Liszt Cheat Sheet!

Mesh types:

`Mesh` – the entire unstructured mesh.

`Cell` – a 3D element composed of several faces.

`Face` – a 2D element composed of several edges

`Edge` – a 1D element connecting two vertices

`Vertex` – a 0D element representing a single point.

`Set[T <: MeshObj]` – a set of *vertices*, *edges*, *faces* or *cells* (the `MeshObj` subclasses).

Accessing adjacent mesh elements by index:

Some topological operators allow indexing adjacent mesh objects.

Ex: `vertex(cell, 3)` accesses the 4th vertex of the cell.

vertex: `vertex(cell, i), vertex(face, i)`

edge: `edge(cell, i), edge(face, i)`

face: `face(cell, i), face(edge, i)`

cell: `cell(cell, i), cell(edge, i)`

Accessing the mesh:

- Use the built-in `mesh` to reference the global mesh object.
- Accessing **all vertices / edges / faces / cells** in the mesh: `vertices(mesh), edges(mesh), faces(mesh), cells(mesh)`
- Accessing adjacent elements by **vertex**:

  `cells(vertex), faces(vertex), edges(vertex):` Return the set of all cells, faces or edges containing the vertex

  `vertices(vertex):` Returns the set of all vertices sharing an edge with the vertex.
- Accessing elements adjacent to an **edge**:

  `cells(edge), faces(edge):` Return the set of all cells or faces containing the edge

  `vertices(edge):` Return the two vertices that the edge contains.

  `facesCW(edge), facesCCW(edge):` Return the set of all faces *f* containing the edge, oriented such that when viewed from vertex `head(edge)`, cell `outside(`*f*`)` is clock-wise / counter-clockwise from *f*.

  `head(edge), tail(edge):` Return the vertex that the edge points towards / away from

  `flip(edge):` Returns the same edge, oriented in the opposite direction. (Note that `head(edge) == tail(flip(edge))`.)
- Accessing elements adjacent to a **face:**

  `cells(face):` Returns the set of cells containing a face.

  `edges(face), vertices(face):` Return the set of edges/vertices contained by the face.

  `edgesCW(face), edgesCCW(face):` Return the set of edges contained by the face oriented such clock-wise / counter-clockwise around the edge when observed from the cell `outside(edge)`.

  `outside(face), inside(face):` Return the cell on the face which is the dual of head / tail.

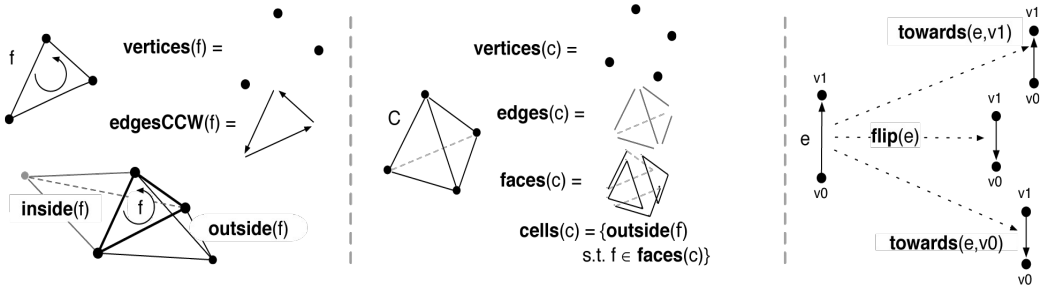
  `flip(face):` returns the same face, oriented in the opposite direction. (Note that `outside(face) == inside(flip(face))`.)
- Accessing elements adjacent to a **cell**:

  `vertices(cell), edges(cell), faces(cell):` Return the set of all vertices / edges / faces that are contained by the cell.

  `cells(cell):` Returns the set of cells that share a face with the cell.
- Conditionally re-orienting elements:

  `towards(edge, vertex):` Returns edge *e* such that head(*e*) == vertex. *e* is either `edge` or `flip(edge)`.

  `towards(face, cell):` Returns face *f* such that `outside(`*f*`) == cell`. *f* is either `face` or `flip(face)`.



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Vector and Matrix Construction:

- creating **vectors** of n elements:

```
var vec1: Vec[_1, Float] = Vec(1.f)
var vec2: Vec[_2, Float] = Vec(1.f,1.f)
var vec3: Vec[_3, Float] = Vec(1.f,1.f,1.f)
...
```

- creating *row* x *column* **matrices**:

```
var mat2x3 = Mat(vec3, vec3)
var mat3x4 = Mat(vec4, vec4, vec4)
...
```

Vector and Matrix Operators:

- **<Vec[N,T]> +- <Vec[N,T]>**
  Vector addition/subtraction.
- **<Mat[R,C,T]> +- <Mat[R,C,T]>**
  Matrix addition/subtraction.
- **<Numeric> */ <Vec[N,T]>, <Vec[N,T]> */ <Numeric>**
  Scalar multiplication /division, returns a `Vec[N,T]`.
- **<Numeric> */ <Mat[R,C,T>, <Mat[R,C,T]> */ <Numeric>**
  Scalar multiplication/division, returns a `Mat[R,C,T]`.
- **<Mat[R,C,T]> * Vec[R,T]**
  Matrix vector multiply, returns type `Vec[C,T]` if T is numeric.
- **<Vec[N,T]> min / max <Vec[N,T]>**
  Maps the `min/max` operator over the vectors, returns type `Vec[N,T]`.

Vector and Matrix Component manipulation:

- Use **meta-integer literals** (**_0**, **_1**, …) to access vector and matrix components:
  v(_0), v(_2), v(_4) - accesses the 1st, 3rd and 5th element of vector `v`.
  m(_0,_2), m(_3,_1) - accesses element at row 0, col 2 and row 3, col 1 of matrix `m`.

Vector mathematical built-ins:

cross Compute the cross product of two 3-vectors.
Ex: `val normal = cross(v1, v2)`

dot Takes the dot product of the two vectors.
Ex: `var mag = dot(v1, v1)`

normalize Return the normalized vector.
Ex: `v1 = normalize(v1)`

Constructing fields and boundary sets:

FieldWithConst[MO <: MeshObj, VT](s : VT) : Field[MO, VT]

Creates a new field over `MO` with value type `VT` and initial value `s`. This can only be called at object scope, not within any function.
Ex: `val pressure = FieldWithConst[Cell, Float](0.f)`

FieldWithLabel[MO >: MeshObj, VT](url: String) : Field[MO, VT]

Creates a new field over `MO` with value type `VT`, and load the initial values using the locator string `url`. (The only currently supported locator is "position", which loads the positions of vertices in the mesh.) This can only be called at object scope.
Ex. `val position = FieldWithLabel[Vertex, Vec[_3,Float]]("position")`

BoundarySet[MO <: MeshObj(name : String) : Set[MO]

Loads the set of mesh topology of the given identifier fro the mesh filename.
Ex: `val wall = BoundarySet[Face]("wall")`

Associative Operators for Fields and Scalar reduction variables:

- **+=** and/or **-=**
- ***=** and/or **/=**
- **min** (use form "`a = a min b`")
- **max** (use form "`a = a max b`")
- **&=**
- **|=**

Do not use different associative operators on the same reduction variable within a single for-comprehension unless they are in the same bullet point!

Miscellaneous built-ins:

- **Print(as: Any*) : Unit**
  Output all arguments, newline terminated.
  Ex: `Print("Temperature is: ", num_degrees)`
- **size[MO <: MeshObj](s:Set[MO]**
  Retrieve the size of a set.
  Ex: `val num_cells = size(cells(mesh))`
- **ID[MO >: MeshObj](m : MO) : Int**
  Return the unique ID of the mesh object as it was named in the input file.
  Ex. `val id = ID(cell0)`
- **wall_time()**
  Return time in seconds since the program started. Low resolution, accurate to 2ms.
- **processor_time()**
  Return a time in seconds according to the processor's tick count. Accurate to 1ns, but will produce inconsistent results if the thread switches processors, so accurate only for short (<1s) events.