Modularly Programmable Syntax

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List Syntax

DERIVED FORM

```
[1, 2, 3, 4, 5]
```

EXPANSION

```
Cons(1, Cons(2, Cons(3, Cons(4, Cons(5, Nil)))))
```

HTML Syntax

DERIVED FORM

```
<h1>Welcome back, <%name></h1>
```

EXPANSION

```
H1Element(Empty, Seq(
  TextNode("Welcome back, "), TextNode(name)))
```

Regular Expression Syntax

DERIVED FORM

```
/A|T|G|C/
```

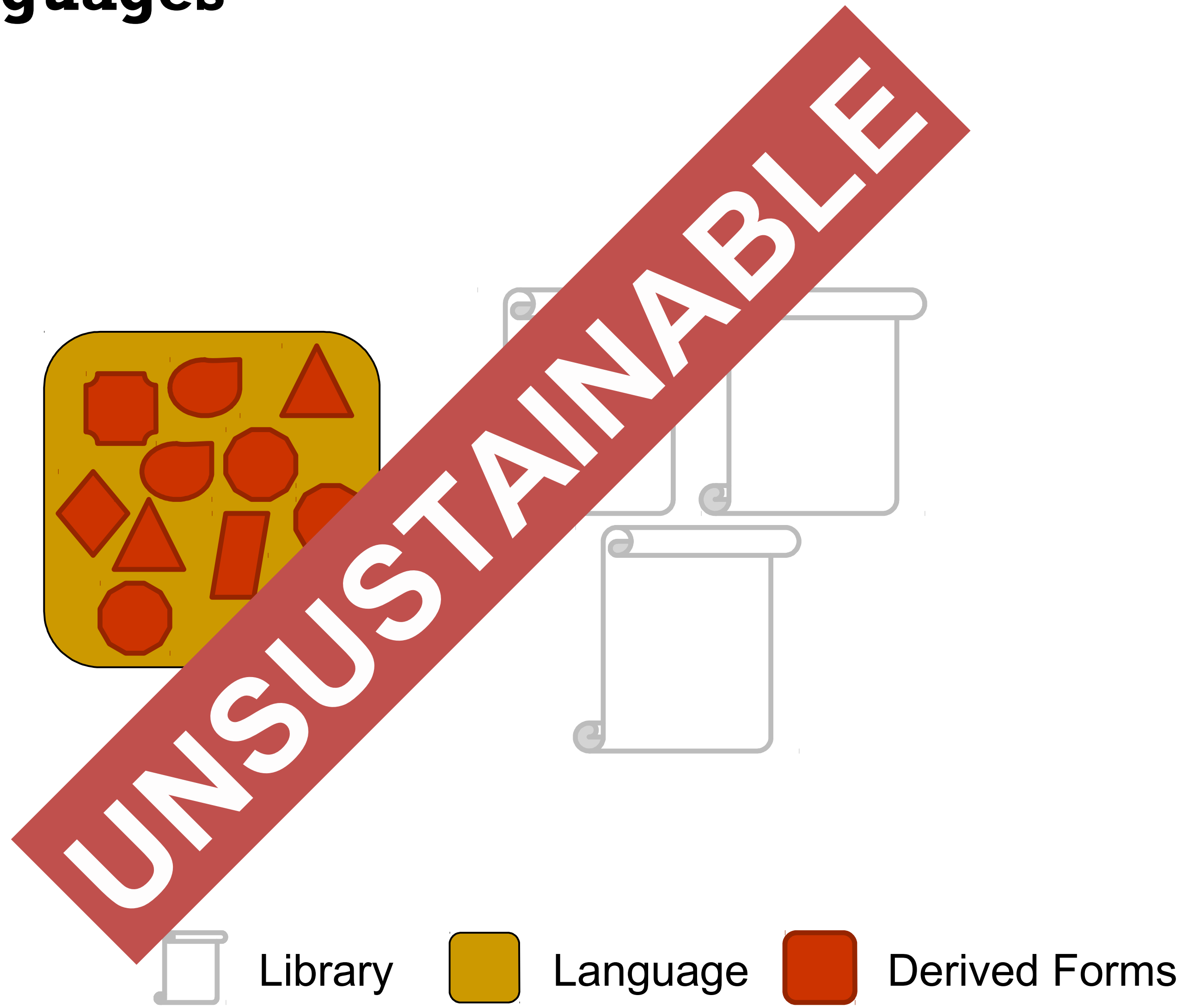
EXPANSION

```
Or(Str “A”, Or(Str “T”, Or(Str “G”, Str “C”)))
```

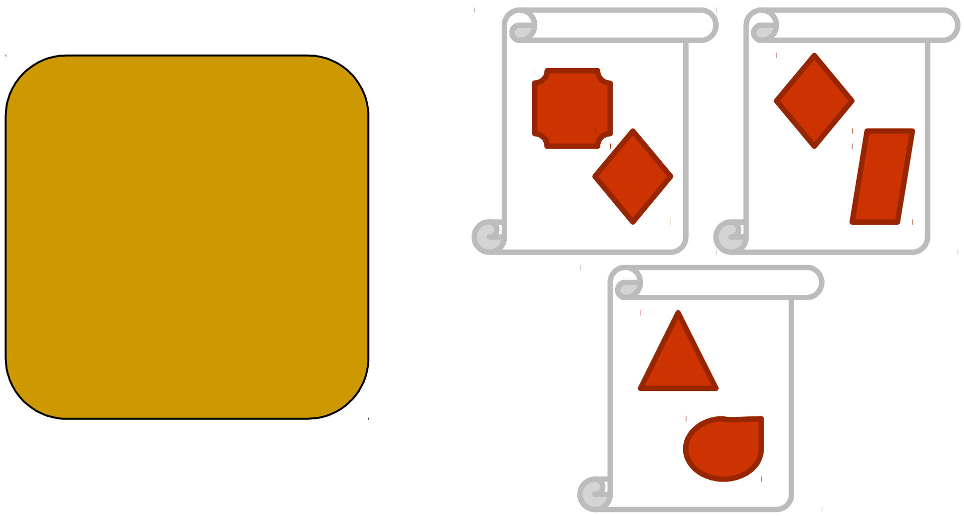
Many Examples

- Lists, sets, maps, multisets, vectors, arrays, …
- Monadic commands (ala Haskell **do** notation)
- Regular expressions, SQL, other database query languages
- HTML, CSS, SASS, LESS, JSON, ...
- Dates, times, URLs, paths, …
- Quasiquotation, object language syntax
- Grammars
- Mathematical and scientific notations (e.g. SMILE)

Large Languages



A Better Approach: Programmable Syntax



```
import rx, html, json, kdb, list, xml

let x = /A|T|G|C/
fun greet(name : string) => <h1>Hello, <%name></h1>
```

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import rx, html, json, kdb, list, xml

let x = /A|T|G|C/
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Composability: Can there be **conflicts**?
With the base language? Between extensions?

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Identifiability: Where did this syntax come from?

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Type Discipline: What type does q have?

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Composability: Can there be **conflicts**? With the base language? Between extensions?

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Hygiene: Can I rename other variables safely? (or does the expansion *capture* specific variables?)

Our Solution: Typed Syntax Macros (TSMs)

```
import rx, html, json, kdb, list, xml

let x = rx.$regex /A|T|G|C/
fun greet(name : string) => html.$html <h1>Hello, <%name></h1>
let q = kdb.$query {(!R)@&{&/x!/:2_!x}'!R}
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A fixed set of available **outer delimiters** prevent conflict.

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```
syntax $query at Query {
  static fn(body : Body) : Exp option => (* … query parser here … *)
}
```

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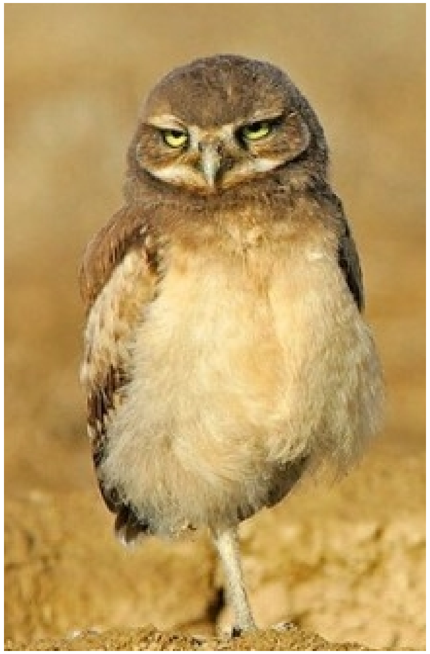

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```
syntax $query at Query {
  static fn(body : Body) : Exp option => (* … query parser here … *)
}
```

Type annotation requires that expansion be of this type.

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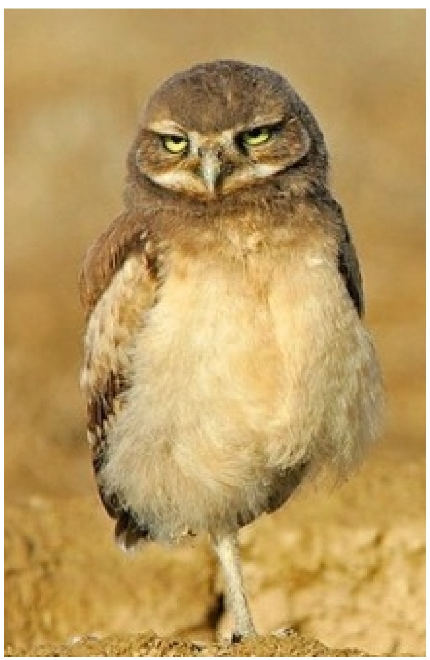

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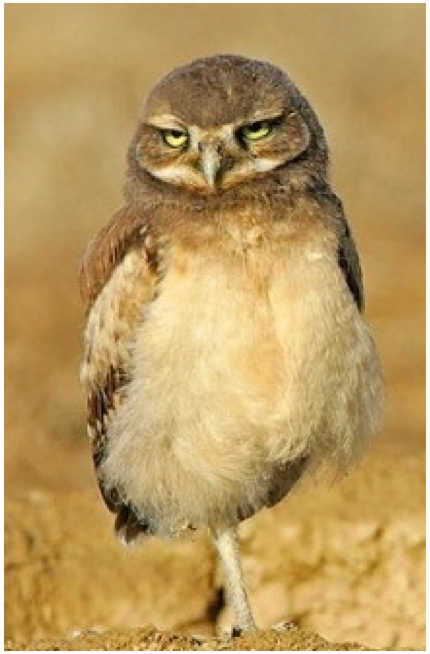
```

Only spliced subexpressions can refer to surrounding context.



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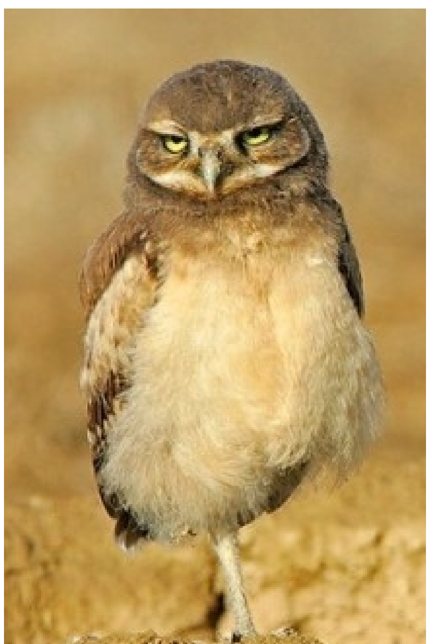

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Our Solution: Typed Syntax Macros (TSMs)

Expanded expressions

$$\Delta\ \Gamma \vdash \hat{e} \leadsto e : \tau$$

Unexpanded expressions

Pattern TSMs

```
pattern syntax $html at HTML {
  static fn(body : Body) : Pat option => (* … HTML pattern parser … *)
}
```

```
import rx, html, json, kdb, list, xml

fun get_name(x : HTML) => match x with
      html.$html <h1>Hello, <%name></h1> => name
    | _ => raise Error
```

Pattern TSMs

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pattern syntax $html at HTML {
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```
import rx, html, json, kdb, list, xml

fun get_name(x : HTML) => match x with
    html.$html <h1>Hello, <%name></h1> => name
  | _ => raise Error
```

Only spliced subpatterns can bind variables.

The ML Module System

Abstract Datatypes

```
signature RX = sig
  type t
  val Empty : t
  val Str : string -> t
  val Seq : t * t -> t
  val Or : t * t -> t
  val Star : t -> t
  val case : (t -> ’a ->
    (string -> ’a) ->
    (t * t -> ’a) ->
    (t * t -> ’a) ->
    (t -> ’a)
    -> ’a)
end
```

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    (t * t -> 'a) ->
    (t * t -> 'a) ->
    (t -> 'a)
    -> 'a)
end
```

```
structure Rx1 :> RX = struct
  type t = string
  (* … *)
end
```

```
structure Rx2 :> RX = struct
  type t = Empty | Str of string
         | Seq of t * t | Or of t * t
         | Star of t
  (* … *)
end
```

…

The ML Module System

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end
```

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  type t = string
  (* … *)
end
```

```
structure Rx2 :> RX = struct
  type t = Empty | Str of string
         | Seq of t * t | Or of t * t
         | Star of t
  (* … *)
end
```

…

```
let base = Rx1.Or(Rx1.Str("A"), Rx1.Or(Rx1.Str("T"),
  Rx1.Or(Rx1.Str("G"), Rx1.Str("C"))))
```

Our Solution: Parameterized TSMs

Definition

```
syntax $rx(R : RX) at R.t {
  static fn(body : Body) : Exp option => (* … rx parser here … *)
}
```

Usage

```
let base = $rx Rx1 /A|T|G|C/
let renzyme = $rx Rx1 /GC%{base}GC/
```

Our Solution: Parameterized TSMs

Definition

```
syntax $rx(R : RX) at R.t {
  static fn(body : Body) : Exp option => (* … rx parser here … *)
}
```

Usage

```
let base = $rx Rx1 /A|T|G|C/
let renzyme = $rx Rx1 /GC%{base}GC/
```

Our Solution: Type-Specific Languages (TSLs)

Definition

```
structure Rx1 :> RX = struct
  type t = string
  (* … *)
end with syntax $rx
```

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Definition

```
structure Rx1 :> RX = struct
  type t = string
  (* … *)
end with syntax $rx
```

The TSM `$rx(Rx1)` is now associated with abstract type `Rx1.t`.

Our Solution: Type-Specific Languages (TSLs)

Definition

```
structure Rx1 :> RX = struct
  type t = string
  (* … *)
end with syntax $rx
```

The TSM `$rx(Rx1)` is now associated with abstract type `Rx1.t`.

Usage

```
let base : Rx1.t = /A|T|G|C/
let renzyme : Rx1.t = /GC%{base}GC/
```

When a literal form appears by itself, the TSM associated with the **type it is being checked against** is applied.

Our Solution: Type-Specific Languages (TSLs)

We associate TSMs with abstract types at abstraction boundaries.

```
functor F(R : RX with syntax $rx) =
struct
  val x : R.t = /A|T|G|C/
end
```

Our Solution: Type-Specific Languages (TSLs)

```
functor G() :> RX = struct
  type t = string
  (* … *)
end with syntax $rx

structure G1 = G() (* G1.t has TSL $rx(G1) *)
structure G2 = G() (* G2.t has TSL $rx(G2) *)
```

We associate TSMs with abstract types at abstraction boundaries.

Conclusion

Large Languages and Syntactic DSLs considered harmful.

Typed syntax macros (TSMs) allow library providers to programmatically introduce new typed syntactic expansions in a safe, hygienic and modular manner.

Ongoing/Future Work

- Non-textual display forms in a structured editor.
- Modularly programmable type structure.