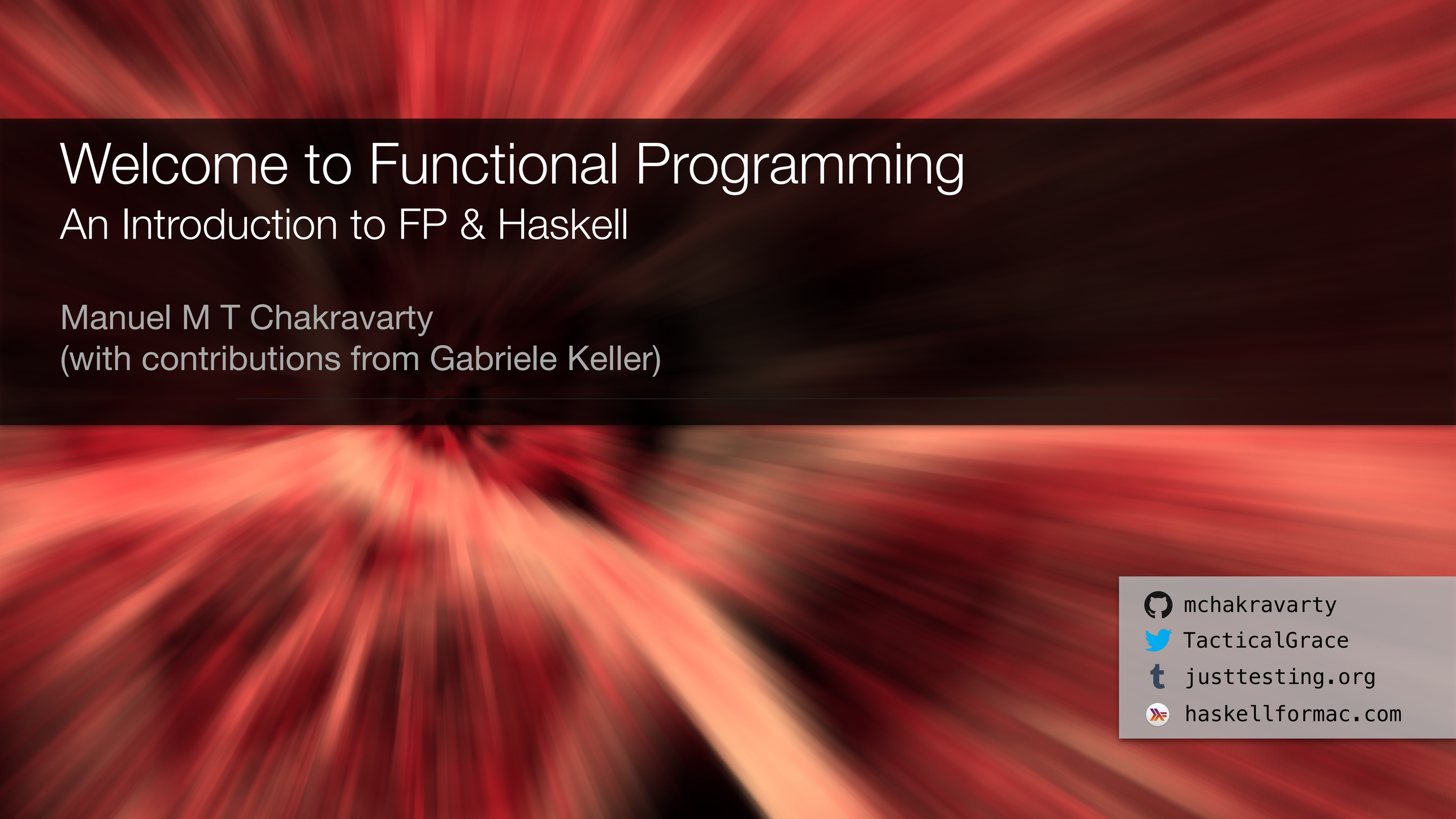
Welcome to Functional Programming

An Introduction to FP & Haskell

Manuel M T Chakravarty
(with contributions from Gabriele Keller)



Who am I?

Who am I?

Formerly

UNSW SYDNEY

Associated Professor

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Haskell for Mac

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Functional Programming
Evangelist

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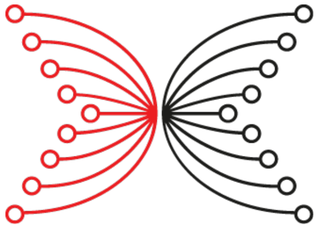

INPUT | OUTPUT

Blockchain Language Architect

What are we going to do?

What are we going to do?

Overview over functional programming

Taxonomy of FP languages & features

What are we going to do?

Overview over functional programming

Taxonomy of FP languages & features

Fundamentals of Haskell & functional programming

Core concepts of writing code in an FP language

What are we going to do?

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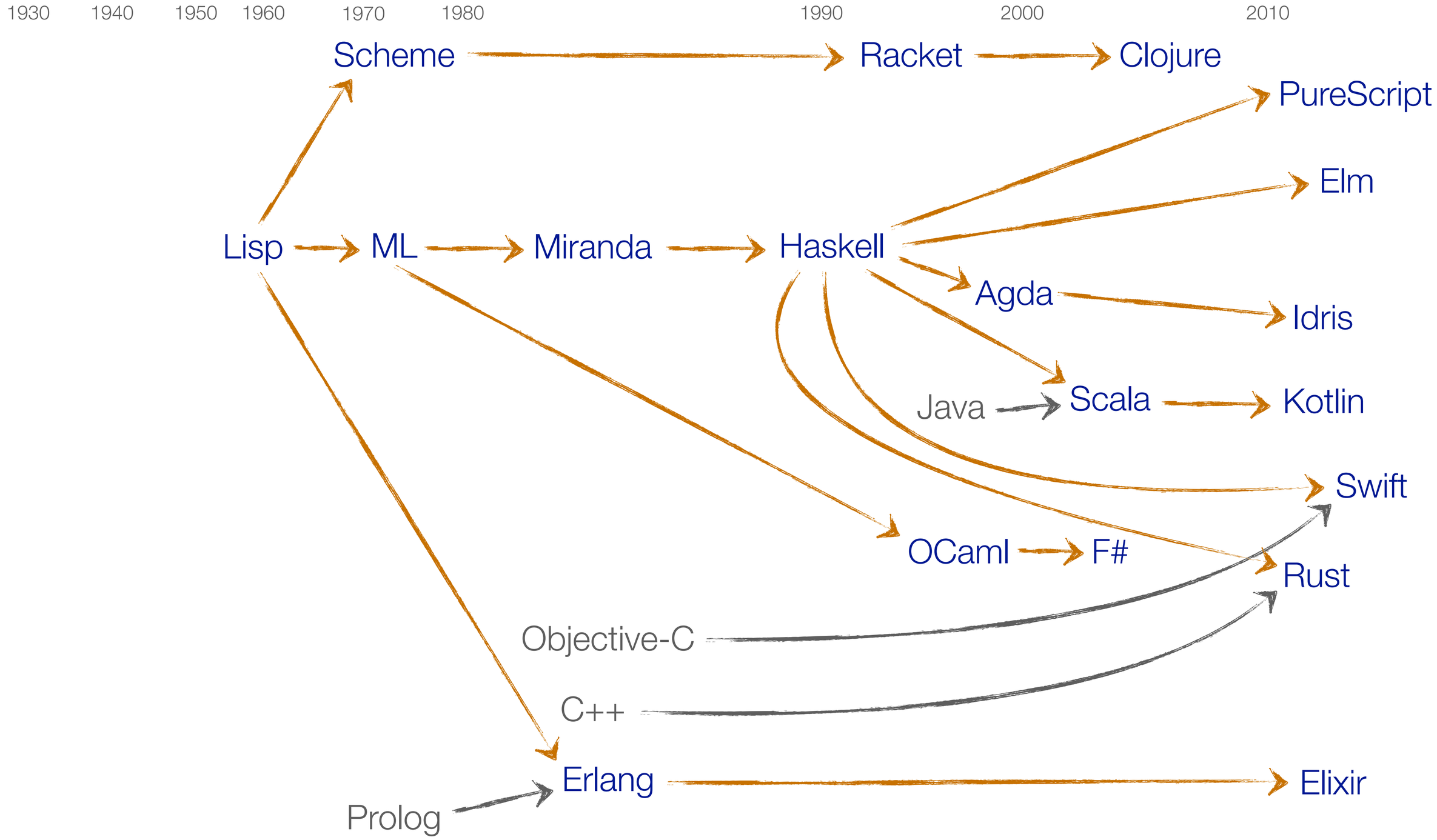
Core concepts of writing code in an FP language

Actually use Haskell

Get a taste for writing programs in Haskell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Lisp

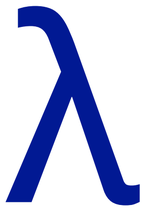
Lambda calculus

Lambda calculus

Church (1930s)

λ

Lambda calculus



Church (1930s)

exp →	var	— variables
|	(λvar. exp)	— abstraction
|	(exp_1 exp_2)	— application

Lambda calculus

λ

Church (1930s)

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| (λvar. exp) — abstraction

| (exp_1 exp_2) — application

(λvar. exp_1) exp_2

Lambda calculus

Church (1930s)

$$
\begin{array}{lll}
\text{exp} \rightarrow \text{var} & & \text{— variables} \\
\quad \mid \ (\lambda \text{var}.\ \text{exp}) & & \text{— abstraction} \\
\quad \mid \ (\text{exp}_1\ \ \text{exp}_2) & & \text{— application}
\end{array}
$$

replace every var in exp_1 by exp_2

$$
(\lambda \text{var}.\ \text{exp}_1)\ \ \text{exp}_2 \xrightarrow{\beta} [\text{exp}_2/\text{var}]\ \text{exp}_1
$$

— execution step

Lambda calculus

Church (1930s)

$$
\begin{aligned}
\text{exp} &\rightarrow \text{var} && \text{— variables}\\
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— execution step

Turing-complete

Lambda calculus

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exp → var — variables

| (λvar. exp) — abstraction

| (exp_1 exp_2) — application

replace every var in exp_1 by exp_2

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Turing-complete

Foundations of mathematics

Lambda calculus

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Church (1930s)

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| (exp_1 exp_2) — application

replace every var in exp_1 by exp_2

$(\lambda var.\ exp_1)\ exp_2 \xrightarrow{\beta} [exp_2/var]\ exp_1$ — execution step

Typed lambda calculus in 1940!

Turing-complete

Foundations of mathematics

Lisp

Lisp

McCarthy (1958)

Lisp

McCarthy (1958)

```
(lambda (arg) (+ arg 1))
```

Lisp

McCarthy (1958)

```
(lambda (arg) (+ arg 1))
```

```
(defun factorial (n)
   (if (= n 0) 1
       (* n (factorial (- n 1)))))
```

Lisp

Lisp

McCarthy (1958)

Lisp

McCarthy (1958)

Lambdas

Lisp

McCarthy (1958)

Lambdas

Recursion

Lisp

McCarthy (1958)

Lambdas

Tree structures

Recursion

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Tree structures

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Garbage collection

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McCarthy (1958)

Lambdas

Meta programming (macros)

Tree structures

Recursion

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Meta programming (macros)

Tree structures

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Read-eval-print loop (REPL)

Garbage collection

Lisp

McCarthy (1958)

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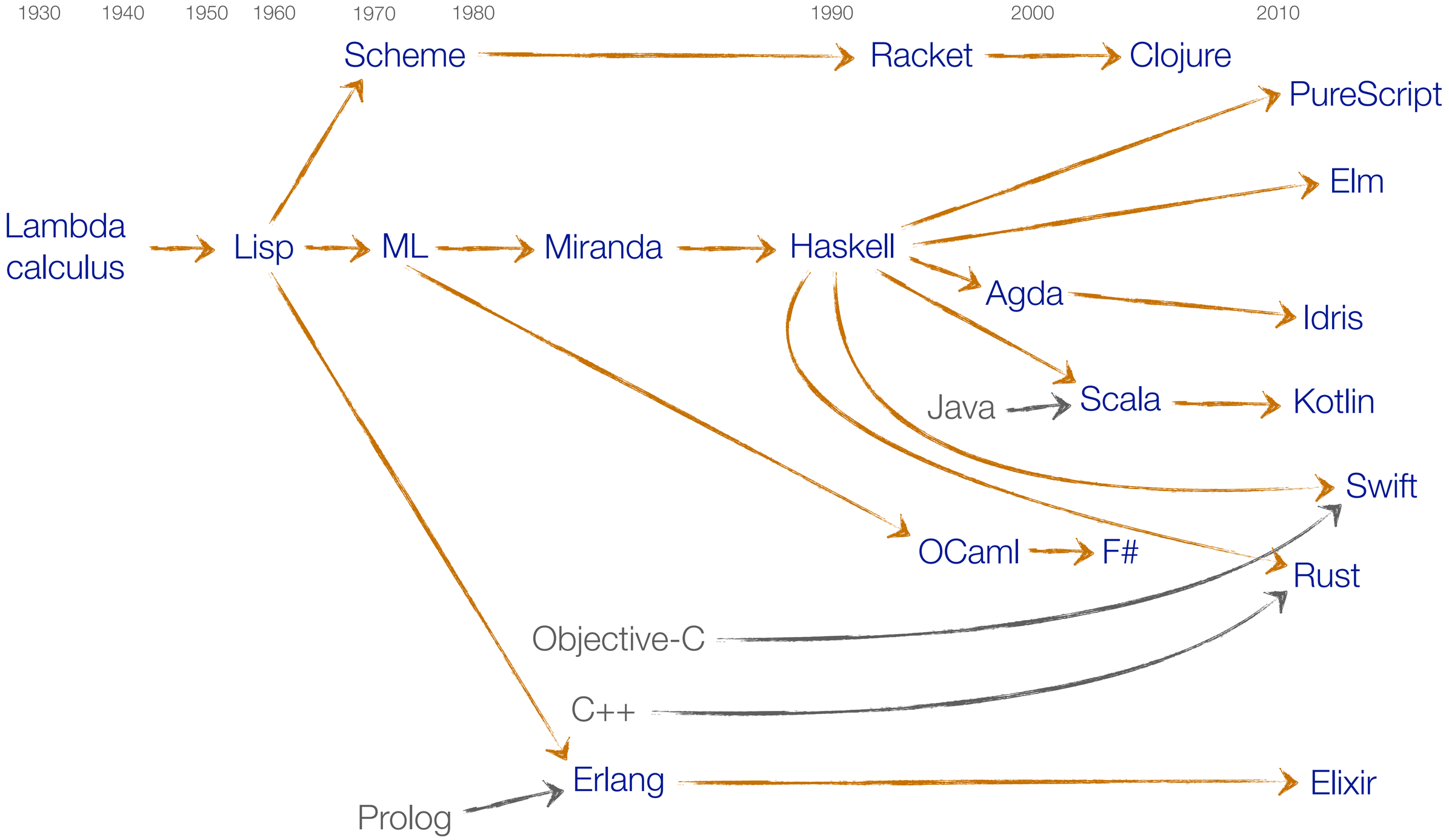
Garbage collection

Metacircular interpreter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Scheme Racket Clojure

Scheme

λ

Steele/Sussman
(1975)

Racket

PLT Inc
(1994)

Clojure

Hickey
(2007)

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Lexical scoping

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Lexical scoping

Tail call optimisation

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```

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Tail call optimisation

First-class continuations

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Lexical scoping

Education

Tail call optimisation

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Domain-specific
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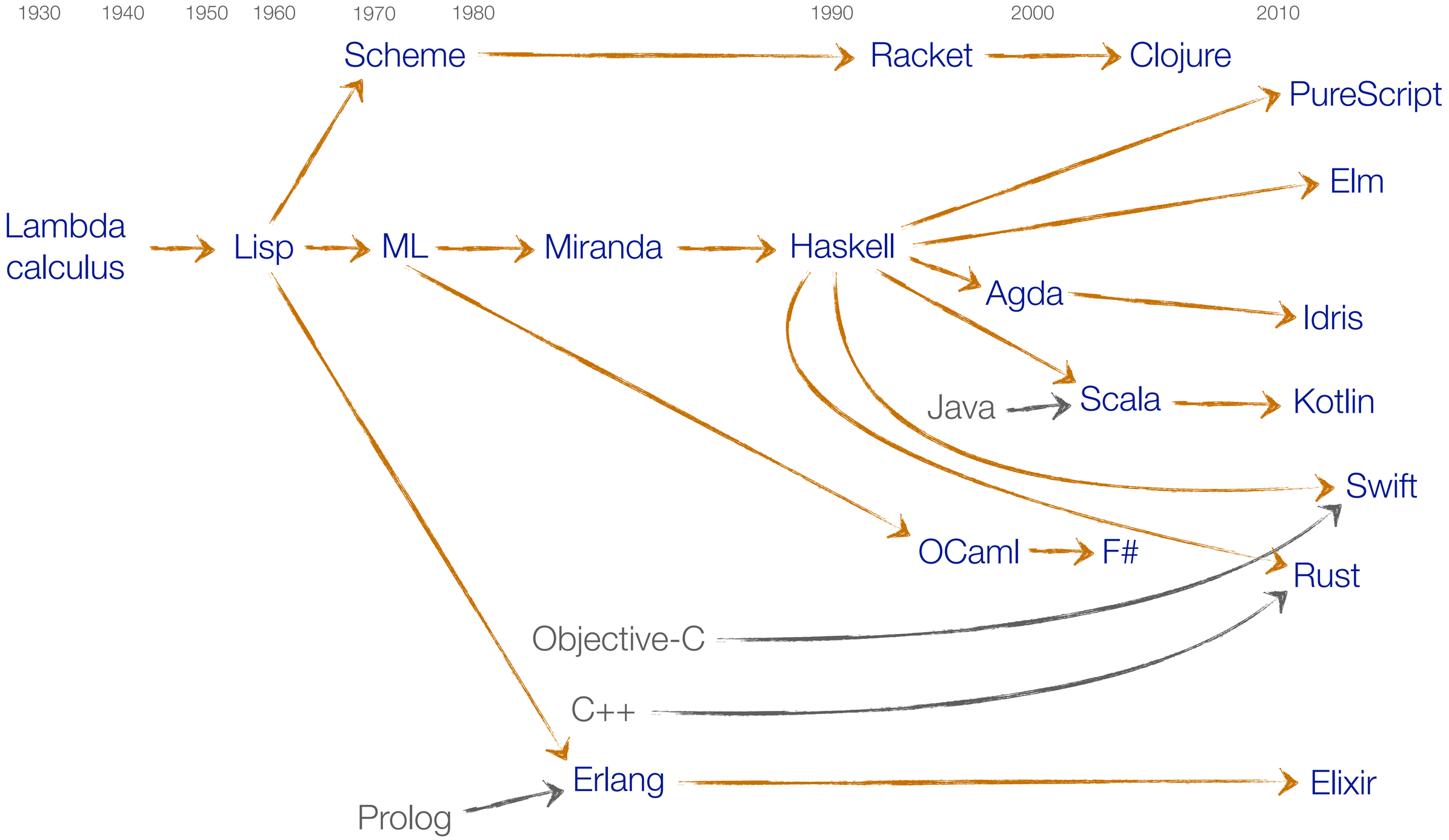
JVM

ClojureScript

Immutability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Armstrong et al.
(1986)

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Concurrent

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Distributed

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Fault-tolerant

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Hot swapping

Elixir

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Metaprogramming

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Metaprogramming

Protocols

Erlang

Armstrong et al.
(1986)

Concurrent

Distributed

Fault-tolerant

Hot swapping

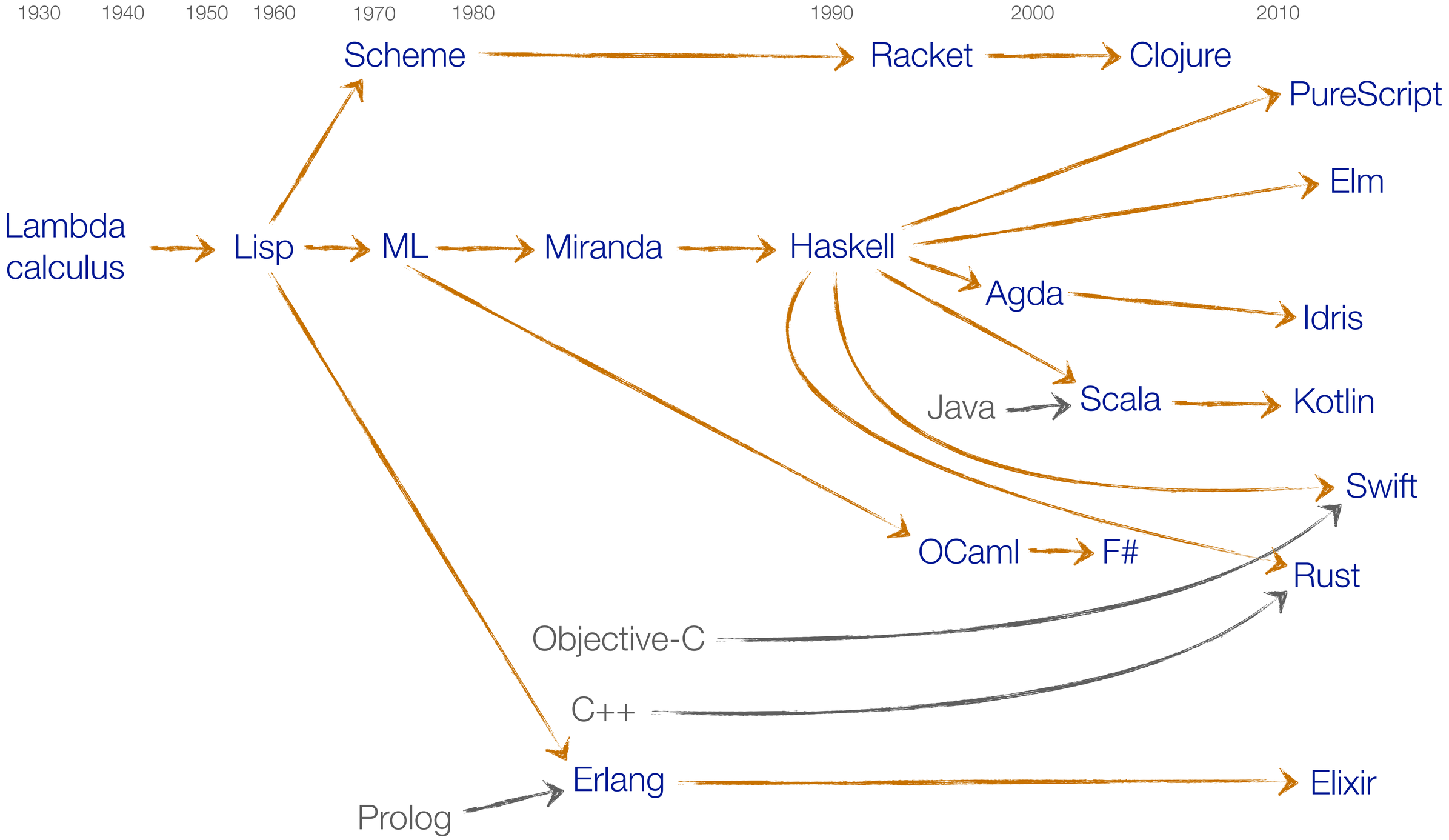
Elixir

Valim
(2011)

Metaprogramming

Protocols

Tooling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(Standard) ML

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Miller/Tofte/Harper (1973)

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  | fact (n : int) : int = n * fact (n - 1)
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(Standard) ML

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Algebraic data types

(Standard) ML

Miller/Tofte/Harper (1973)

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Algebraic data types

Pattern matching

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Parametric polymorphism
(aka generics)

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Algebraic data types

Type inference

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Algebraic data types

Type inference

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Parametric polymorphism
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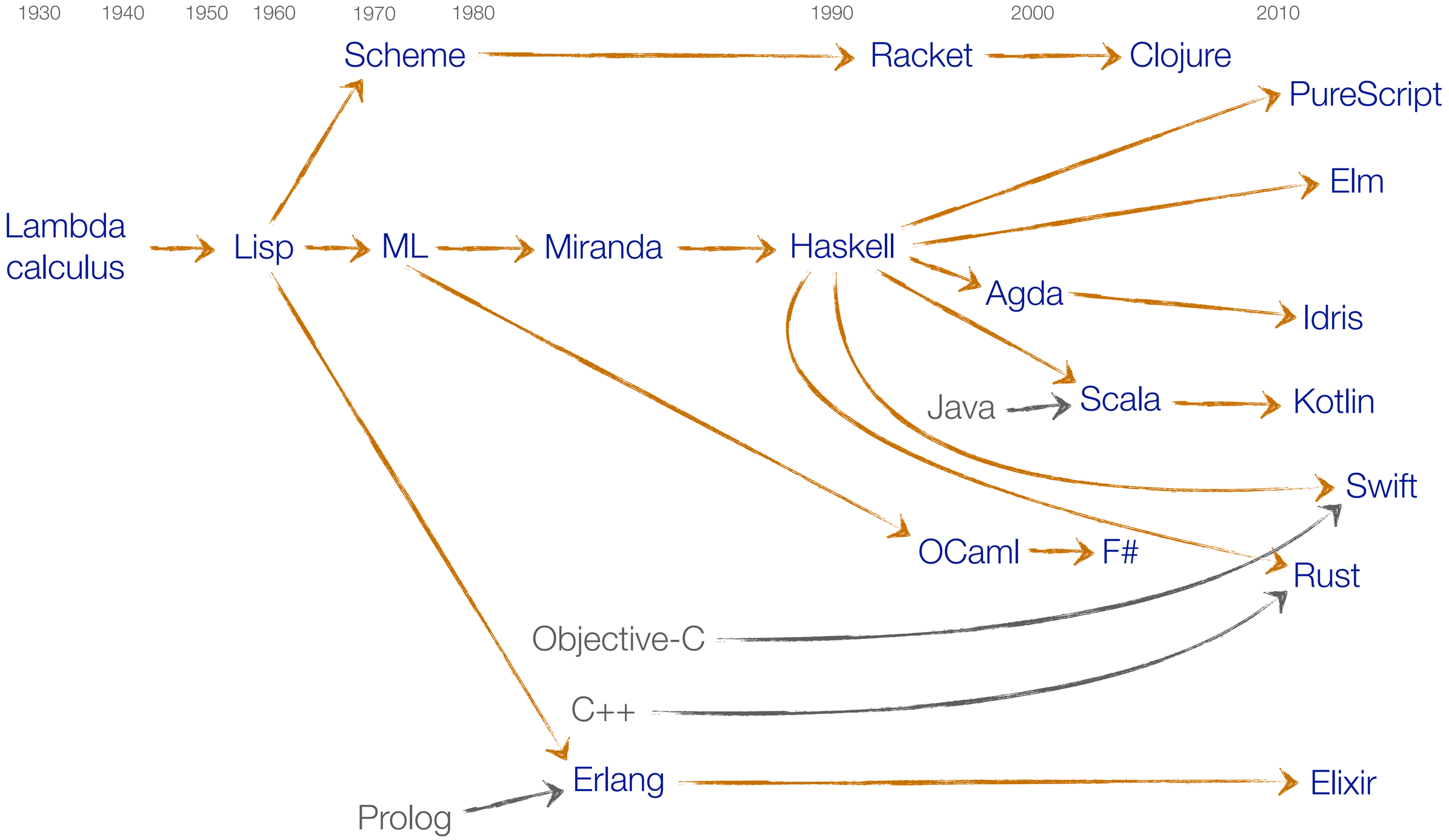
Higher-order
module system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Object system

Structural subtyping

OCaml

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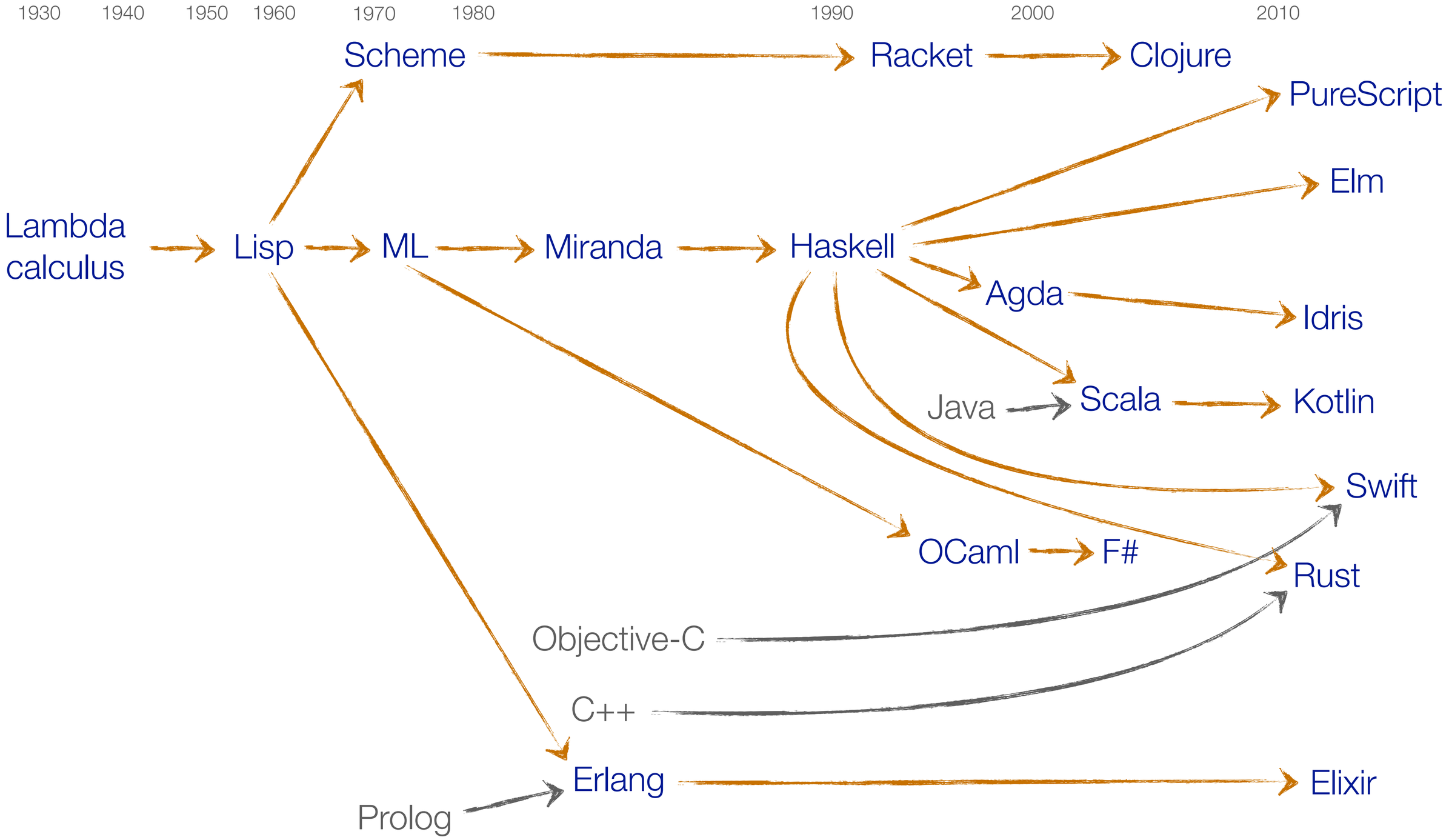
Structural subtyping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(1985)

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Laziness

Miranda

Turner
(1985)

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Laziness

List comprehensions

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Turner
(1985)

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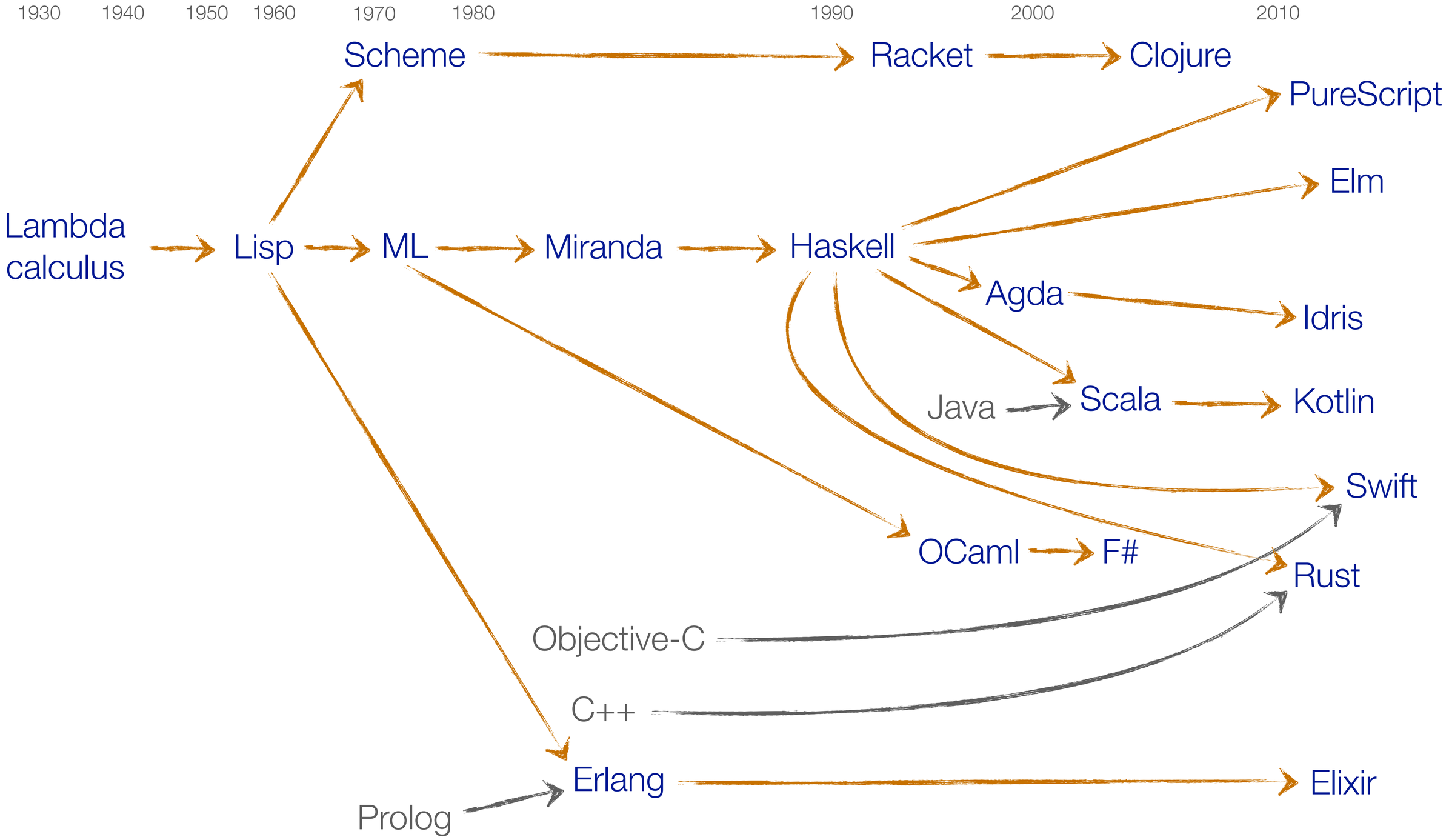
Laziness

List comprehensions

```
primes       = sieve [2..]
sieve (p:x) = p : sieve [n | n <- x; n mod p ~= 0]
```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Haskell

Haskell

Augustsson et al.

(1990)

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Type classes

Haskell

Augustsson et al.
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Type classes

Monads
(and other categorial structures)

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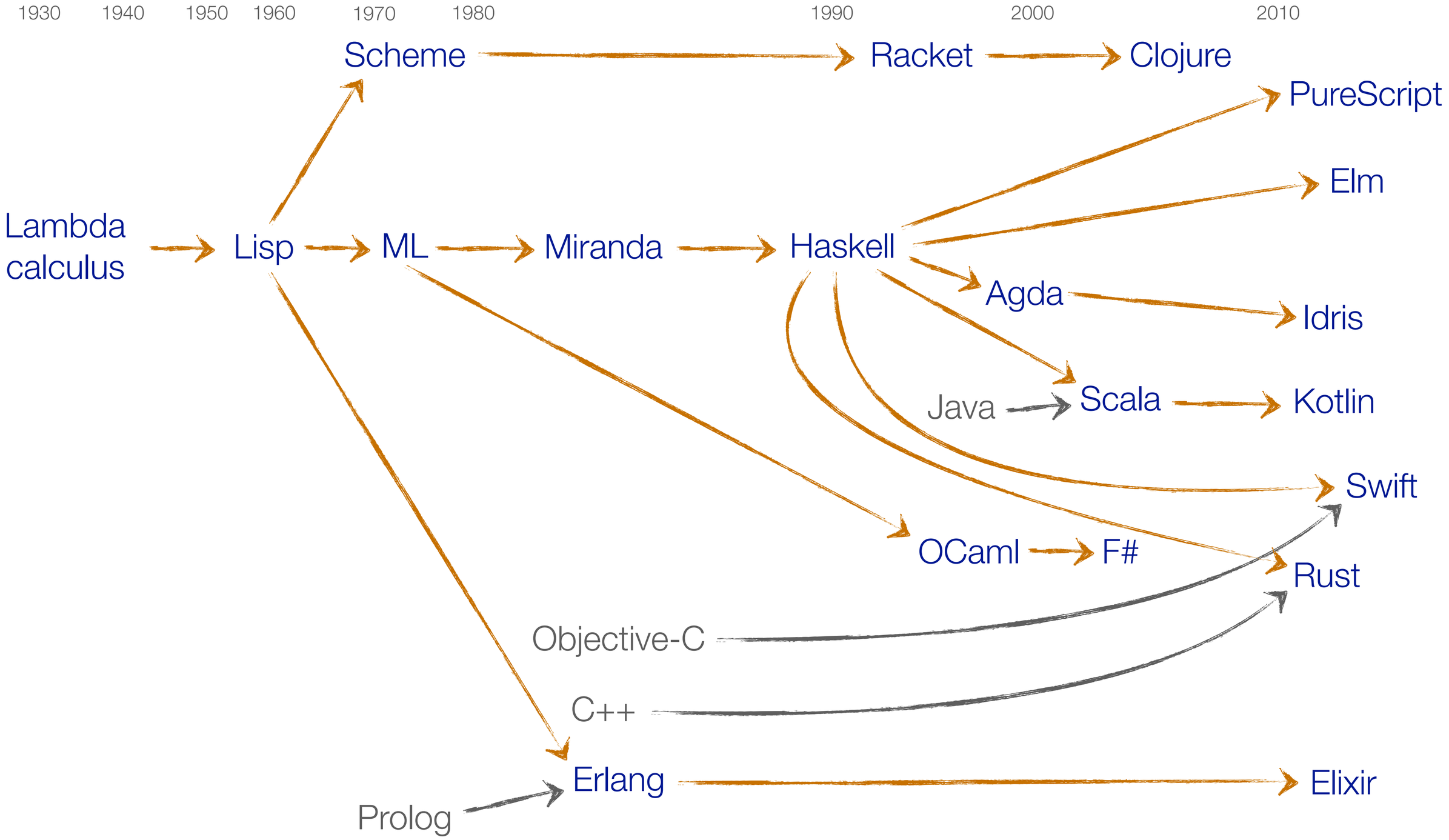
Type classes

Monads
(and other categorial structures)

Type families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Dependent types

Agda

Norell/Coquand
(1999)

Idris

Brady
(2011)

Dependent types

Termination checking

Agda

Norell/Coquand
(1999)

Idris

Brady
(2011)

Dependent types

Termination checking

```
data _≤_ : ℕ → ℕ → Set where
  z≤n : {n : ℕ} → zero ≤ n
  s≤s : {n m : ℕ} → n ≤ m → suc n ≤ suc m
```

Agda

Norell/Coquand
(1999)

Dependent types

Termination checking

Idris

Brady
(2011)

Effect system

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Effect system

EDSL support

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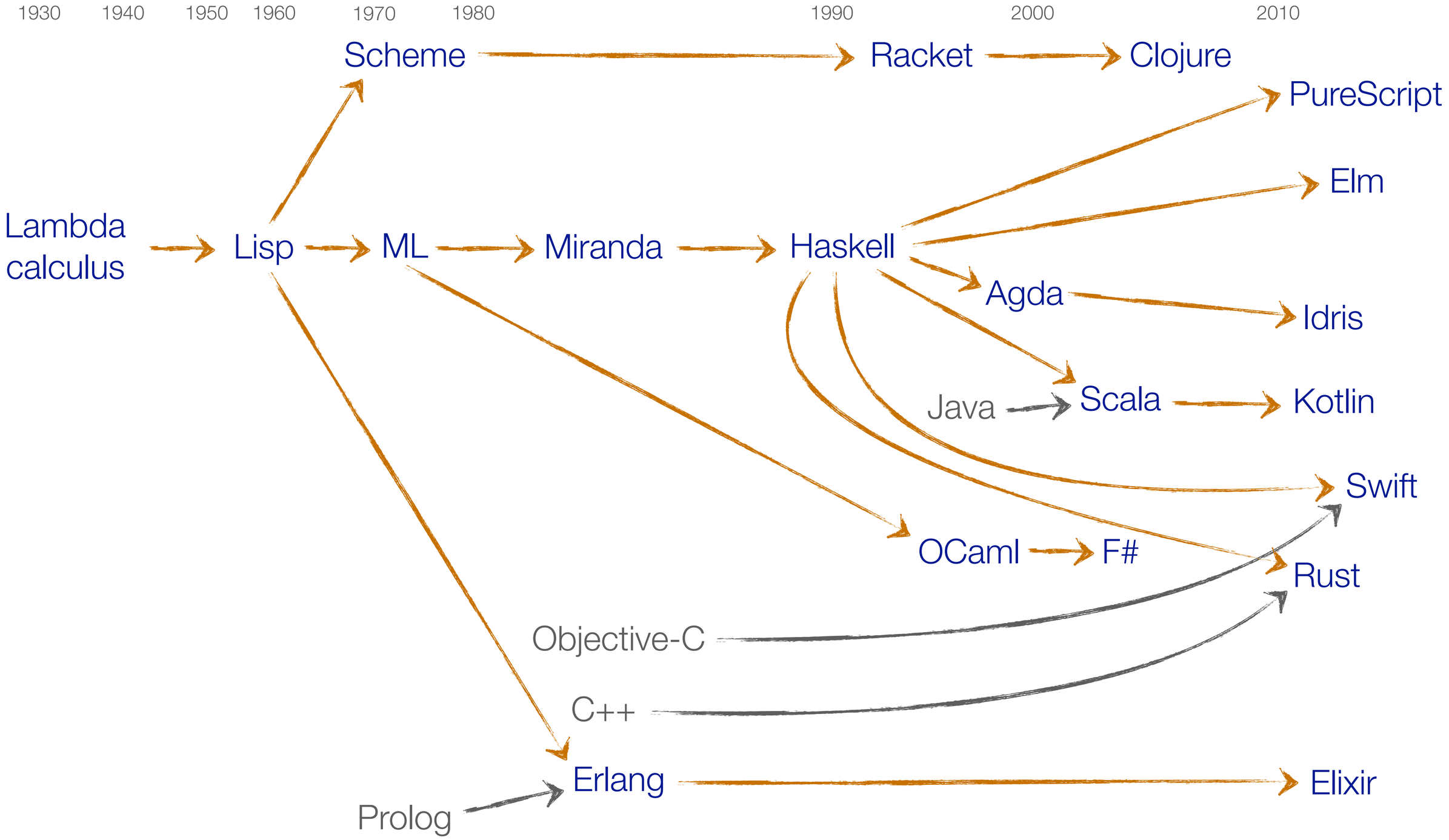
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Extensible effects

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Stays closer
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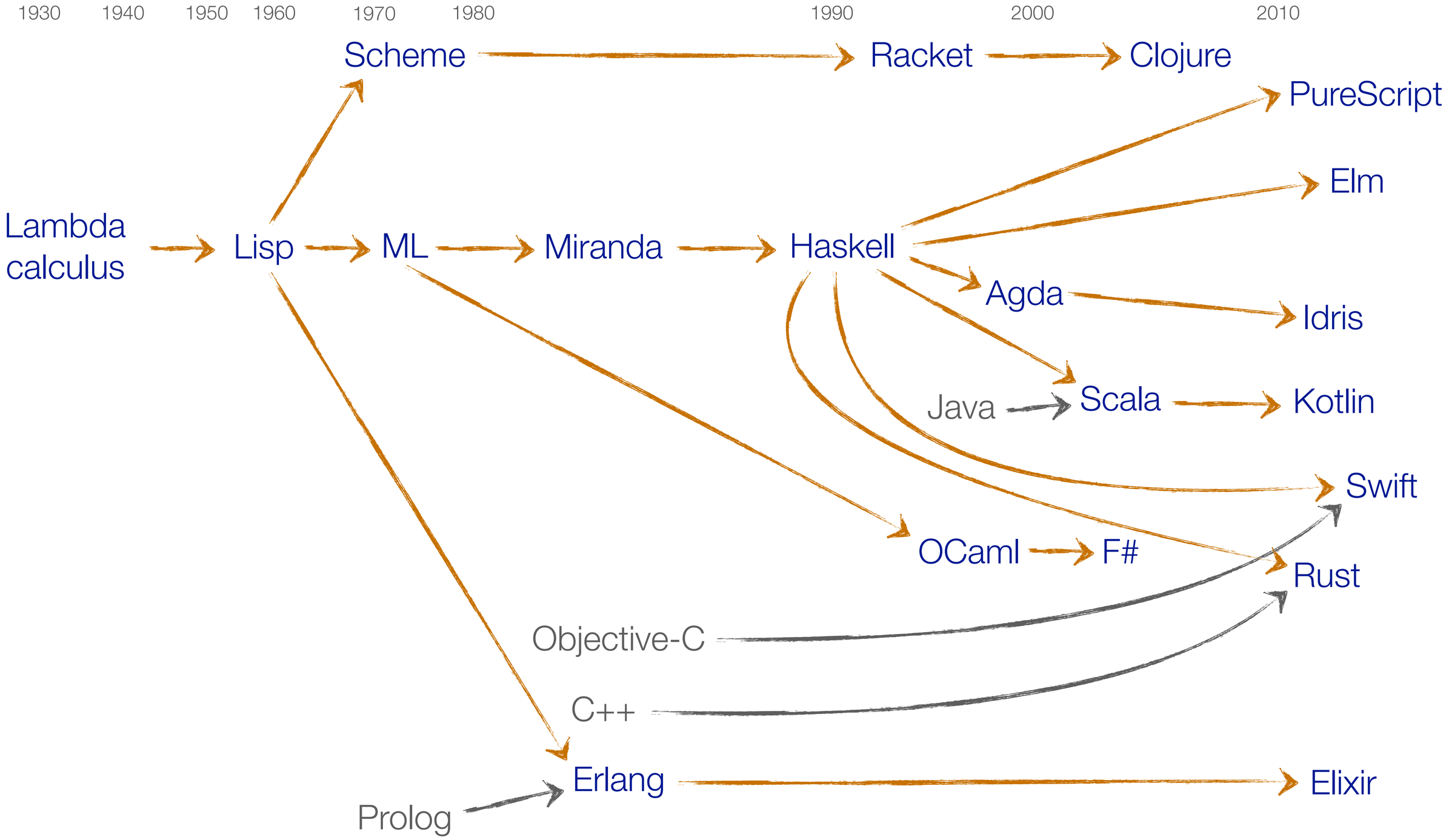
Extensible effects

Row-polymorphic records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Objective-C
C++
Erlang
Elixir
Prolog

Scala Kotlin Swift Rust

Scala	Kotlin	Swift	Rust
			
Odersky (2004)	JetBrains (2011)	Lattner (2014)	G. Hoare (2010)

Scala

Odersky
(2004)

JVM

Kotlin

JetBrains
(2011)

JVM

Swift

Lattner
(2014)

Rust

G. Hoare
(2010)

Scala	Kotlin	Swift	Rust
			
Odersky (2004)	JetBrains (2011)	Lattner (2014)	G. Hoare (2010)
JVM	JVM		

Java interoperability

Scala	Kotlin	Swift	Rust
			
Odersky (2004)	JetBrains (2011)	Lattner (2014)	G. Hoare (2010)
JVM	JVM		

Java interoperability

Hybrid, but objects first

Scala

Odersky
(2004)

JVM

Kotlin

JetBrains
(2011)

JVM

Swift

Lattner
(2014)

Objective-C
object system

Rust

G. Hoare
(2010)

Java interoperability

Hybrid, but objects first

Scala

Odersky
(2004)

JVM

Java interoperability

Hybrid, but objects first

Kotlin

JetBrains
(2011)

JVM

Swift

Lattner
(2014)

Objective-C
object system

Value types

Rust

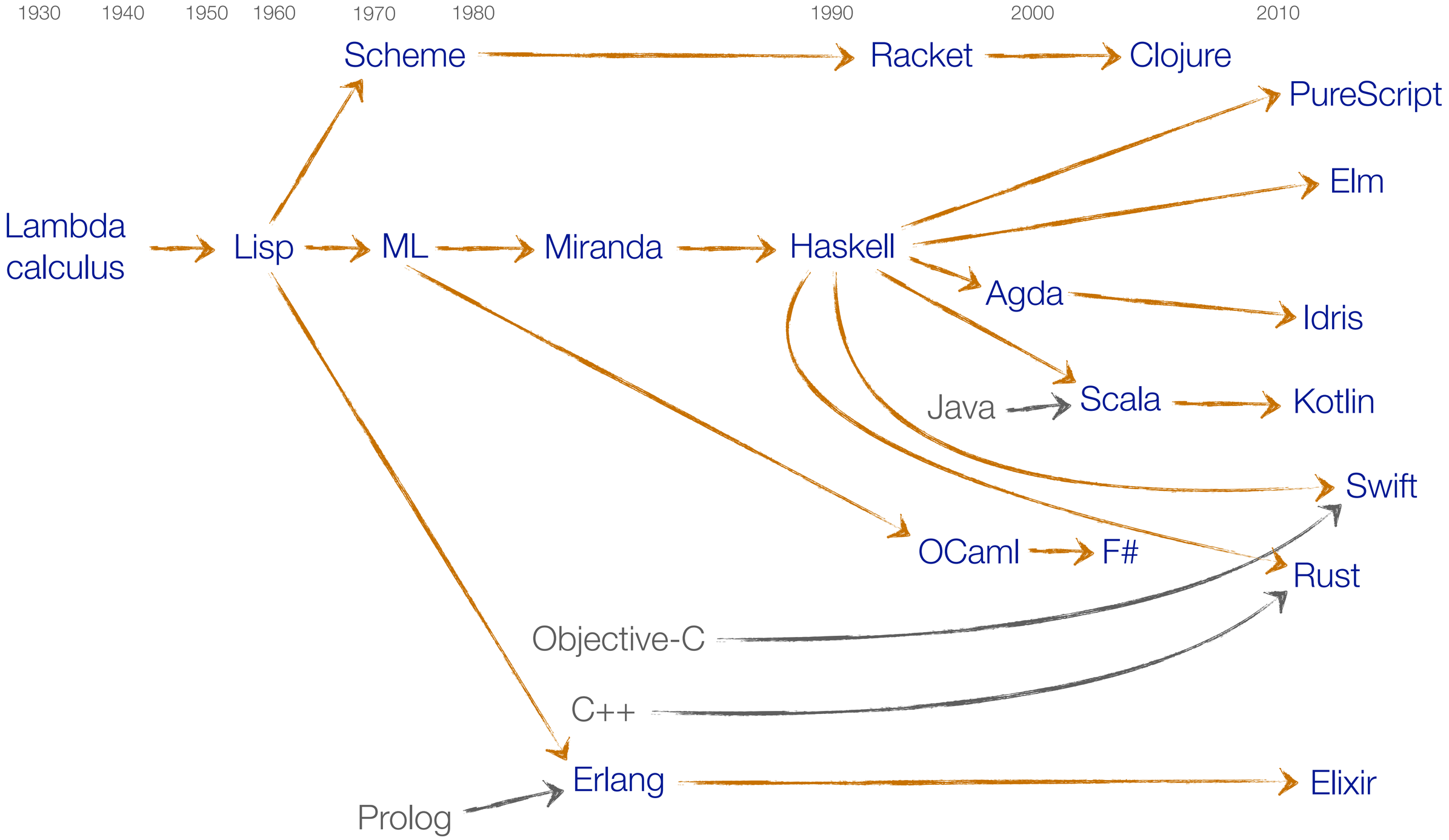
G. Hoare
(2010)

Scala	Kotlin	Swift	Rust
			
Odersky (2004)	JetBrains (2011)	Lattner (2014)	G. Hoare (2010)
JVM	JVM	Objective-C object system	
Java interoperability		Value types	
Hybrid, but objects first		Protocol-oriented	

Scala	Kotlin	Swift	Rust
			
Odersky (2004)	JetBrains (2011)	Lattner (2014)	G. Hoare (2010)
JVM	JVM	Objective-C object system	Affine types
Java interoperability		Value types	
Hybrid, but objects first		Protocol-oriented	

Scala	Kotlin	Swift	Rust
			
Odersky (2004)	JetBrains (2011)	Lattner (2014)	G. Hoare (2010)
JVM	JVM	Objective-C object system	Affine types
Java interoperability		Value types	Performance
Hybrid, but objects first		Protocol-oriented	

Scala	Kotlin	Swift	Rust
			
Odersky (2004)	JetBrains (2011)	Lattner (2014)	G. Hoare (2010)
JVM	JVM	Objective-C object system	Affine types
Java interoperability		Value types	Performance
Hybrid, but objects first		Protocol-oriented	Systems


1930
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Scheme
Racket
Clojure
PureScript
Elm
Lambda calculus
Lisp
ML
Miranda
Haskell
Agda
Idris
Java
Scala
Kotlin
Swift
OCaml
F#
Rust
Objective-C
C++
Erlang
Elixir
Prolog

Clone

`https://github.com/mchakravarty/welcome-to-fp-workshop`

Haskell for Mac Licence Code

`chak@applicative.co`