#### Smart Contracts

Plutus & Marlowe

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### Introduction

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- Although both have been created to add smart-contract capabilities to Cardano, they could in principle be used on other blockchains as well.
- Both are written in Haskell.
- Plutus is Turing-complete and general, Marlowe is a non-Turing-complete DSL for financial contracts.





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- This is similar to the relationship between imperative programming languages (like Java and Python) and functional languages (like Haskell).
- This makes it a good fit to write smart contracts for an account-based blockchain like Ethereum in an imperative language like Solidity and contracts for the UTxO-based Cardano in the functional language Haskell.

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- Plutus is also Turing-complete (and uses a similar system to the one Ethereum uses in order to prevent infinite loops).
- Taken together, these properties make it possible to write smart contracts in Plutus which are as least as powerful as Ethereum smart contracts.



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- Not only has Plutus been implemented in Haskell, you also program in Haskell, which means that Haskell is for Plutus Core what Solidity is for the EVM.
- This enables a seamless interplay between onchain code and offchain code (whereas Solidity only supports onchain code, so that offchain code has to be written in something like JavaScript.)



#### Lambda Calculus

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- Haskell is based upon and compiles to a (typed!) version of the lambda Calculus (as first intermediate compiler target, Core).

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- Relation to programming languages clarified in the 1960s.

### Lambda expressions

Lambda expressions (or lambda terms) are composed of

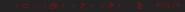
- variables  $v_1, v_2, \ldots, v_n, \ldots$
- ullet the abstraction symbols  $\lambda$  and  $\dots$
- parentheses ().

The set of lambda expressions  $\Lambda$  is inductively defined as:

- If x is a variable, then  $x \in \Lambda$ .
- If x is a variable and  $M \in \Lambda$ , then  $(\lambda x.M) \in \Lambda$ .
- If  $M, N \in \Lambda$ , then  $(MN) \in \Lambda$ .

(variable)

(lambda abstraction) (application)



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- In an abstraction  $\lambda x.M$ , we call the variable x bound.

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- This act of "plugging in" an expression for the bound variable in an abstraction is what constitutes the idea of computation in lambda Calculus.

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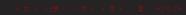
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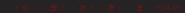
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• System  $F_{\omega}$  adds functions from types to types (type constructors) to System F.



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- Marlowe is not Turing-complete, and it is simple enough to allow for static analysis, which can automatically derive and prove important properties of Marlowe contracts.
- Marlowe is also powerful enough to implement a significant part of all commonly used financial contracts.



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- Marlowe guarantees that no money will be "trapped" in a contract forever: By the end of the contract, all money that has been paid into the contract will have been paid back to one of the parties participating in the contract.



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- Marlowe's host language is Haskell.
- An EDSL has the advantage that all features of the host language are available to help facilitate creating expressions in the DSL.
- This means for Marlowe, that we can use Haskell to write Marlowe contracts and that Marlowe contracts are nothing more than values of a specific Haskell type.



## Blockly

 Alternatively, Marlowe contracts can be written in Blockly, a simple graphical language.



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- This is tedious for complex contracts, but a good way for beginners.



## **JavaScript**

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- This will hopefully make Marlowe more accessible for non-Haskellers.



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- Using this method makes It possible to classify and describe the majority of all financial instruments in about 30 types and patterns.
- IOHK plans to use Plutus and Marlowe to implement the complete Actus Standard in Cardano.

