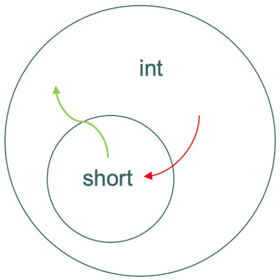
# Semester Review

- Imperative Programming
  - Inspired by the explicit state manipulation of Von-Neuman hardware architecture
  - CPU↔Memory

# Semester Review



- Type Systems
  - *"A type is a set of values"*
  - Help identify programming errors
    - A type mismatch usually indicates a programming error
    - Type propagation
  - Dynamic/static type systems
  - Subtypes/Supertypes
    - Type hierarchies
    - Automatic type coercion (conversion, promotion)
    - Widening/narrowing conversions

# Semester Review

- Pattern matching
  - Simple patterns are expressions that consist purely of constructors and variables
  - Canonical representations!
  - Destructuring
    - let (x,y) = (1,2)
  - Powerful declarative way of accessing substructures of objects

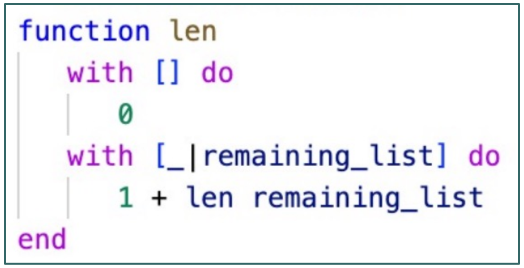
# Semester Review

- OOP
  - “classic” vs “modern” OOP
  - Modern OOP
    - No classes, instead structures with behavior
    - No (class) inheritance – traits/interfaces instead or object composition
    - Limited if any member protection – facilitates pattern matching on objects.
  - Subtype polymorphism with dynamic dispatch for statically typed languages
  - *Duck typing* for dynamically typed languages

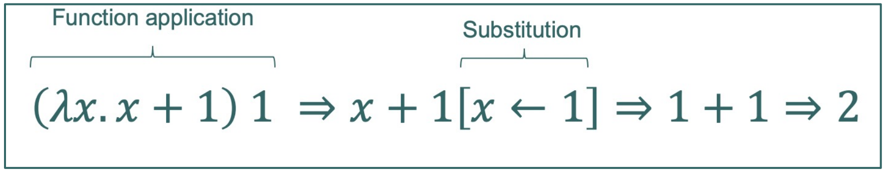
# Semester Review


Everything is a Value!

- Functional Programming
  - Based on the lambda calculus
  - *"Everything is a value"*
  - No explicit state
  - First-class functions
  - Declarative:
    - *"The What rather than the How"*

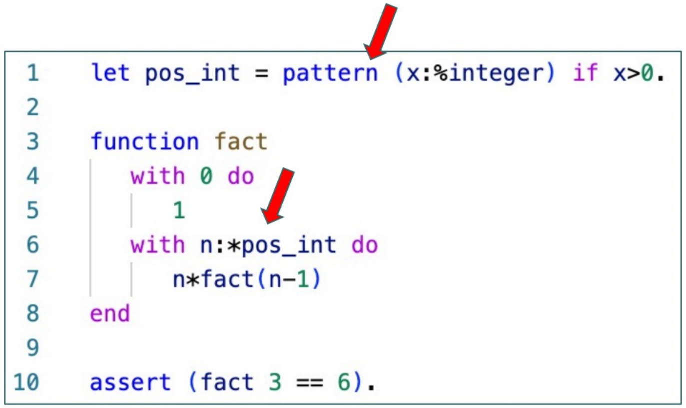


```
function len
   with [] do
      0
   with [_|remaining_list] do
      1 + len remaining_list
end
```



$$\overbrace{(\lambda x.\, x + 1)\, 1}^{\text{Function application}} \Rightarrow x + 1\overbrace{[x \leftarrow 1]}^{\text{Substitution}} \Rightarrow 1 + 1 \Rightarrow 2$$

# Semester Revie

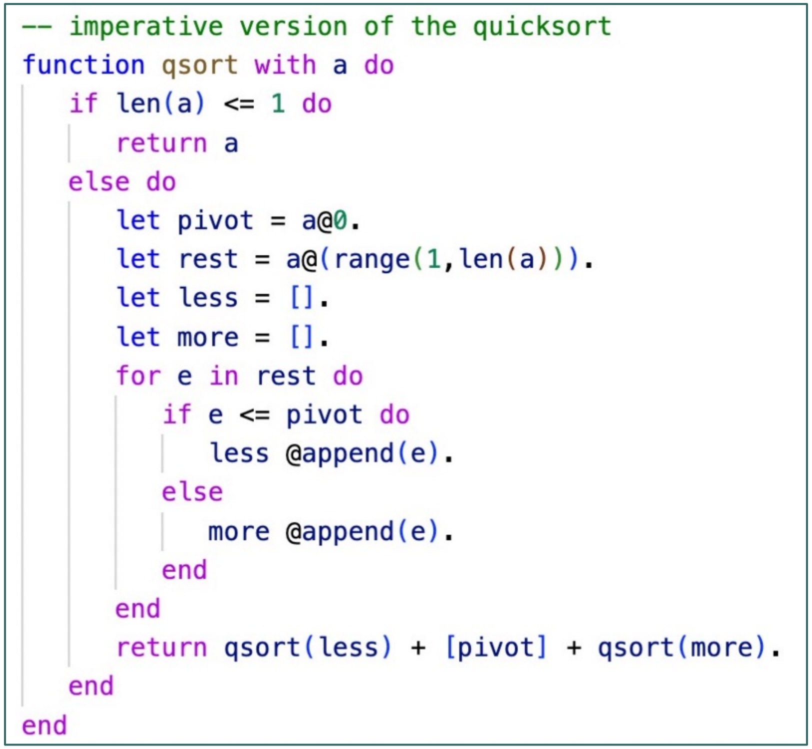


```
let pos_int = pattern (x:%integer) if x>0.

function fact
  with 0 do
    1
  with n:*pos_int do
    n*fact(n-1)
end

assert (fact 3 == 6).
```

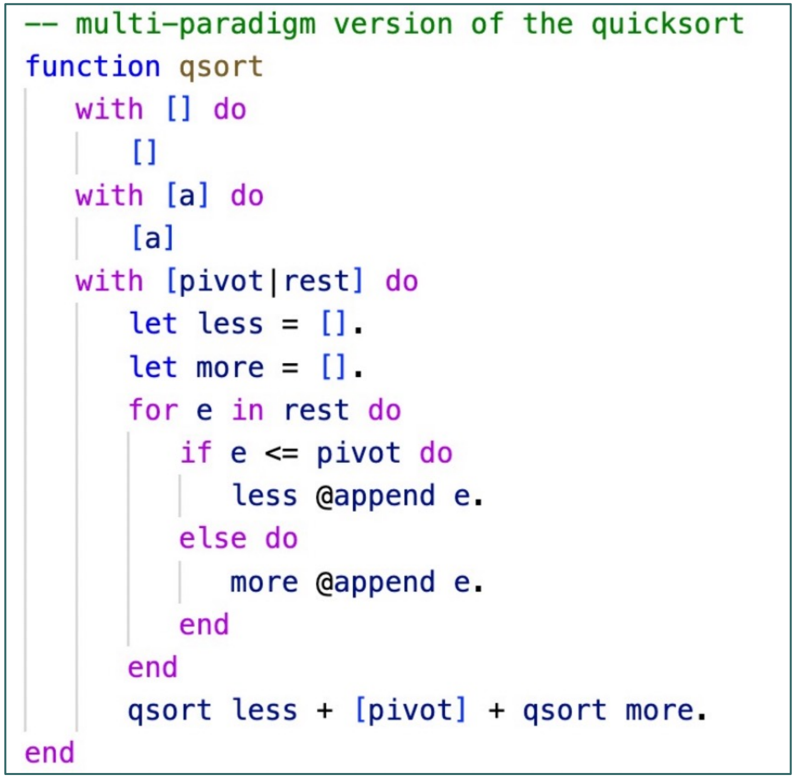
- First-Class Patterns
  - Patterns themselves are considered values
    - Store in variables
    - Pass to/from functions
  - Promoting features to *first-class status increases expressiveness* of programming languages
    - Shorter programs that make intentions of programmer clearer.

# Semester Review

- Putting it all together



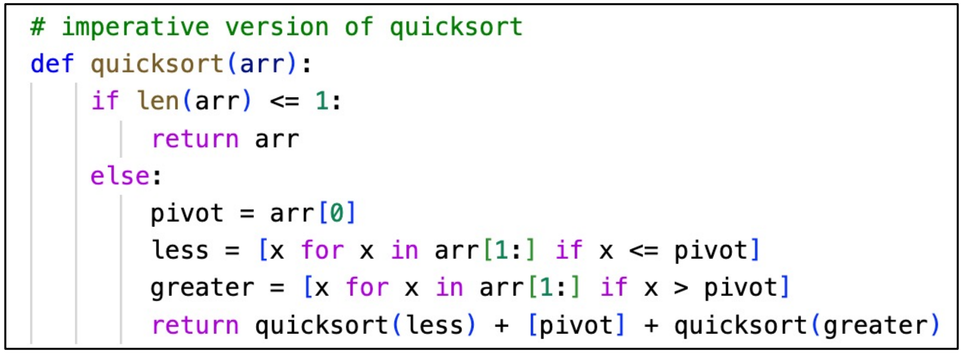
```
-- imperative version of the quicksort
function qsort with a do
  if len(a) <= 1 do
    return a
  else do
    let pivot = a@0.
    let rest = a@(range(1,len(a))).
    let less = [].
    let more = [].
    for e in rest do
      if e <= pivot do
        less @append(e).
      else
        more @append(e).
      end
    end
    return qsort(less) + [pivot] + qsort(more).
  end
end
```



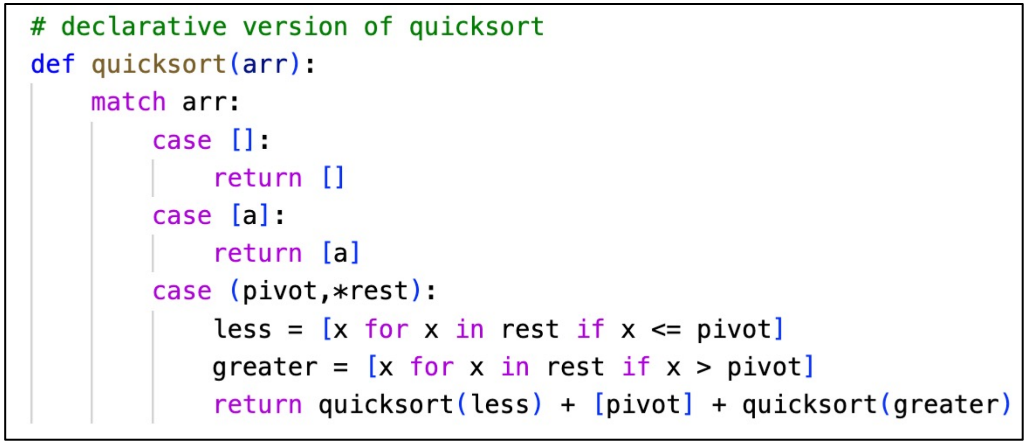
```
-- multi-paradigm version of the quicksort
function qsort
  with [] do
    []
  with [a] do
    [a]
  with [pivot|rest] do
    let less = [].
    let more = [].
    for e in rest do
      if e <= pivot do
        less @append e.
      else do
        more @append e.
      end
    end
    qsort less + [pivot] + qsort more.
end
```

# Semester Review

- Putting it all together – multi-paradigm



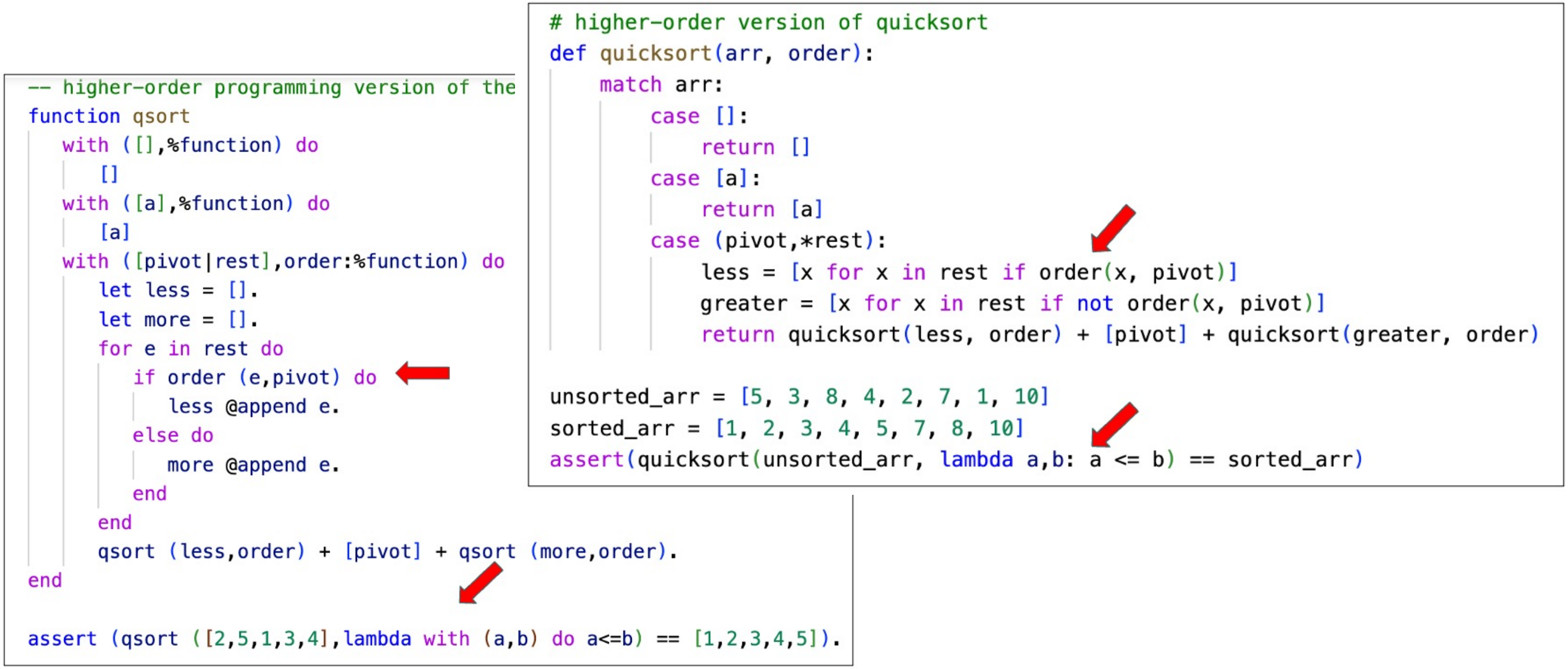
```python
# imperative version of quicksort
def quicksort(arr):
    if len(arr) <= 1:
        return arr
    else:
        pivot = arr[0]
        less = [x for x in arr[1:] if x <= pivot]
        greater = [x for x in arr[1:] if x > pivot]
        return quicksort(less) + [pivot] + quicksort(greater)
```



```python
# declarative version of quicksort
def quicksort(arr):
    match arr:
        case []:
            return []
        case [a]:
            return [a]
        case (pivot,*rest):
            less = [x for x in rest if x <= pivot]
            greater = [x for x in rest if x > pivot]
            return quicksort(less) + [pivot] + quicksort(greater)
```

# Semester Review

- Putting it all together – higher-order



```
-- higher-order programming version of the
function qsort
   with ([],%function) do
      []
   with ([a],%function) do
      [a]
   with ([pivot|rest],order:%function) do
      let less = [].
      let more = [].
      for e in rest do
         if order (e,pivot) do
            less @append e.
         else do
            more @append e.
         end
      end
      qsort (less,order) + [pivot] + qsort (more,order).
end

assert (qsort ([2,5,1,3,4],lambda with (a,b) do a<=b) == [1,2,3,4,5]).
```

```
# higher-order version of quicksort
def quicksort(arr, order):
    match arr:
        case []:
            return []
        case [a]:
            return [a]
        case (pivot,*rest):
            less = [x for x in rest if order(x, pivot)]
            greater = [x for x in rest if not order(x, pivot)]
            return quicksort(less, order) + [pivot] + quicksort(greater, order)

unsorted_arr = [5, 3, 8, 4, 2, 7, 1, 10]
sorted_arr = [1, 2, 3, 4, 5, 7, 8, 10]
assert(quicksort(unsorted_arr, lambda a,b: a <= b) == sorted_arr)
```

# Semester Review

The End