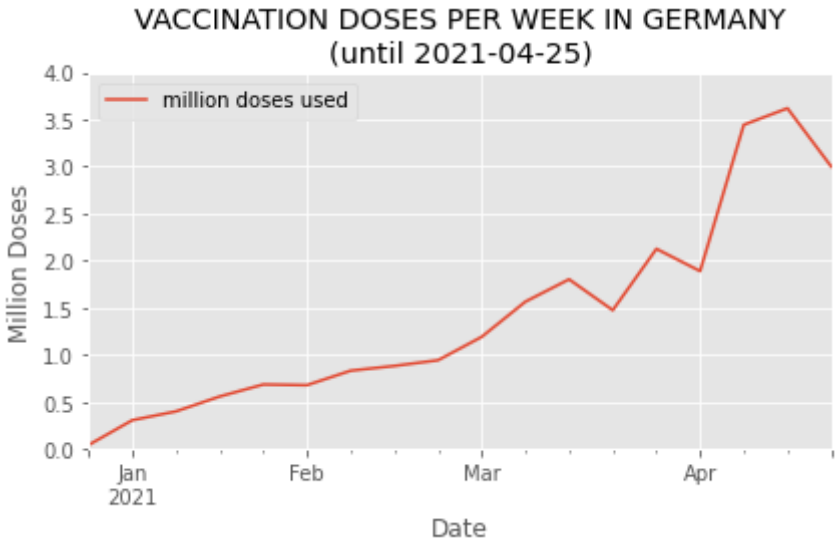
In [27]:
```
# What is the highest number of doses used in a week?
```

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

Out[27]: 3.61976

In [28]:
```
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[28]: <AxesSubplot:title={'center':'VACCINATION DOSES PER WEEK IN GERMANY\n(until 2021-04-25)'}, xlabel='Date', ylabel='Million Doses'>




## Doses per Month

In [29]:
```
# M = month end frequency
doses_monthly = doses.groupby(pd.Grouper(key='date',freq='M')).sum()
doses_monthly.tail()
```

Out[29]:

| | doses used |
|---|---|
| **date** | |
| **2020-12-31** | 0.204534 |

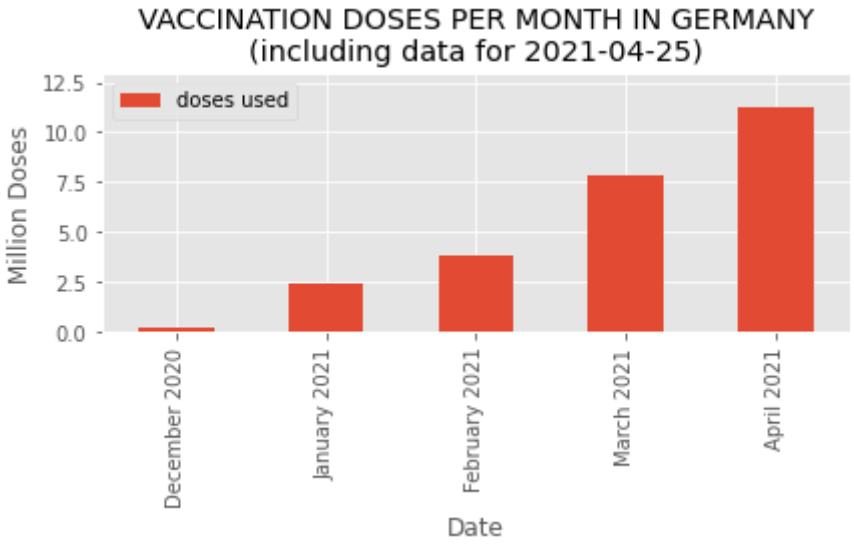
| date | doses used |
|---|---|
| **2021-01-31** | 2.345083 |
| **2021-02-28** | 3.776766 |
| **2021-03-31** | 7.828447 |
| **2021-04-30** | 11.292111 |

In [30]:
```
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[30]:

| label | doses used |
|---|---|
| **December 2020** | 0.204534 |
| **January 2021** | 2.345083 |
| **February 2021** | 3.776766 |
| **March 2021** | 7.828447 |
| **April 2021** | 11.292111 |

In [31]:
```
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 [32]:
```
fig = monthly_plot.get_figure()
fig.savefig('img/monthly_doses_germany.png')
```

# Vaccination Campaign Progress

In [33]:
```
doses_cumulative = vaccinations.loc[ : , ['date', 'personen_erst_kumulativ', 'personen_voll_kumulativ']]
doses_cumulative.set_index('date', inplace=True)
doses_cumulative.tail(3)
```

Out[33]:

| date | personen_erst_kumulativ | personen_voll_kumulativ |
|---|---|---|
| **2021-04-23** | 18977896 | 5859012 |
| **2021-04-24** | 19266469 | 5913688 |
| **2021-04-25** | 19486698 | 5960243 |

In [34]:
```
population_germany = 83_200_000
# Calculate new fields
doses_cumulative['first vaccination'] = round(
    doses_cumulative['personen_erst_kumulativ'] * 100 / population_germany,
    2)
```

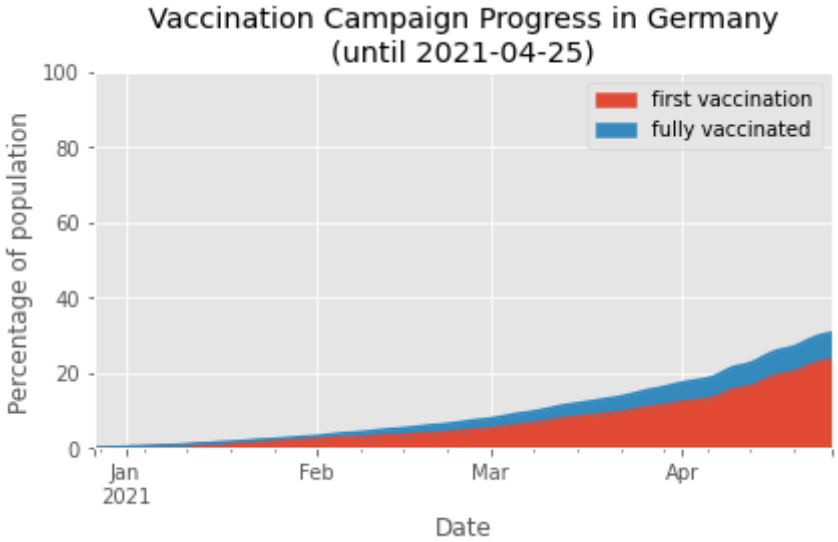
```
doses_cumulative['fully vaccinated'] = round(
    doses_cumulative['personen_voll_kumulativ'] * 100 / population_germany,
    2)
doses_cumulative.drop(columns=['personen_erst_kumulativ','personen_voll_kumulativ'], inplace=True)
doses_cumulative.tail(3)
```

Out[34]:

| date | first vaccination | fully vaccinated |
|---|---|---|
| **2021-04-23** | 22.81 | 7.04 |
| **2021-04-24** | 23.16 | 7.11 |
| **2021-04-25** | 23.42 | 7.16 |

In [35]:

```
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 [36]:

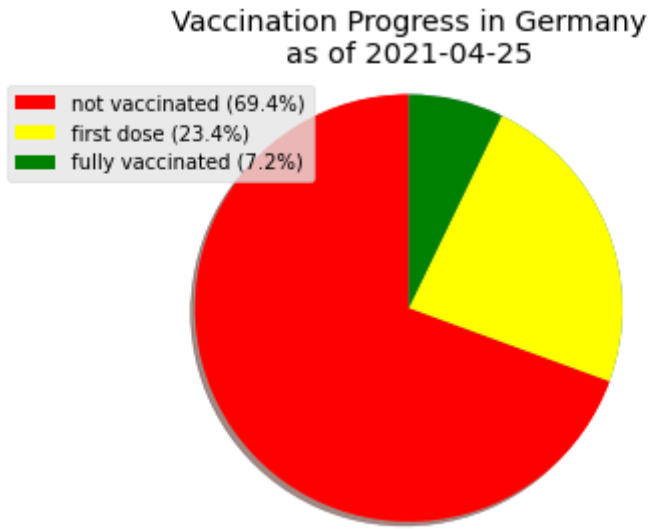
```
fig = doses_area_plot.get_figure()
fig.savefig('img/vaccinations_germany_area_plot.png')
```

## As of Today

In [37]:
```
# get the last line of the data
current_state = doses_cumulative.iloc[-1]
current_state
```

Out[37]:
```
first vaccination    23.42
fully vaccinated      7.16
Name: 2021-04-25 00:00:00, dtype: float64
```

In [38]:
```
percentage_not_vacc = 100 - current_state['first vaccination'] - current_state['fully vaccinated']
labels = [f"not vaccinated ({round(percentage_not_vacc, 1)}%)",
          f"first dose ({round(current_state['first vaccination'],1)}%)",
          f"fully vaccinated ({round(current_state['fully vaccinated'],1)}%)"]
colors = ['red', 'yellow', 'green']
sizes = [percentage_not_vacc,
         current_state['first vaccination'],
         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()
```



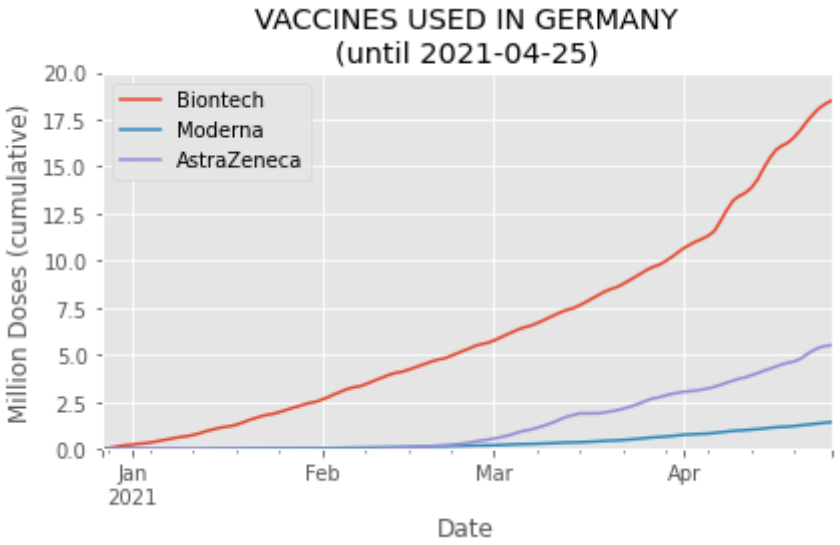

# Vaccines in Use

In [39]:
```
vaccine_use = vaccinations.loc[ : , ['date', 'dosen_biontech_kumulativ',
                                     'dosen_moderna_kumulativ',
                                     'dosen_astrazeneca_kumulativ']]
# Rename columns
vaccine_use.columns = ['date', 'Biontech', 'Moderna', 'AstraZeneca']
# 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.tail(3)
```

Out[39]:

| date | Biontech | Moderna | AstraZeneca |
|---|---|---|---|
| **2021-04-23** | 18.093104 | 1.359863 | 5.383941 |
| **2021-04-24** | 18.320801 | 1.396718 | 5.462638 |
| **2021-04-25** | 18.501881 | 1.422978 | 5.522082 |

In [40]:
```
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 [41]:
```
fig = vaccines_used.get_figure()
fig.savefig('img/vaccines_used_in_germany.png')
```

In [ ]: