We talk of 0, 1, 2, 3.14 as values, but 0, 1, 2, 3.14 are also names of values; we cannot refer to values without naming them. In the computing world, a value is “stored” in memory as bits. How a sequence of bits relates to a value is determined by a particular coding and decoding scheme. For instance, the scheme that represents nonnegative integers in base 2 over 8 bits can let us “store” the value (named) 9 as 00001001 somewhere in memory. Neither a name nor a sequence of bits is a value; to refer to the name of a value and to the storage of a value somewhere in memory, let us talk about \textit{v-name} and \textit{v-storage}, respectively, without investigating further what the value itself actually is…

A v-name can have many \textit{occurrences}: in the expression \(X = 2+2\), there are two occurrences of the v-name 2. As much as “value” is an abstract notion, occurrences of v-names and v-storages can be concretely located in the text of a program and in computer memory, respectively.

An occurrence of a v-name is always \textit{referring} to a v-storage that determines some value according to an implicit coding and decoding scheme. The following diagram is fundamental; it indicates that an occurrence \(\nu\) of a v-name is always, necessarily, associated with, referencing, a v-storage \(s\), that is, a sequence of bits stored at a particular memory address; a particular coding and decoding scheme is implicit and determines the value that is named via \(\nu\) and stored as \(s\).

There are two kinds of v-names, \textit{constant expressions} and \textit{variable expressions}, with as particular cases, \textit{constants} and \textit{variables}, respectively.

For instance, 2 and 1+1 are two constant expressions, the first of which is a constant. In the following code, the two occurrences of 2 and the unique occurrence of 1+1 are seen to refer to the same v-storage, with the expectation that it “stores” the value 2 thanks to an appropriate coding and decoding scheme.

```python
>>> id(2), id(2), id(1+1)
(4481604704, 4481604704, 4481604704)
```

\[ \begin{array}{c}
\nu \\
\downarrow
\end{array} \quad \begin{array}{c}
s \quad \begin{array}{c}
1 \\
0 \\
1 \\
\cdots \\
\cdots \\
1
\end{array}
\end{array} \]

\[ \begin{array}{c}
2 \\
\downarrow
\end{array} \quad \begin{array}{c}
\quad \begin{array}{c}
\quad
\quad
\quad
\quad
\quad
\quad
\quad
\quad
\quad
\quad
\end{array}
\end{array} \]

\[ \begin{array}{c}
1+1 \\
\downarrow
\end{array} \quad \begin{array}{c}
\quad \begin{array}{c}
\quad
\quad
\quad
\quad
\quad
\quad
\quad
\quad
\quad
\quad
\end{array}
\end{array} \]

Date: Session 1, 2016.
The code

```python
>>> 2 is 2, 2 is 1+1
(True, True)
```

allows us to draw the diagrams

![Diagram 1](image1.png)

and suspect that $s_1$ and $s_2$ are actually identical, so that the picture could actually be:

![Diagram 2](image2.png)

Whereas the value named by a constant expression is fully determined by the syntactic rules and semantics of the language, the value named by a variable is arbitrary. With the assignment operator =, we let a variable refer to a v-storage. Thanks to the code `X = 2`, we are somehow letting `X` be a v-name for the value 2, but more precisely, and fundamentally, we are letting `X` be another v-name for the value (named) 2 by letting `X` reference the same v-storage as the occurrence of the v-name 2 to the right of the assignment operator does, and this for at least as long as we do not change the value of `X`:

![Diagram 3](image3.png)

So from the code

```python
>>> X = 2; Y = 2
>>> X is Y
True
```

we are justified in drawing the diagram

![Diagram 4](image4.png)
whereas from the code

```python
>>> X = [2]; Y = [2]
>>> X is Y
False
```

we are justified in drawing the diagram

The code

```python
>>> X = 1; Y = 0; id(X), id(Y)
(4481604672, 4481604640)
>>> X = 0; Y = 1; id(X), id(Y)
(4481604640, 4481604672)
```

leads to the diagram:

The code

```python
>>> X = [0]; Y = [1]; id(X), id(Y)
(4521980104, 4521980360)
>>> X = [1]; Y = [0]; id(X), id(Y)
(4521980296, 4521980104)
```

leads to the diagram:
The following code involves 5 occurrences of names for the same value and 3 v-storages.

```python
>>> id([0, 1]); id([0, 1]); id([0, 1]); id([0, 1]); id([0, 1])
4511633480
4486339464
4486339464
4486339464
4511631496
```

In reference to the four occurrences of `[0, 1]`, either 2 or 3 v-storages are involved with the following code.

```python
>>> id([0, 1]) is id([0, 1])
False
>>> id([0, 1]), id([0, 1])
(4521980232, 4521980232)
```

With the following code

```python
>>> id([0, 1]), id([2, 3])
(4521957128, 4521957128)
```

we see one value “take the place” of another one in memory:

[Diagram: Encoding of [0, 1] and then [2, 3]]
There are more occurrences of v-names than in our code:

```python
>>> import sys
>>> sys.getrefcount(0), sys.getrefcount(1), sys.getrefcount(2), sys.getrefcount(3)
(1459, 1670, 457, 172)
>>> sys.getrefcount(4), sys.getrefcount(5), sys.getrefcount(6), sys.getrefcount(7)
(243, 104, 89, 51)
>>> sys.getrefcount(8), sys.getrefcount(9), sys.getrefcount(254), sys.getrefcount(255)
(187, 60, 4, 18)
>>> sys.getrefcount(256), sys.getrefcount(257), sys.getrefcount(258), sys.getrefcount(259)
(59, 2, 2, 2)
```

The following code provides another illustration of the transition between integers smaller than 257 and integers at least equal to 257.

```python
>>> X = 255
>>> X is 255
True
>>> X = 256
>>> X is 256
True
>>> X = 257
>>> X is 257
False
>>> X = 258
>>> X is 258
False
```

But the following code does not.

```python
>>> X = 255; X is 255
True
>>> X = 256; X is 256
True
>>> X = 257; X is 257
True
>>> X = 258; X is 258
True
```

In the following code, each of the 4 occurrences of `[0, 1]` refers to a different v-storage of the value `[0, 1]`, and each of those v-storages is minimally referred to.

```python
>>> X = [0, 1]; Y = [0, 1]; Z = [0, 1]
>>> X is Y, Y is Z, X is Z
(False, False, False)
>>> sys.getrefcount([0, 1])
1
>>> sys.getrefcount(X), sys.getrefcount(Y), sys.getrefcount(Z)
(2, 2, 2)
```
The following three pieces of code deal with a list of integers and lists of lists of integers.

```python
>>> X = [0] * 3; X
[0, 0, 0]
>>> id(X), id(X[0]), id(X[1]), id(X[2])
(4521957128, 4481604640, 4481604640, 4481604640)
>>> X[0] = 1; X
[1, 0, 0]
>>> id(X), id(X[0]), id(X[1]), id(X[2])
(4521957128, 4481604672, 4481604640, 4481604640)
```

```python
>>> X = [[0]] * 3; X
[[0], [0], [0]]
>>> id(X), id(X[0]), id(X[1]), id(X[2])
(4521981960, 4511587784, 4511587784, 4511587784)
>>> X[0][0] = 1; X
[[1], [1], [1]]
>>> id(X), id(X[0]), id(X[1]), id(X[2])
(4521981960, 4511587784, 4511587784, 4511587784)
```
>>> X = [[0], [0], [0]]; X
[[0], [0], [0]]
>>> id(X), id(X[0]), id(X[1]), id(X[2])
(4521980424, 4521980104, 4521981832, 4521980680)
>>> X[0][0] = 1; X
[[1], [0], [0]]
>>> id(X), id(X[0]), id(X[1]), id(X[2])
(4521980424, 4521980104, 4521981832, 4521980680)

\[
\begin{align*}
&\text{Encoding of } [[0], [0], [0]] \\
&\text{and then } [[1], [0], [0]]
\end{align*}
\]