Session 1

In this first session we will familiarize ourselves with the working environment and some datasets, starting with iris. Then, you can follow with digits and olivetti. Finally, you should get to know the openml platform from which a dataset will be drawn as part of the exercise in the exam.

The Iris dataset

The Iris dataset has been widely used to introduce basic machine learning concepts and methods. It consists of $N = 150$ samples, 50 for each of $C = 3$ classes, represented by vectors of $D = 4$ homogeneous real features. One of the classes is linearly separable from the rest, but the other two are not linearly separable. Although today it is considered a "toy" dataset, it is still very useful for introducing basic concepts and methods.

First we import some standard and sklearn libraries:

In [1]:
```
import pandas as pd
import seaborn as sns
from sklearn.datasets import load_iris
```

Reading the Iris dataset:

In [2]:
```
iris = load_iris()
print(dir(iris))
X = iris.data
y = iris.target
fn = iris.feature_names
cn = iris.target_names
print(iris.DESCR)
```

```
['DESCR', 'data', 'data_module', 'feature_names', 'filename', 'frame', 'target', 'target_names']
.. _iris_dataset:

Iris plants dataset
--------------------

**Data Set Characteristics:**

:Number of Instances: 150 (50 in each of three classes)
:Number of Attributes: 4 numeric, predictive attributes and the class
:Attribute Information:
    - sepal length in cm
    - sepal width in cm
    - petal length in cm
    - petal width in cm
    - class:
            - Iris-Setosa
            - Iris-Versicolour
            - Iris-Virginica

:Summary Statistics:

============== ==== ==== ======= ===== ====================
                Min  Max   Mean    SD   Class Correlation
============== ==== ==== ======= ===== ====================
sepal length:   4.3  7.9   5.84   0.83    0.7826
sepal width:    2.0  4.4   3.05   0.43   -0.4194
petal length:   1.0  6.9   3.76   1.76    0.9490  (high!)
petal width:    0.1  2.5   1.20   0.76    0.9565  (high!)
============== ==== ==== ======= ===== ====================

:Missing Attribute Values: None
:Class Distribution: 33.3% for each of 3 classes.
:Creator: R.A. Fisher
:Donor: Michael Marshall (MARSHALL%PLU@io.arc.nasa.gov)
:Date: July, 1988

The famous Iris database, first used by Sir R.A. Fisher. The dataset is taken
from Fisher's paper. Note that it's the same as in R, but not as in the UCI
Machine Learning Repository, which has two wrong data points.

This is perhaps the best known database to be found in the
pattern recognition literature.  Fisher's paper is a classic in the field and
is referenced frequently to this day.  (See Duda & Hart, for example.)  The
data set contains 3 classes of 50 instances each, where each class refers to a
```

```
type of iris plant.  One class is linearly separable from the other 2; the
latter are NOT linearly separable from each other.

.. dropdown:: References

  - Fisher, R.A. "The use of multiple measurements in taxonomic problems"
    Annual Eugenics, 7, Part II, 179-188 (1936); also in "Contributions to
    Mathematical Statistics" (John Wiley, NY, 1950).
  - Duda, R.O., & Hart, P.E. (1973) Pattern Classification and Scene Analysis.
    (Q327.D83) John Wiley & Sons.  ISBN 0-471-22361-1.  See page 218.
  - Dasarathy, B.V. (1980) "Nosing Around the Neighborhood: A New System
    Structure and Classification Rule for Recognition in Partially Exposed
    Environments".  IEEE Transactions on Pattern Analysis and Machine
    Intelligence, Vol. PAMI-2, No. 1, 67-71.
  - Gates, G.W. (1972) "The Reduced Nearest Neighbor Rule".  IEEE Transactions
    on Information Theory, May 1972, 431-433.
  - See also: 1988 MLC Proceedings, 54-64.  Cheeseman et al"s AUTOCLASS II
    conceptual clustering system finds 3 classes in the data.
  - Many, many more ...
```

We convert the corpus into a pandas dataframe to facilitate its description:

In [3]:
```
data = pd.DataFrame(data=X, columns=fn)
data['species'] = pd.Series(iris.target_names[y], dtype='category')
data
```

Out[3]:

	sepal length (cm)	sepal width (cm)	petal length (cm)	petal width (cm)	species
0	5.1	3.5	1.4	0.2	setosa
1	4.9	3.0	1.4	0.2	setosa
2	4.7	3.2	1.3	0.2	setosa
3	4.6	3.1	1.5	0.2	setosa
4	5.0	3.6	1.4	0.2	setosa
...	...	...	...	...	...
145	6.7	3.0	5.2	2.3	virginica
146	6.3	2.5	5.0	1.9	virginica
147	6.5	3.0	5.2	2.0	virginica
148	6.2	3.4	5.4	2.3	virginica
149	5.9	3.0	5.1	1.8	virginica

150 rows × 5 columns

Let's look at some basic statistics:

In [4]:
```
data.describe()
```

Out[4]:

	sepal length (cm)	sepal width (cm)	petal length (cm)	petal width (cm)
count	150.000000	150.000000	150.000000	150.000000
mean	5.843333	3.057333	3.758000	1.199333
std	0.828066	0.435866	1.765298	0.762238
min	4.300000	2.000000	1.000000	0.100000
25%	5.100000	2.800000	1.600000	0.300000
50%	5.800000	3.000000	4.350000	1.300000
75%	6.400000	3.300000	5.100000	1.800000
max	7.900000	4.400000	6.900000	2.500000

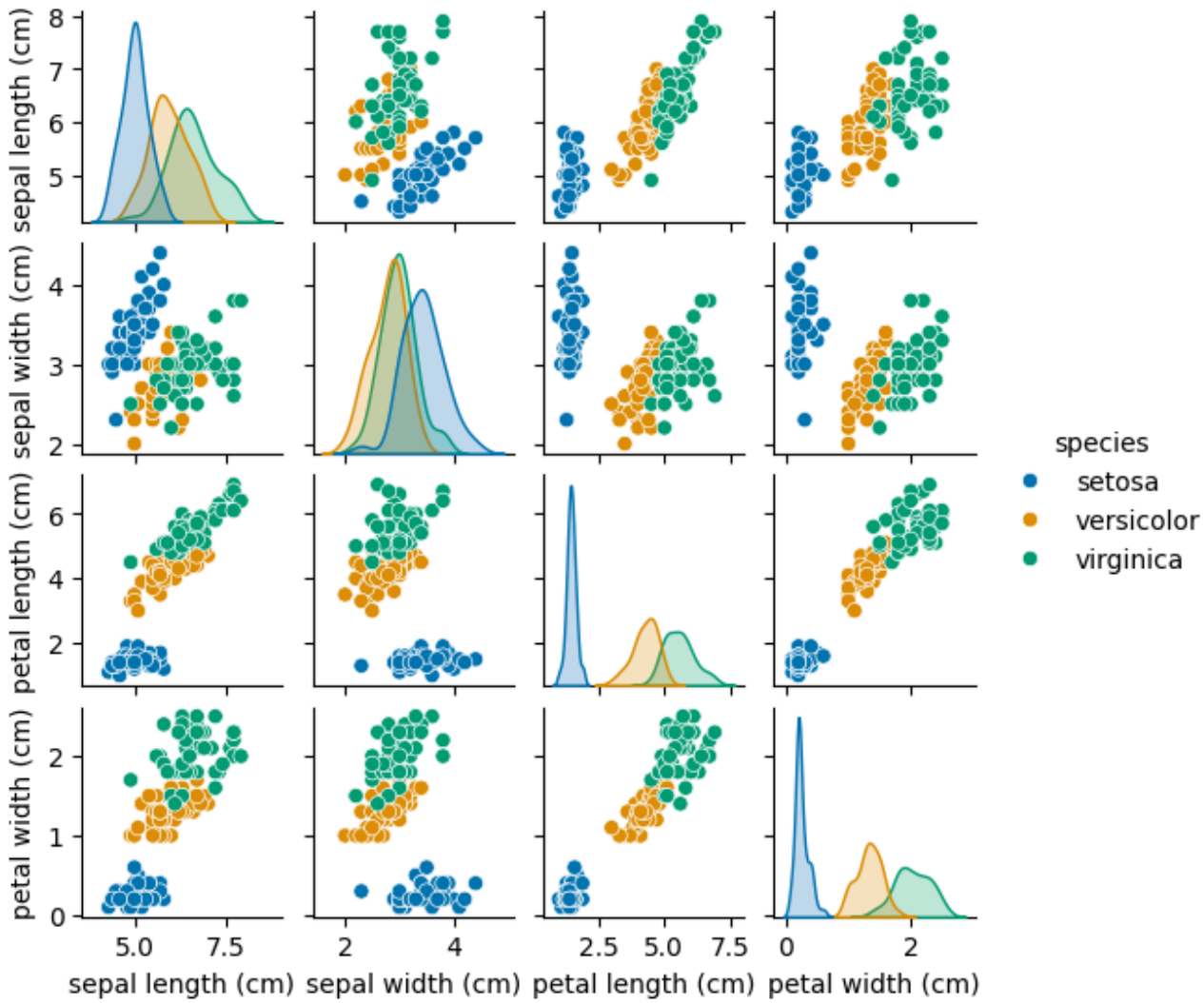
We check that we have 50 samples of each class:

In [5]:
```
data.groupby('species', observed=False).size()
```

Out[5]:
```
species
setosa        50
versicolor    50
virginica     50
dtype: int64
```

Since we have few features, it's a good idea to make a scatter matrix plot:

In [6]:
```
sns.pairplot(data, hue="species", height = 1.4, palette = 'colorblind');
```



Question: which class is linearly separated from the other two?

The Digits dataset

Like iris, Digits can be considered a "toy" dataset. However, compared to iris, Digits represents a jump of complexity due to the greater number of classes, $C = 10$, samples, $N = 1797$, and dimension of feature vectors, $D = 64$. In addition, digits addresses one of the main perceptual tasks of machine learning: optical character recognition (OCR) and, more specifically, handwritten digit recognition. Although handwritten digit recognition has been considered a "solved" task since the 1990s, image classification in general remains a complex task of great academic and commercial interest. So the relative simplicity of Digits is very convenient as an introductory task to image classification.

In [1]:
```
import matplotlib.pyplot as plt
from sklearn.datasets import load_digits
```

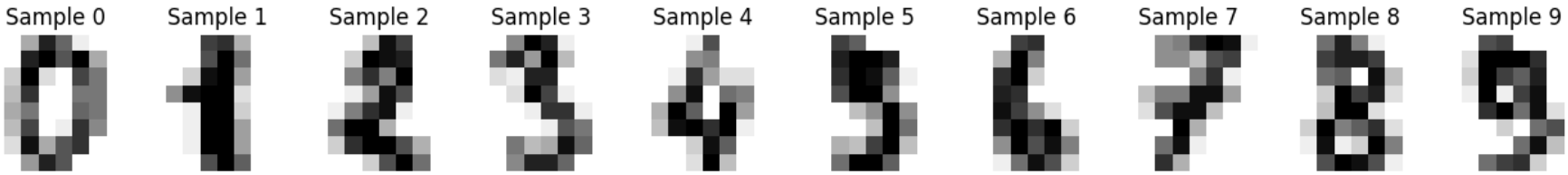
In [2]:
```
digits = load_digits()
print(digits.DESCR)
```

```
.. _digits_dataset:

Optical recognition of handwritten digits dataset
--------------------------------------------------

**Data Set Characteristics:**

:Number of Instances: 1797
:Number of Attributes: 64
:Attribute Information: 8x8 image of integer pixels in the range 0..16.
:Missing Attribute Values: None
:Creator: E. Alpaydin (alpaydin '@' boun.edu.tr)
:Date: July; 1998

This is a copy of the test set of the UCI ML hand-written digits datasets
https://archive.ics.uci.edu/ml/datasets/Optical+Recognition+of+Handwritten+Digits

The data set contains images of hand-written digits: 10 classes where
each class refers to a digit.

Preprocessing programs made available by NIST were used to extract
normalized bitmaps of handwritten digits from a preprinted form. From a
total of 43 people, 30 contributed to the training set and different 13
to the test set. 32x32 bitmaps are divided into nonoverlapping blocks of
4x4 and the number of on pixels are counted in each block. This generates
an input matrix of 8x8 where each element is an integer in the range
0..16. This reduces dimensionality and gives invariance to small
distortions.

For info on NIST preprocessing routines, see M. D. Garris, J. L. Blue, G.
T. Candela, D. L. Dimmick, J. Geist, P. J. Grother, S. A. Janet, and C.
L. Wilson, NIST Form-Based Handprint Recognition System, NISTIR 5469,
1994.

.. dropdown:: References

  - C. Kaynak (1995) Methods of Combining Multiple Classifiers and Their
    Applications to Handwritten Digit Recognition, MSc Thesis, Institute of
    Graduate Studies in Science and Engineering, Bogazici University.
  - E. Alpaydin, C. Kaynak (1998) Cascading Classifiers, Kybernetika.
  - Ken Tang and Ponnuthurai N. Suganthan and Xi Yao and A. Kai Qin.
    Linear dimensionalityreduction using relevance weighted LDA. School of
    Electrical and Electronic Engineering Nanyang Technological University.
    2005.
  - Claudio Gentile. A New Approximate Maximal Margin Classification
```

Algorithm. NIPS. 2000.

Let's see the first 10 images:

In [3]:
```
_, axes = plt.subplots(nrows=1, ncols=10, figsize=(16, 16))
for ax, image, label in zip(axes, digits.images, digits.target):
    ax.set_axis_off()
    ax.imshow(image, cmap=plt.cm.gray_r, interpolation="none")
    ax.set_title("Sample {!s}".format(label))
```



The Olivetti dataset

Olivetti contains $N = 400$ face images of $C = 40$ people, with 10 images per person. The images were acquired at different times, varying the lighting, facial expression (eyes closed or not; smiling or not) and facial details (with or without glasses). All of them are normalized to 64×64 grayscale pixels between 0 and 1; that is, each image can be seen as a vector of $D = 4096$ dimensions of real features in $[0, 1]$. People are identified with an integer class label from 0 to 39.

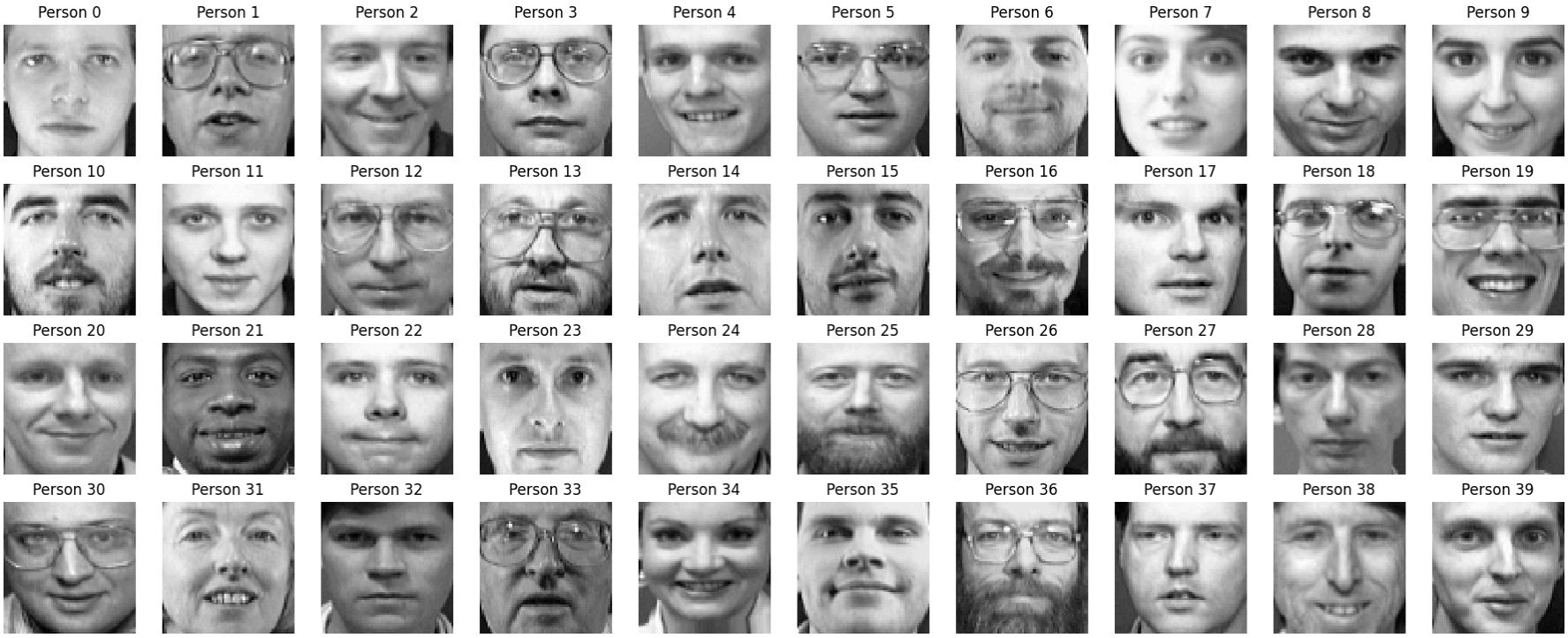
In [1]:
```
import numpy as np
import matplotlib.pyplot as plt
from sklearn.datasets import fetch_olivetti_faces
```

In [2]:
```
orl = fetch_olivetti_faces()
print(orl.DESCR)
```

```
.. _olivetti_faces_dataset:

The Olivetti faces dataset
--------------------------

`This dataset contains a set of face images`_ taken between April 1992 and
April 1994 at AT&T Laboratories Cambridge. The
:func:`sklearn.datasets.fetch_olivetti_faces` function is the data
fetching / caching function that downloads the data
archive from AT&T.

.. _This dataset contains a set of face images: https://cam-orl.co.uk/facedatabase.html

As described on the original website:

    There are ten different images of each of 40 distinct subjects. For some
    subjects, the images were taken at different times, varying the lighting,
    facial expressions (open / closed eyes, smiling / not smiling) and facial
    details (glasses / no glasses). All the images were taken against a dark
    homogeneous background with the subjects in an upright, frontal position
    (with tolerance for some side movement).

**Data Set Characteristics:**

=================   ====================
Classes                              40
Samples total                       400
Dimensionality                     4096
Features            real, between 0 and 1
=================   ====================

The image is quantized to 256 grey levels and stored as unsigned 8-bit
integers; the loader will convert these to floating point values on the
interval [0, 1], which are easier to work with for many algorithms.

The "target" for this database is an integer from 0 to 39 indicating the
identity of the person pictured; however, with only 10 examples per class, this
relatively small dataset is more interesting from an unsupervised or
semi-supervised perspective.

The original dataset consisted of 92 x 112, while the version available here
consists of 64x64 images.

When using these images, please give credit to AT&T Laboratories Cambridge.
```

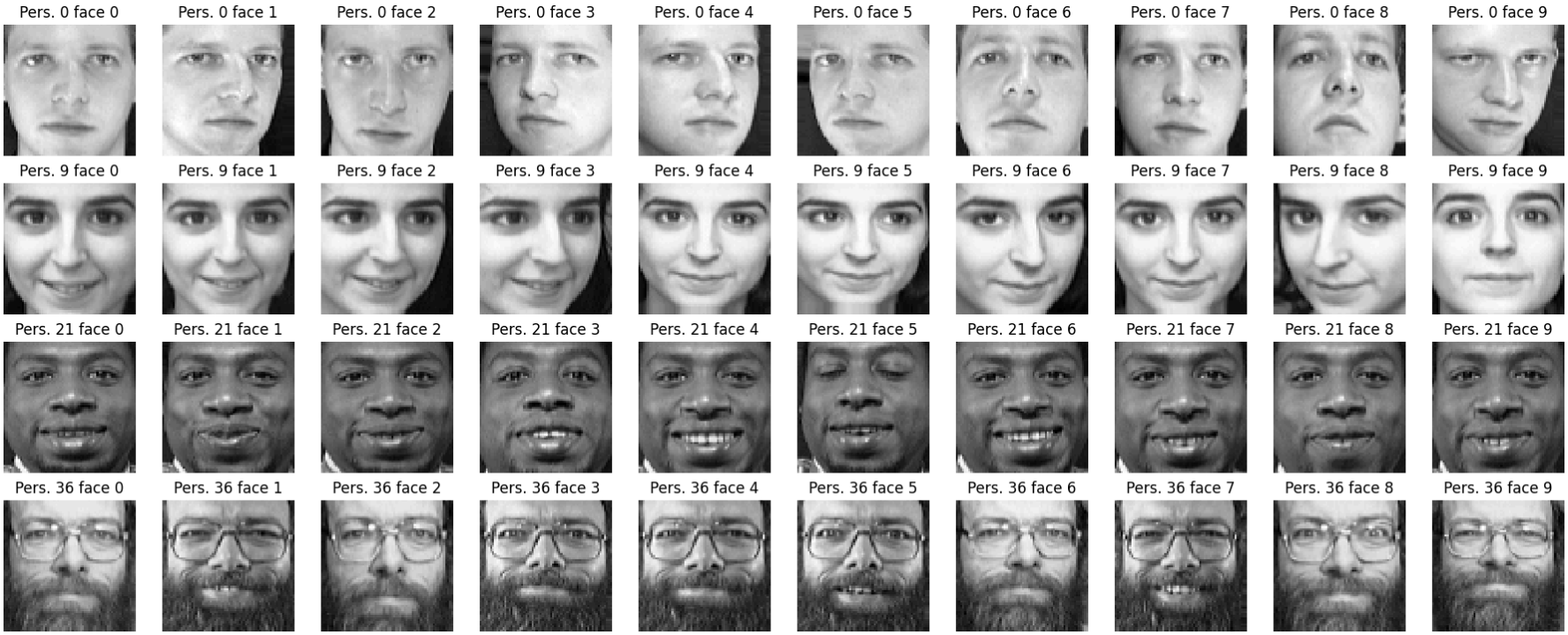
Let's see the first image of each person:

In [3]:
```
nrows, ncols = 4, 10
fig, axes = plt.subplots(nrows=nrows, ncols=ncols, figsize=(18, 18*nrows/ncols), constrained_layout=True)
for c in np.arange(0, 40):
    ax = axes.flat[c]; ax.set_axis_off(); ax.set_title(f"Person {c}")
    ax.imshow(orl.images[10*c], cmap=plt.cm.gray, interpolation="none")
```



Let's see some people's 10 images:

In [4]:
```
cc = [0, 9, 21, 36]
nrows, ncols = len(cc), 10
fig, axes = plt.subplots(nrows=nrows, ncols=ncols, figsize=(18, 18*nrows/ncols), constrained_layout=True)
for i, c in enumerate(cc):
    for j in np.arange(0, 10):
        ax = axes.flat[10*i+j]; ax.set_axis_off(); ax.set_title(f"Pers. {c} face {j}")
        ax.imshow(orl.images[10*c+j], cmap=plt.cm.gray, interpolation="none")
```



openml

openml.org is an open platform for sharing datasets, algorithms and machine learning experiments with tabulated data. The main concepts on which it is based are:

- **Dataset:** set of tabulated data
- **Task:** data set, learning task to be performed and evaluation method
- **Flow:** machine learning pipeline with details on software to use and hyperparameters to adjust
- **Run:** evaluation experiment of a flow in a task

The choice of datasets can be made in the datasets section. The chosen datasets can be downloaded directly or using sklearn's fetch_openml function. However, in general it is preferable to choose datasets previously chosen by other users (with some specific criteria) and published in the benchmarks section. In particular, we can highlight three recent "benchmark suites" for comparing and evaluating classification techniques:

- **OpenML-CC18 Curated Classification benchmark:** 72 sets from Bahri et al, 2022
- **Tabular benchmark categorical classification:** 7 sets from Grinsztajn et al, 2022
- **AutoML Benchmark All Classification:** 71 sets from Gijsbers et al, 2019

In [ ]:
```
!pip install openml
```

In [2]:
```
import openml
# OpenML-CC18 99; Tabular 334; AutoML 271
benchmark_suite = openml.study.get_suite(suite_id=334)
benchmark_suite
```

Out[2]:
```
OpenML Benchmark Suite
======================
ID..............: 334
Name............: Tabular benchmark categorical classification
Status..........: in_preparation
Main Entity Type: task
Study URL.......: https://www.openml.org/s/334
# of Data.......: 7
# of Tasks......: 7
Creator.........: https://www.openml.org/u/26324
Upload Time.....: 2023-01-16 03:22:41
```

In [3]:
```
openml.datasets.list_datasets(data_id=benchmark_suite.data, output_format='dataframe')
```

Out[3]:

	did	name	version	uploader	status	format	MajorityClassSize	MinorityClassSize	NumberOfClasses	NumberOfFeatures	Numbe
44156	44156	electricity	13	26324	active	arff	19237.0	19237.0	2.0	9.0	
44157	44157	eye_movements	8	26324	active	arff	3804.0	3804.0	2.0	24.0	
44159	44159	covertype	13	26324	active	arff	211840.0	211840.0	2.0	55.0	
45035	45035	albert	2	26324	active	arff	29126.0	29126.0	2.0	32.0	
45036	45036	default-of-credit-card-clients	4	26324	active	arff	6636.0	6636.0	2.0	22.0	
45038	45038	road-safety	7	26324	active	arff	55881.0	55881.0	2.0	33.0	
45039	45039	compas-two-years	5	26324	active	arff	2483.0	2483.0	2.0	12.0	

In [4]:
```
openml.tasks.list_tasks(task_id=benchmark_suite.tasks, output_format="dataframe")
```

Out[4]:

	tid	ttid	did	name	task_type	status	estimation_procedure	evaluation_measures	so
361110	361110	TaskType.SUPERVISED_CLASSIFICATION	44156	electricity	Supervised Classification	active	10-fold Crossvalidation	predictive_accuracy	
361111	361111	TaskType.SUPERVISED_CLASSIFICATION	44157	eye_movements	Supervised Classification	active	10-fold Crossvalidation	predictive_accuracy	
361113	361113	TaskType.SUPERVISED_CLASSIFICATION	44159	covertype	Supervised Classification	active	10-fold Crossvalidation	predictive_accuracy	
361282	361282	TaskType.SUPERVISED_CLASSIFICATION	45035	albert	Supervised Classification	active	10-fold Crossvalidation	predictive_accuracy	
361283	361283	TaskType.SUPERVISED_CLASSIFICATION	45036	default-of-credit-card-clients	Supervised Classification	active	10-fold Crossvalidation	predictive_accuracy	
361285	361285	TaskType.SUPERVISED_CLASSIFICATION	45038	road-safety	Supervised Classification	active	10-fold Crossvalidation	predictive_accuracy	
361286	361286	TaskType.SUPERVISED_CLASSIFICATION	45039	compas-two-years	Supervised Classification	active	10-fold Crossvalidation	predictive_accuracy	

Accessing to one of the dataset ("electricity") by their data id provided in the list of datasets above.

In [5]:
```
from sklearn.datasets import fetch_openml
# data id corresponding to dataset "electricity" with 9 features and 2 classes
data_id = 44156
X, y = fetch_openml(data_id=data_id, return_X_y=True, as_frame=False, parser="liac-arff")
```