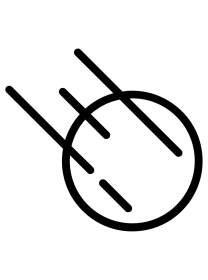
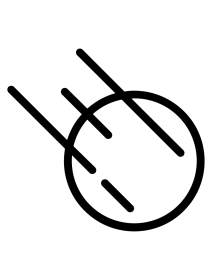
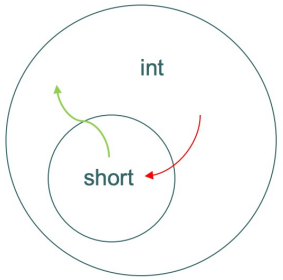


Semester Review

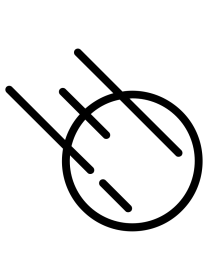
- Imperative Programming
  - Inspired by the explicit state manipulation of Von-Neuman hardware architecture
  - CPU↔Memory



Semester Review

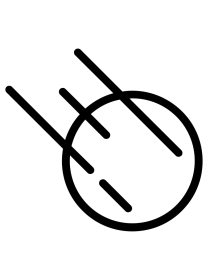


- Type Systems
  - *"A type is a set of values"*
  - Help identify programming errors
    - A type mismatch usually indicates a programming error
    - Type propagation
  - Dynamic/static type systems
  - Subtypes/Supertypes
    - Type hierarchies
    - Automatic type coercion (conversion, promotion)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



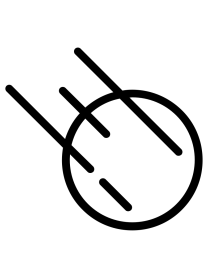
Semester Review

- 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



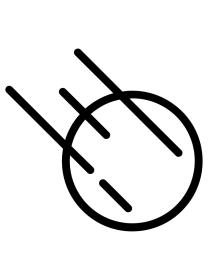
Semester Review

- 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
```

Function application — Substitution

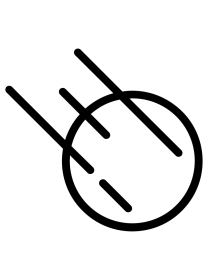
$$(\lambda x.\, x + 1)\ 1 \Rightarrow x + 1[x \leftarrow 1] \Rightarrow 1 + 1 \Rightarrow 2$$



Semester Revie

```
1   let pos_int = pattern (x:%integer) if x>0.
2
3   function fact
4     with 0 do
5       1
6     with n:*pos_int do
7       n*fact(n-1)
8   end
9
10  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.

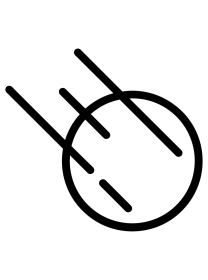


Semester Review

- 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
```

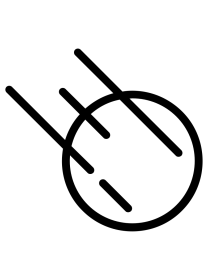


Semester Review

- Putting it all together

```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