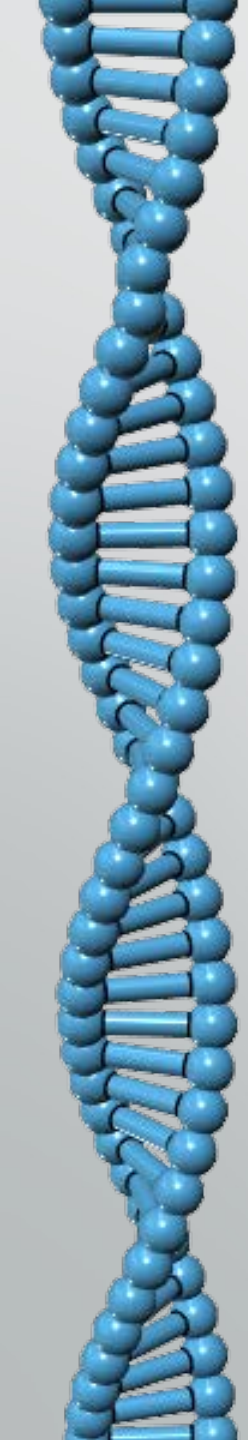
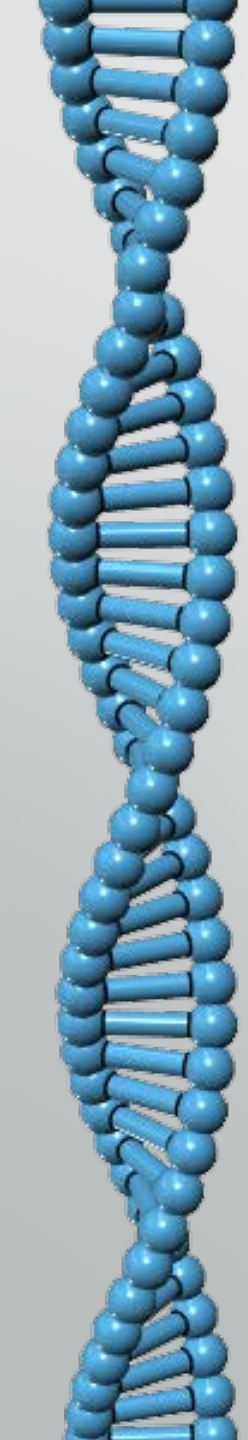


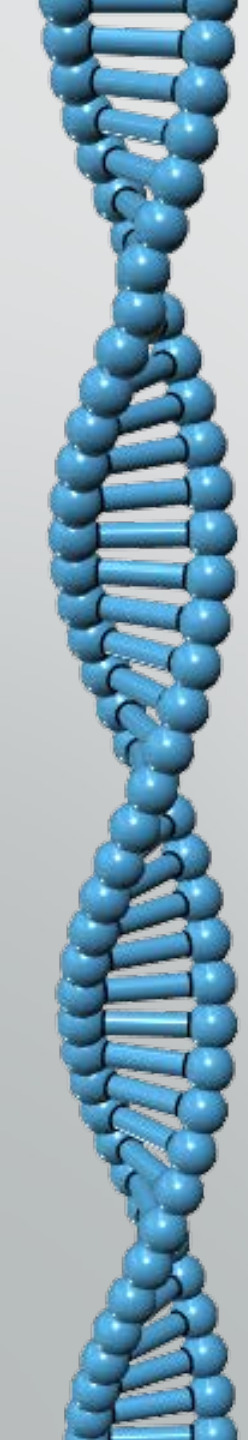
Application of Genetic Algorithm Parameter Optimization on I-V data of multi-crystalline Si solar cells

RM Dix-Peek, CJ Pretorius, EE van Dyk, FJ Vorster



an introduction to

Artemis

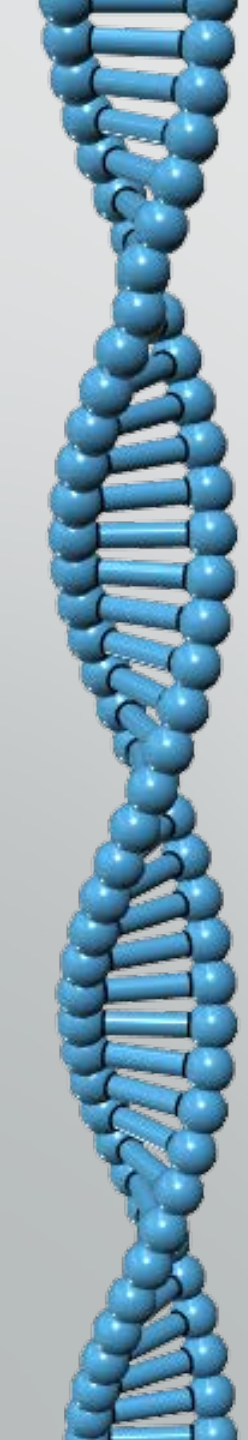


Outcomes

Introduce the concept of Genetic Algorithms for Parameter Optimisation

Custom built Genetic Algorithm for the purpose of:

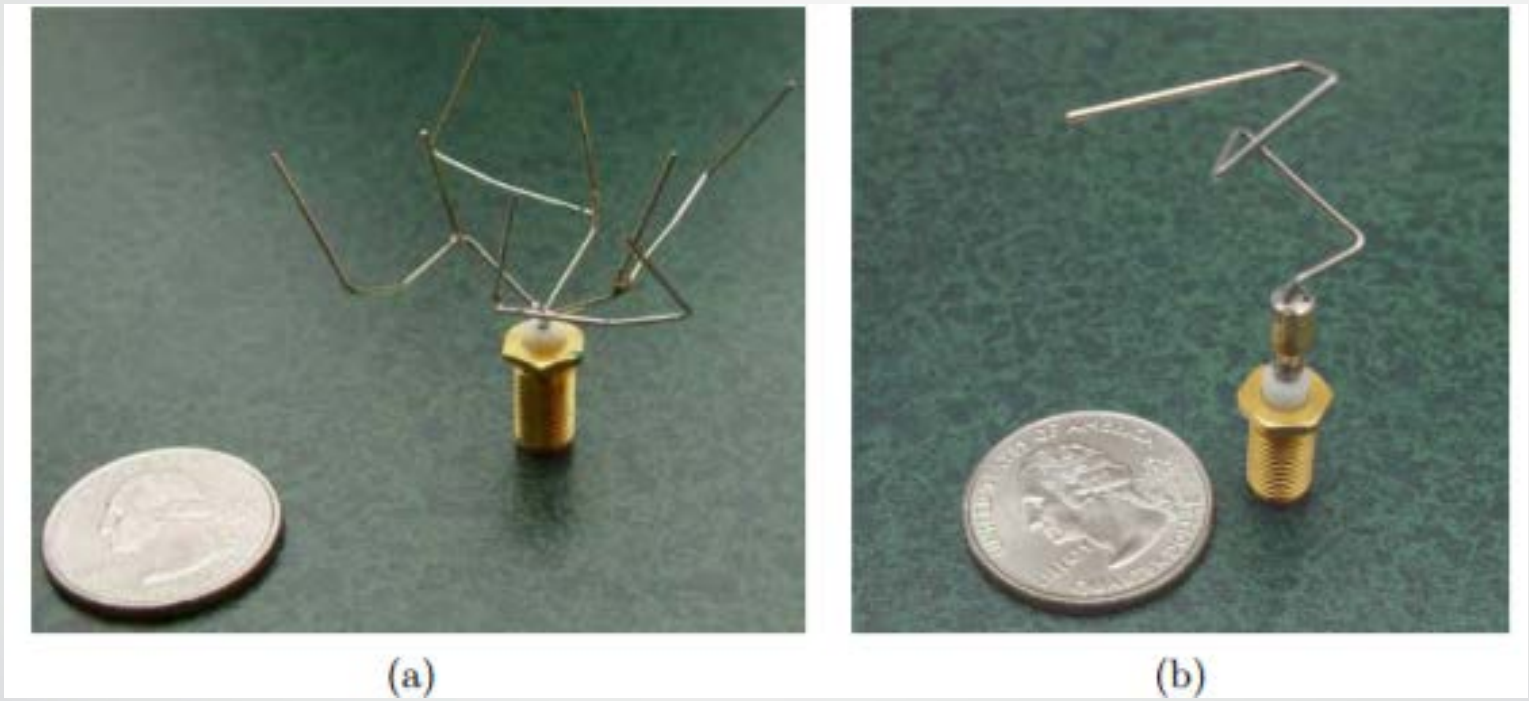
- Characterisation of Current-Voltage data the forward bias



Outline

- Introduction to Genetic Algorithms
- Genetic Algorithm Structure and Implementation
  - Initialization
  - Fitness Evaluation
  - Selection Process
  - Genetic Crossover
  - Genetic Mutation
  - Termination Conditions
- Applied models
- Implementation of code
- Results obtained
- Future applications
- Conclusions

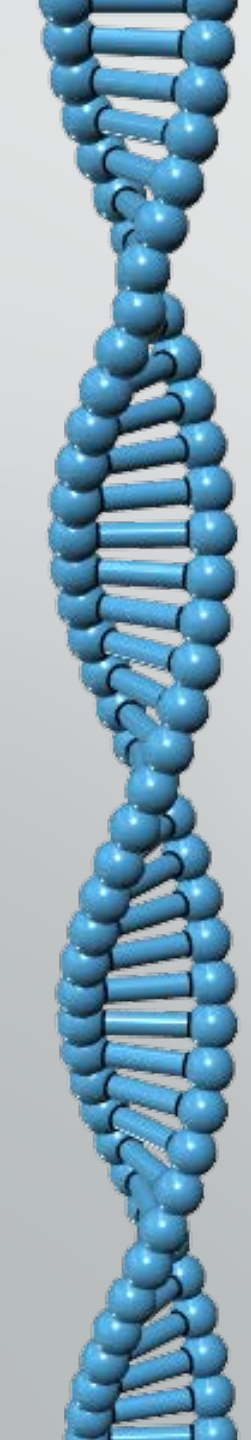
Example



(a) Best evolved design for antenna for original requirements ST5-3-10
(b) Best evolved design for antenna for revised requirements ST5-33-142-7

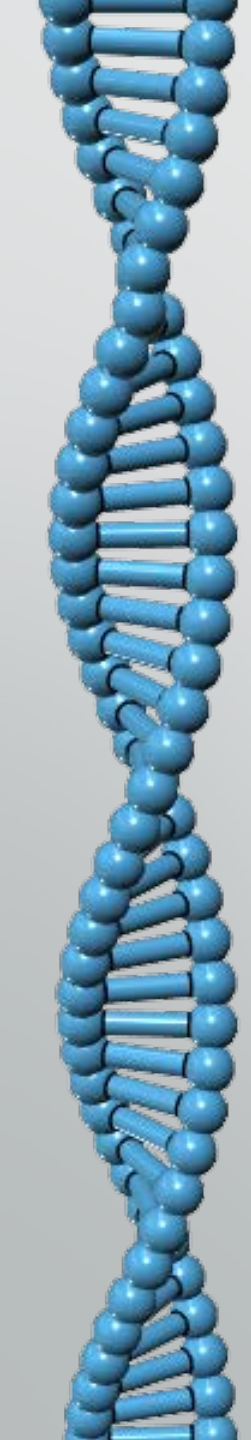
"The 2006 NASA ST5 spacecraft antenna. This complicated shape was found by an evolutionary computer design program to create the best radiation pattern."

Source: Hornby, Gregory S.; Al Globus; Derek S. Linden; Jason D. Lohn (September 2006). "Automated antenna design with evolutionary algorithms" (PDF). American Institute of Aeronautics and Astronautics. Retrieved 2012-02-19.



Introduction to Genetic Algorithms

- Evolutionary algorithm
  - Based upon the biological process of evolution of genetic material
- Pro's:
  - Parallel interacting solutions
  - Increased probability of finding global minimum of error (compared to classical approaches)
  - Customization for case-specific problems
- Con's:
  - Computationally expensive
  - Unsuitable for simple problems
- Partitioning of data
  - Training set
  - Validation set



Introduction: Terminology

Training Set

The set of data used to train the model to the data (determine parameter values)

Validation Set

The set of data used to validate the optimized parameter values for the applied model

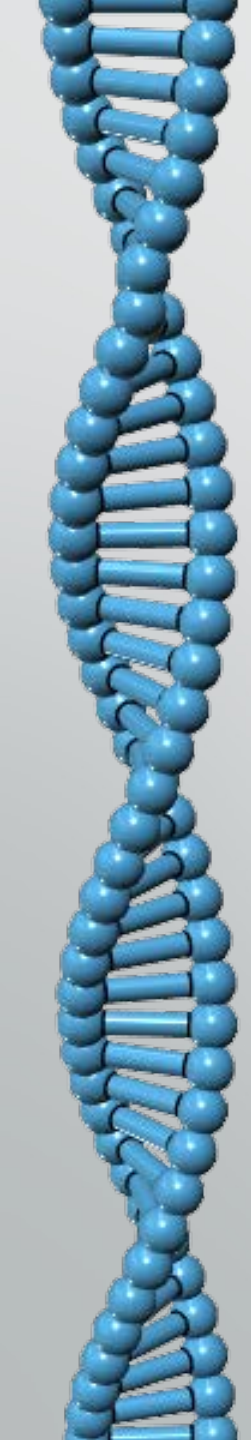
Test of over specification

Genes

In the case of this GA, the parameter values for the model

Individuals

The set of parameters of a proposed solution



Introduction: Terminology

Fitness Function

The function used to test the fitness of an individual, or how well the applied parameter values perform

Diversity

The variety of the population's parameters

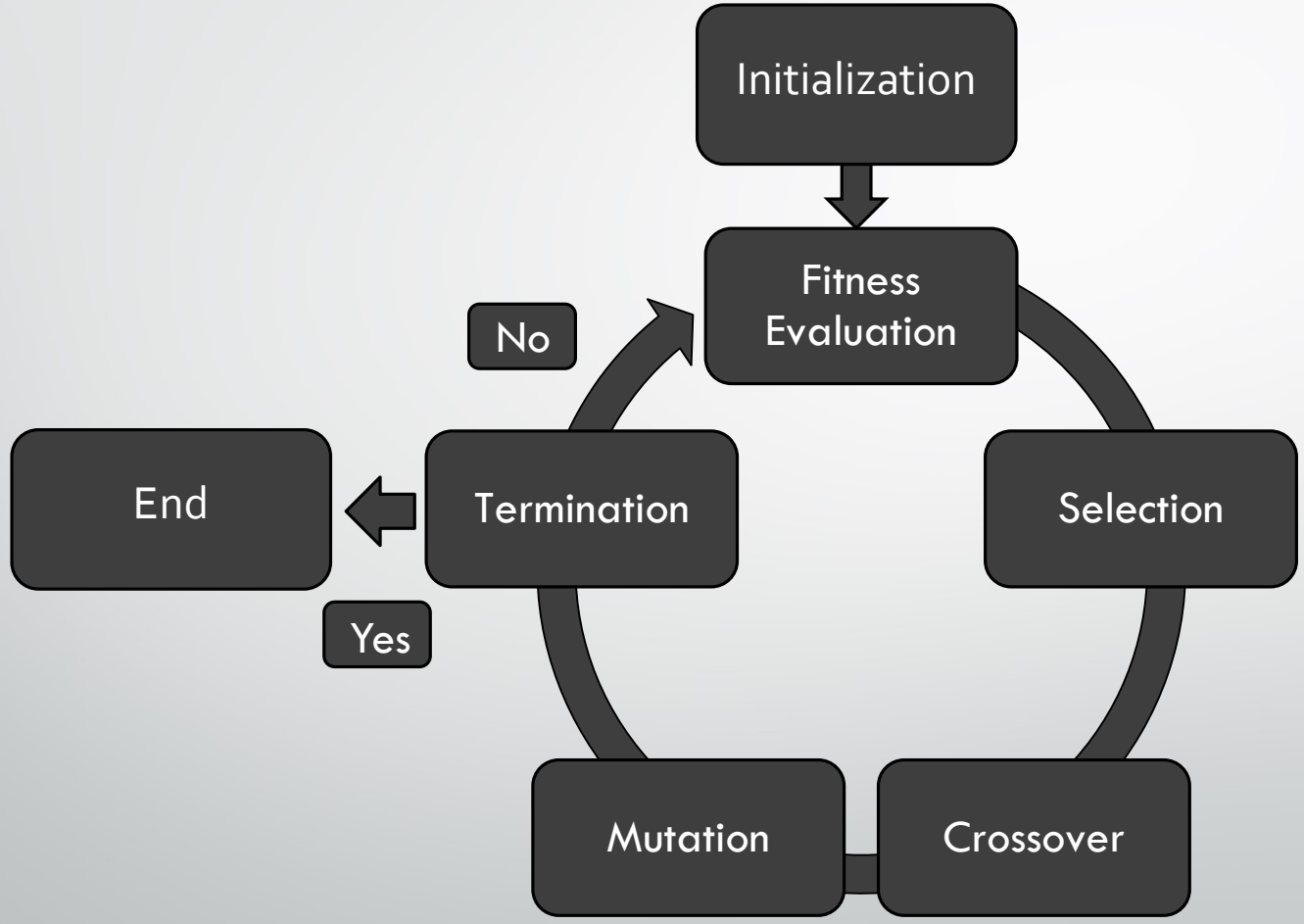
Breeding Set

The set used in the crossover process to generate the new generation

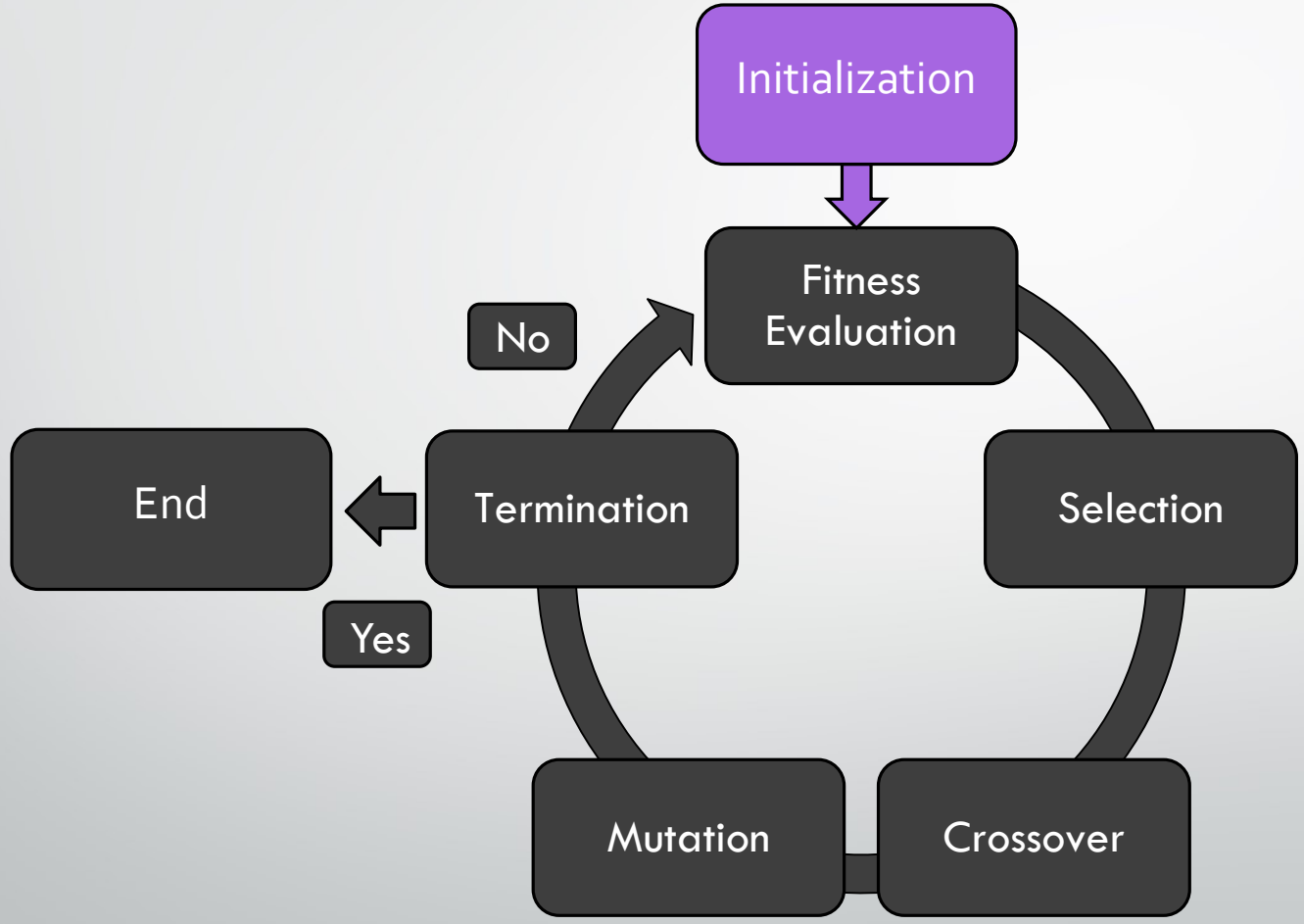
New Generation

The set used in the next iteration of the GA

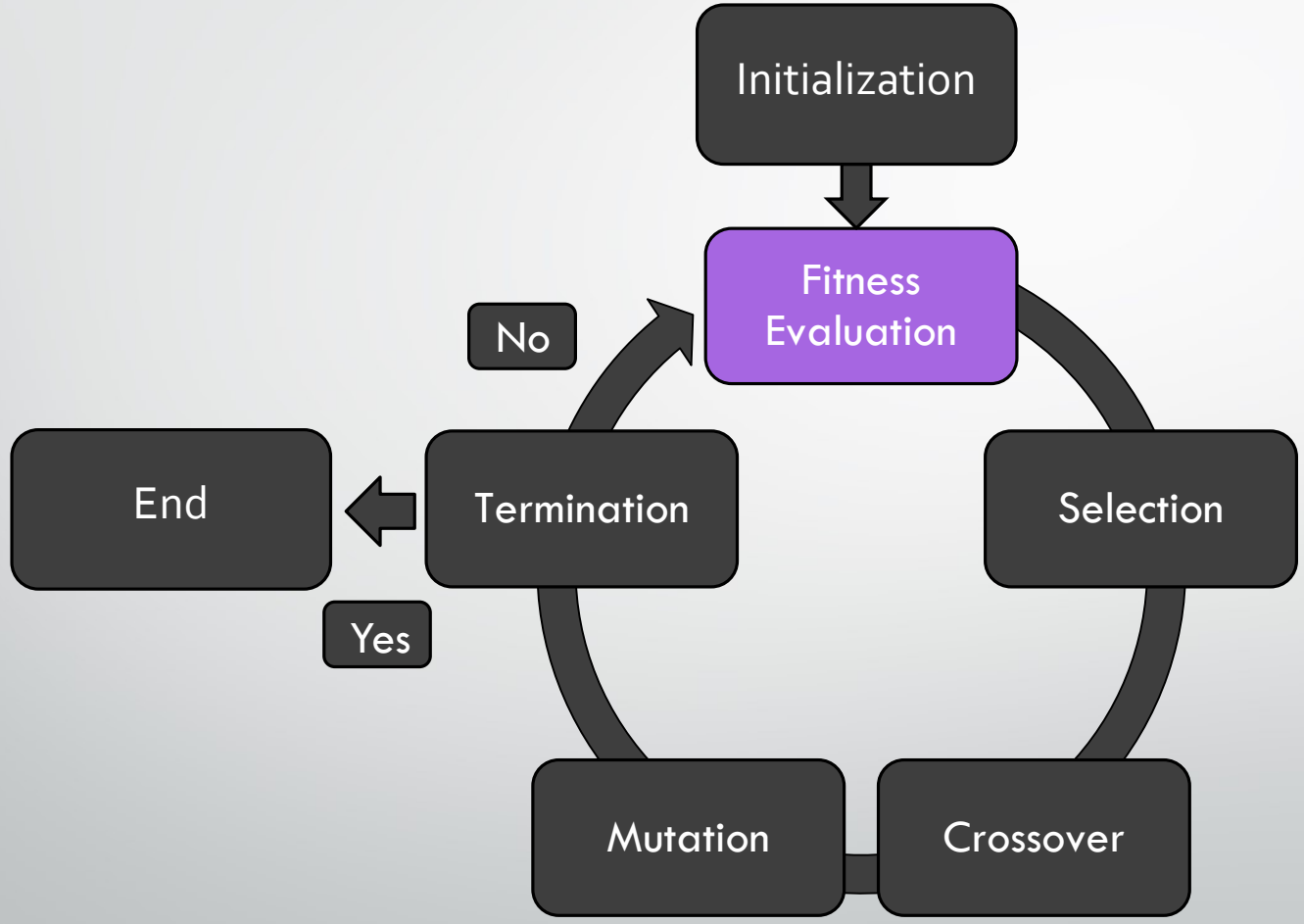
Genetic Algorithm Structure



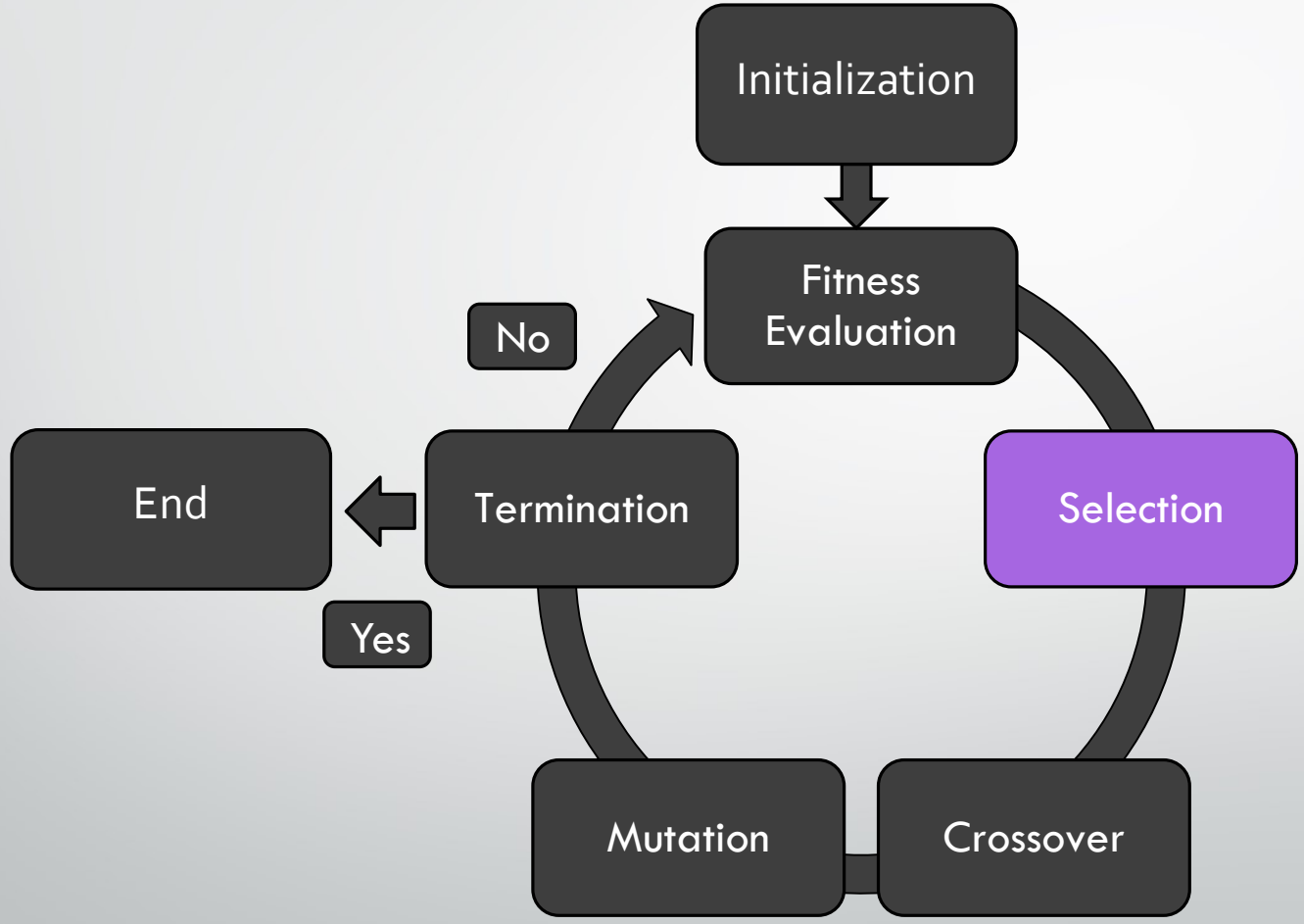
Genetic Algorithm Structure



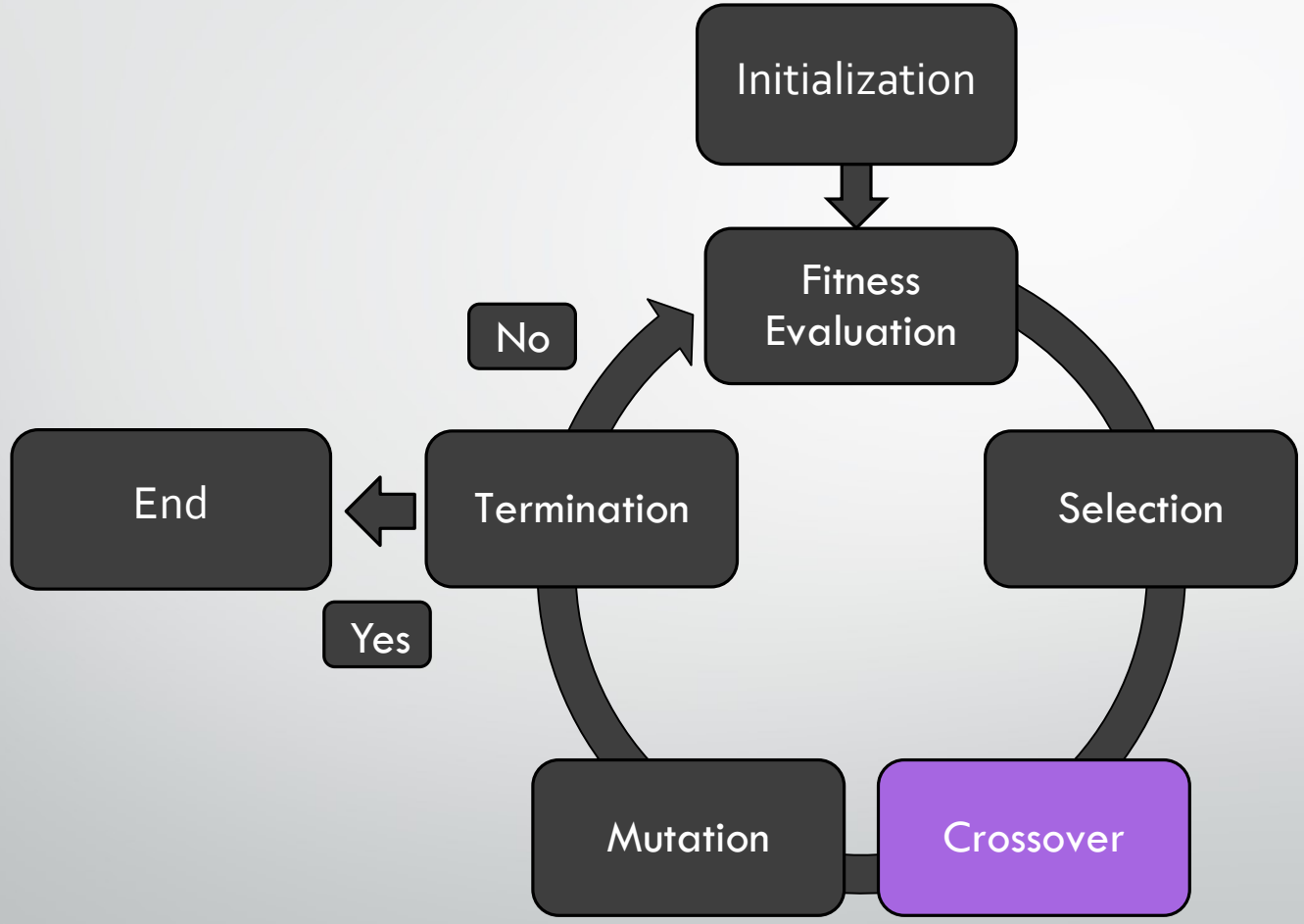
Genetic Algorithm Structure



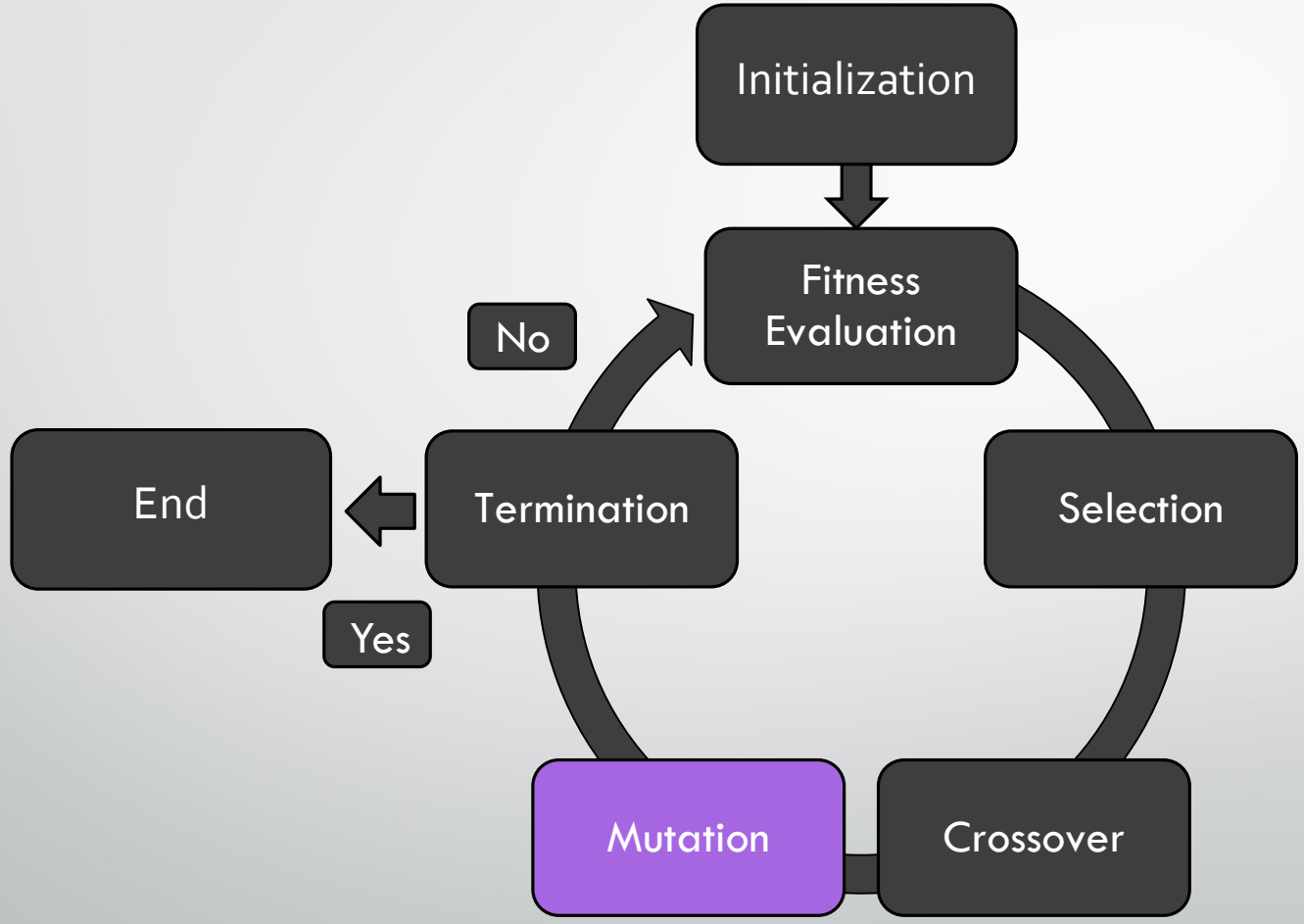
Genetic Algorithm Structure



Genetic Algorithm Structure



Genetic Algorithm Structure

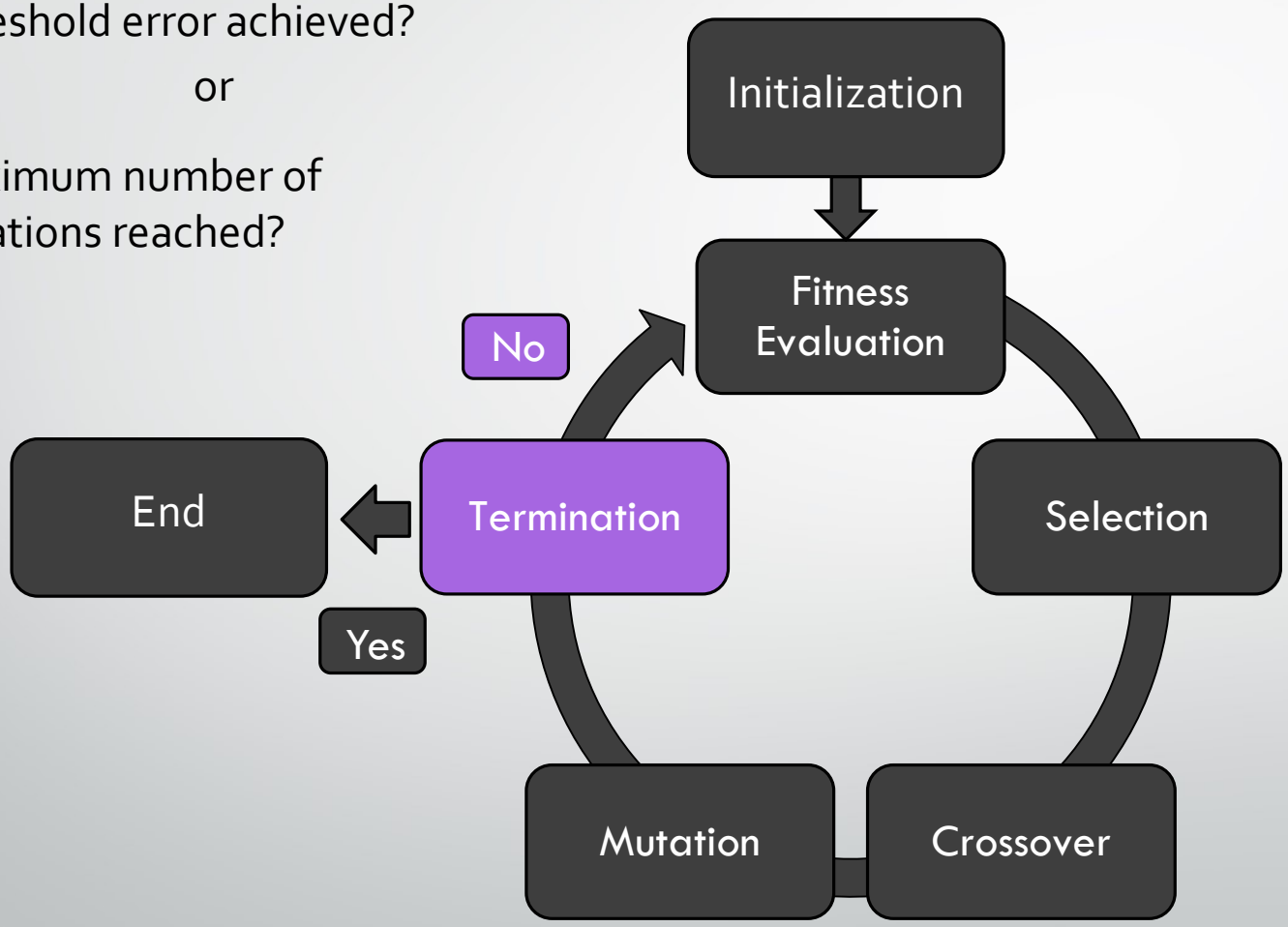


Termination Conditions

Threshold error achieved?

or

Maximum number of iterations reached?



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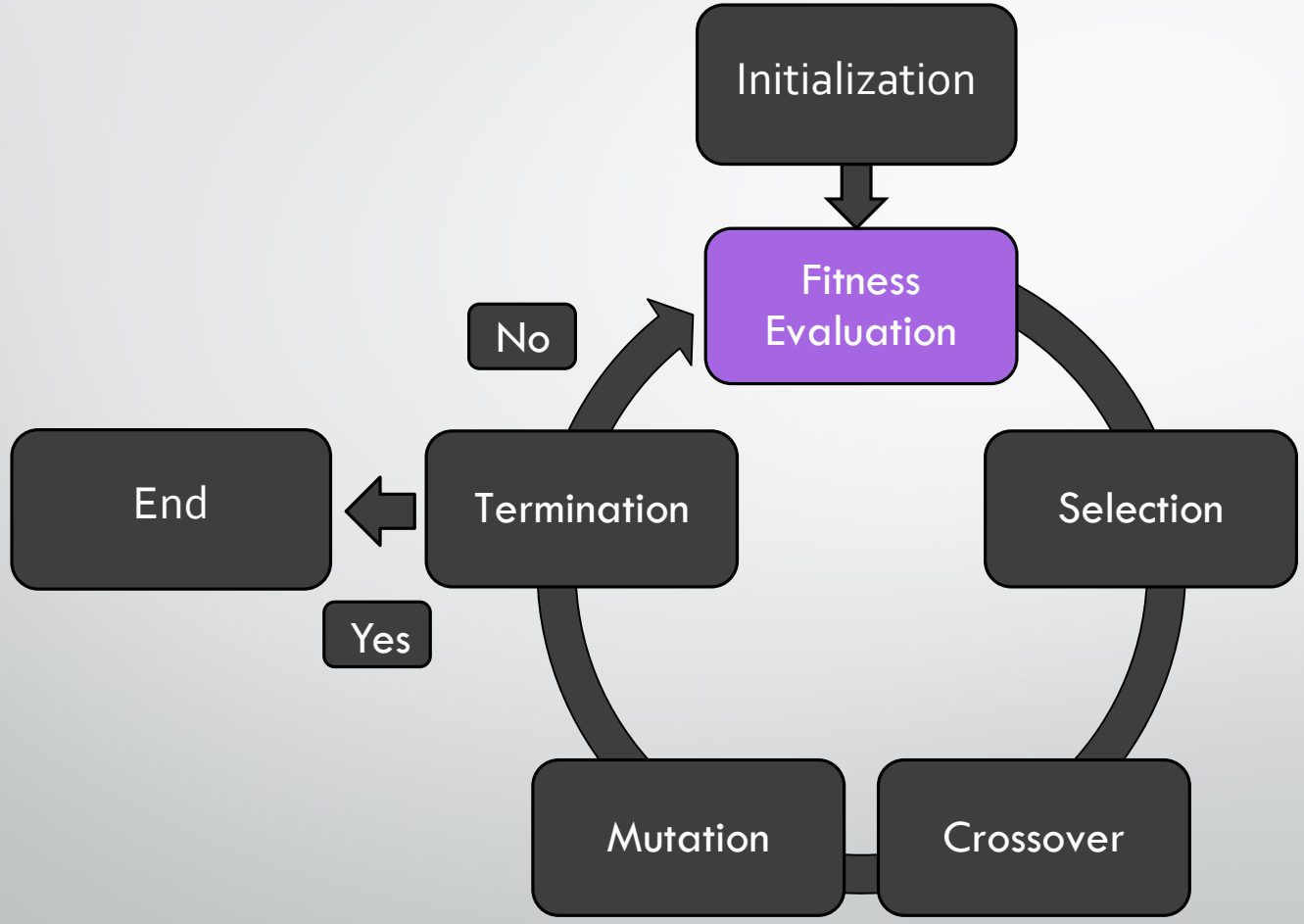

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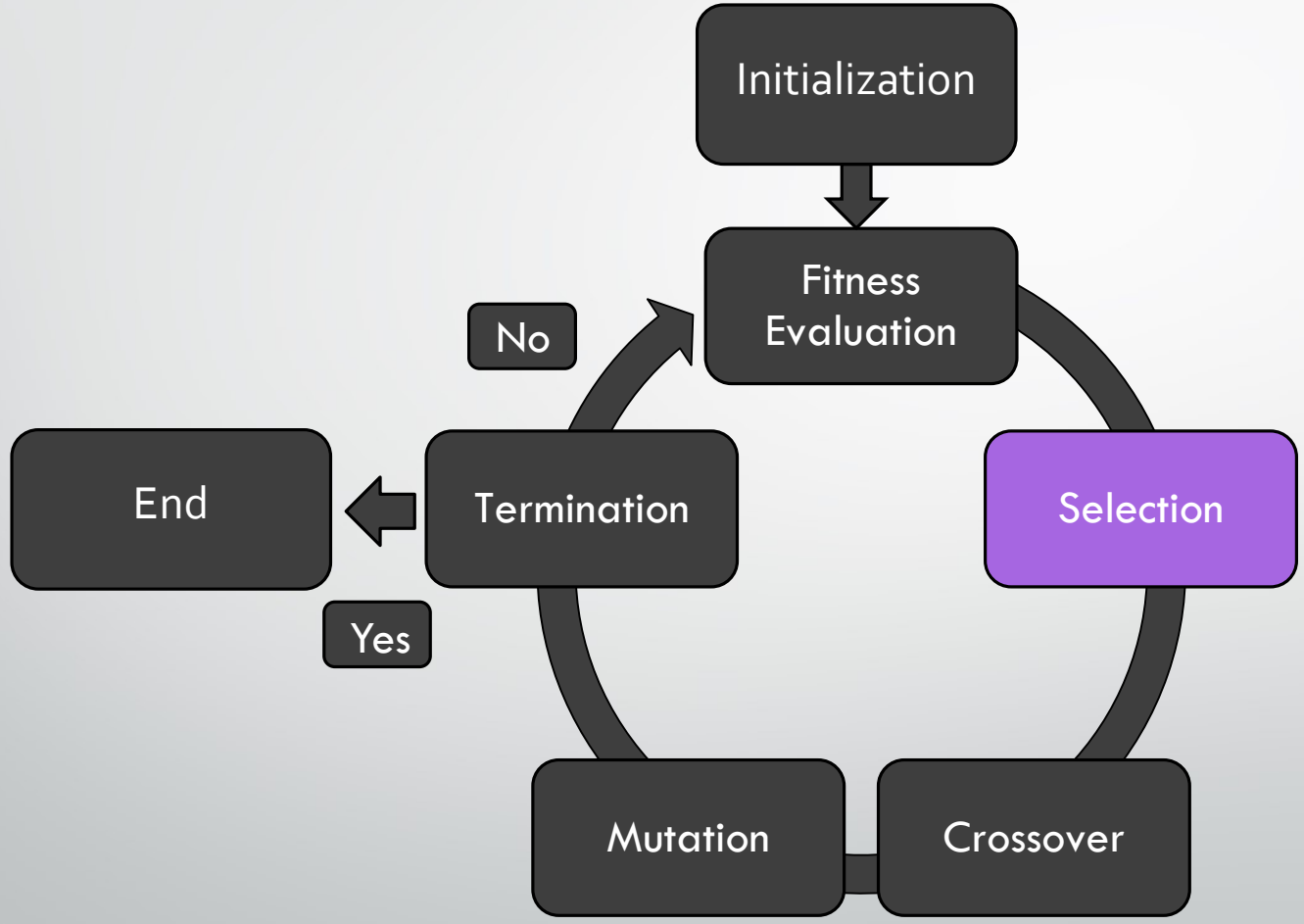

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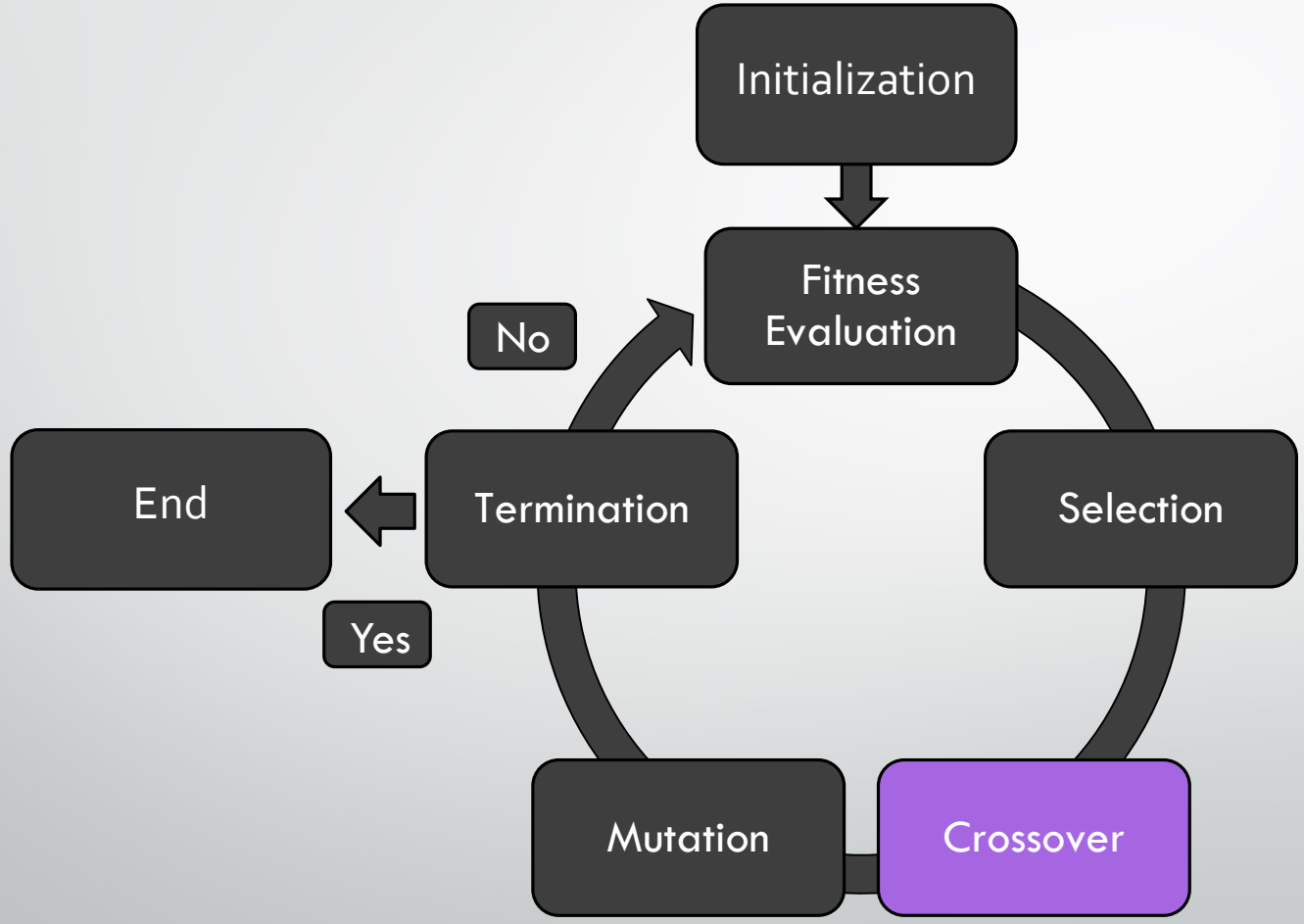

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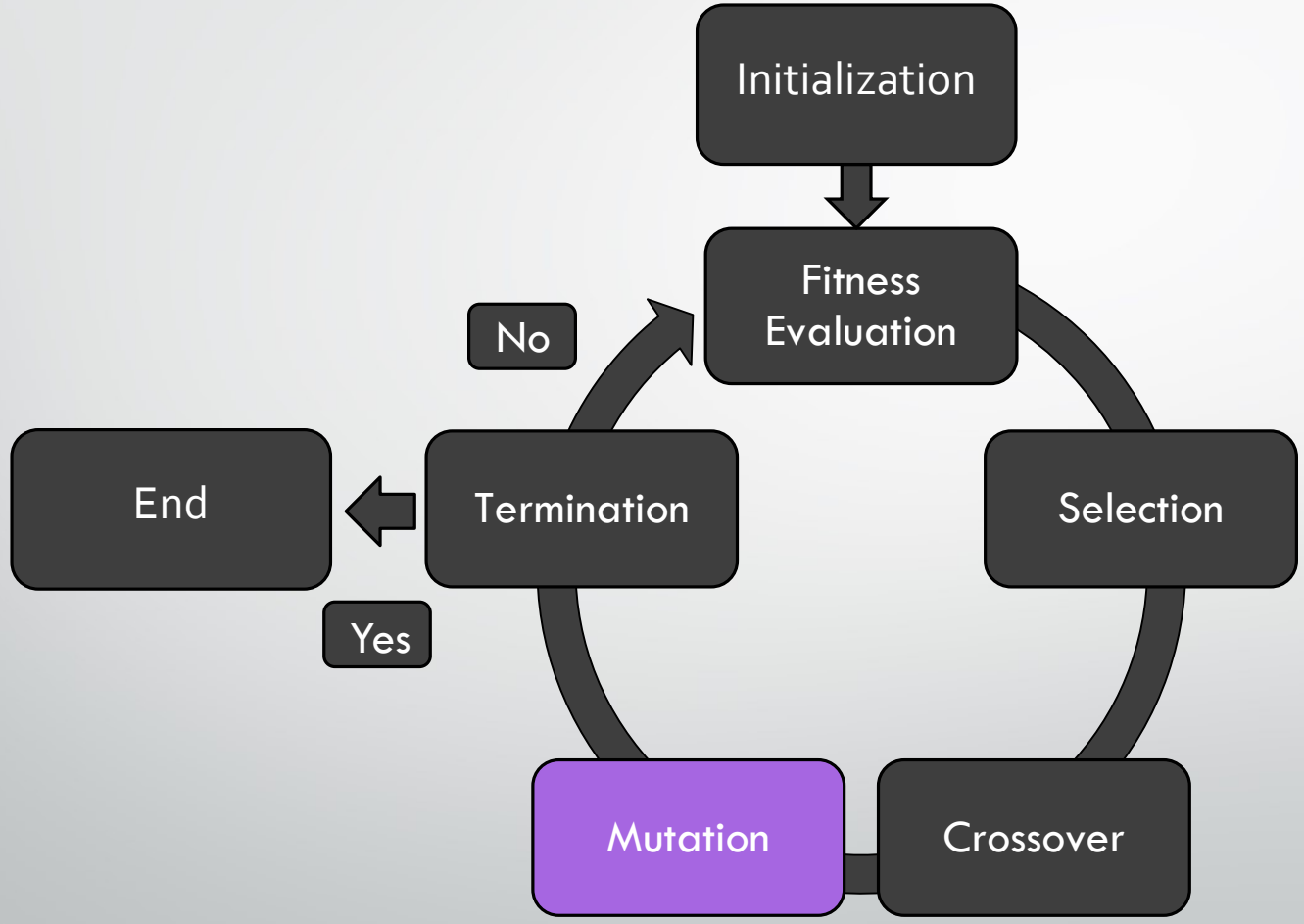

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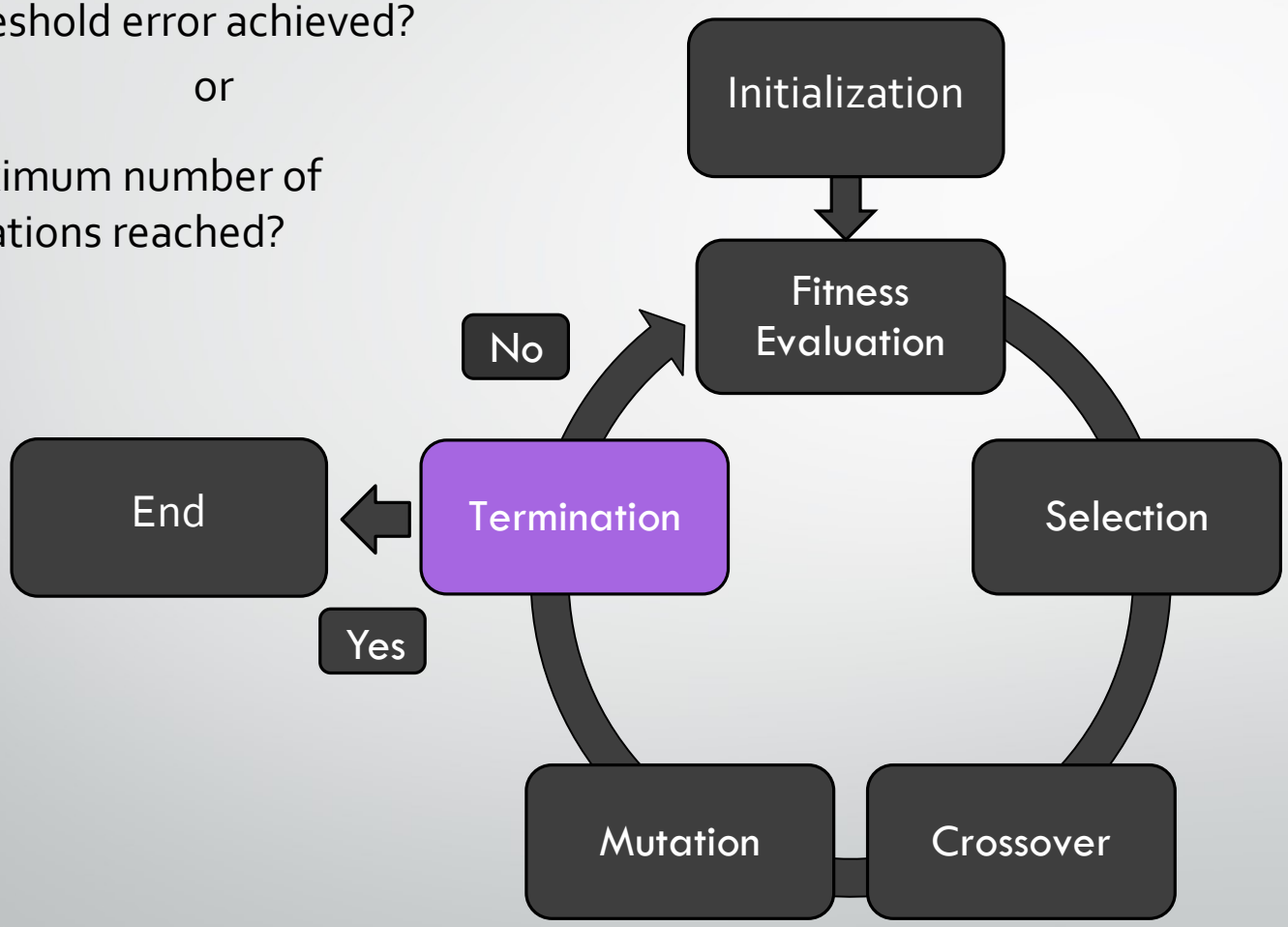

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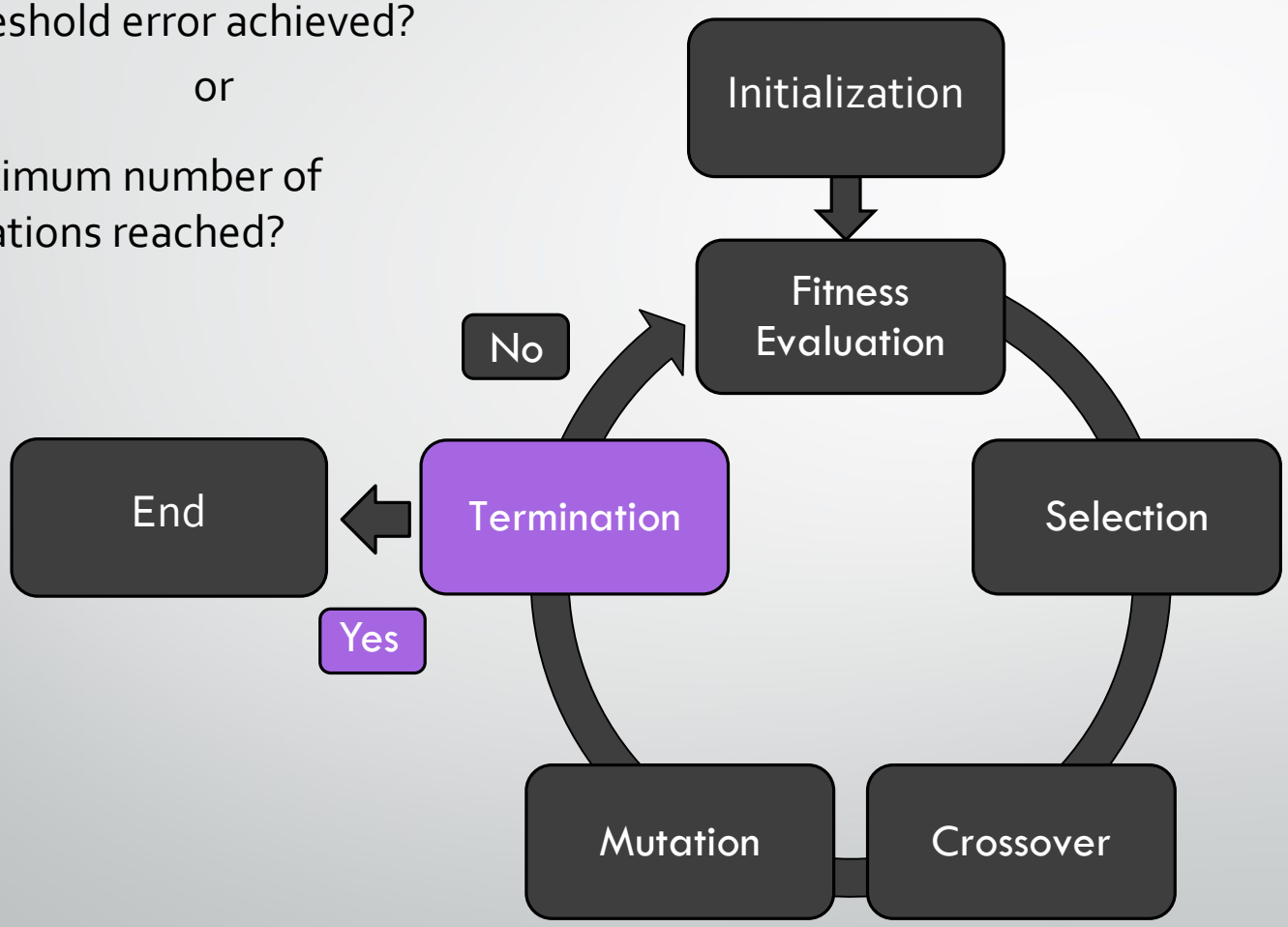

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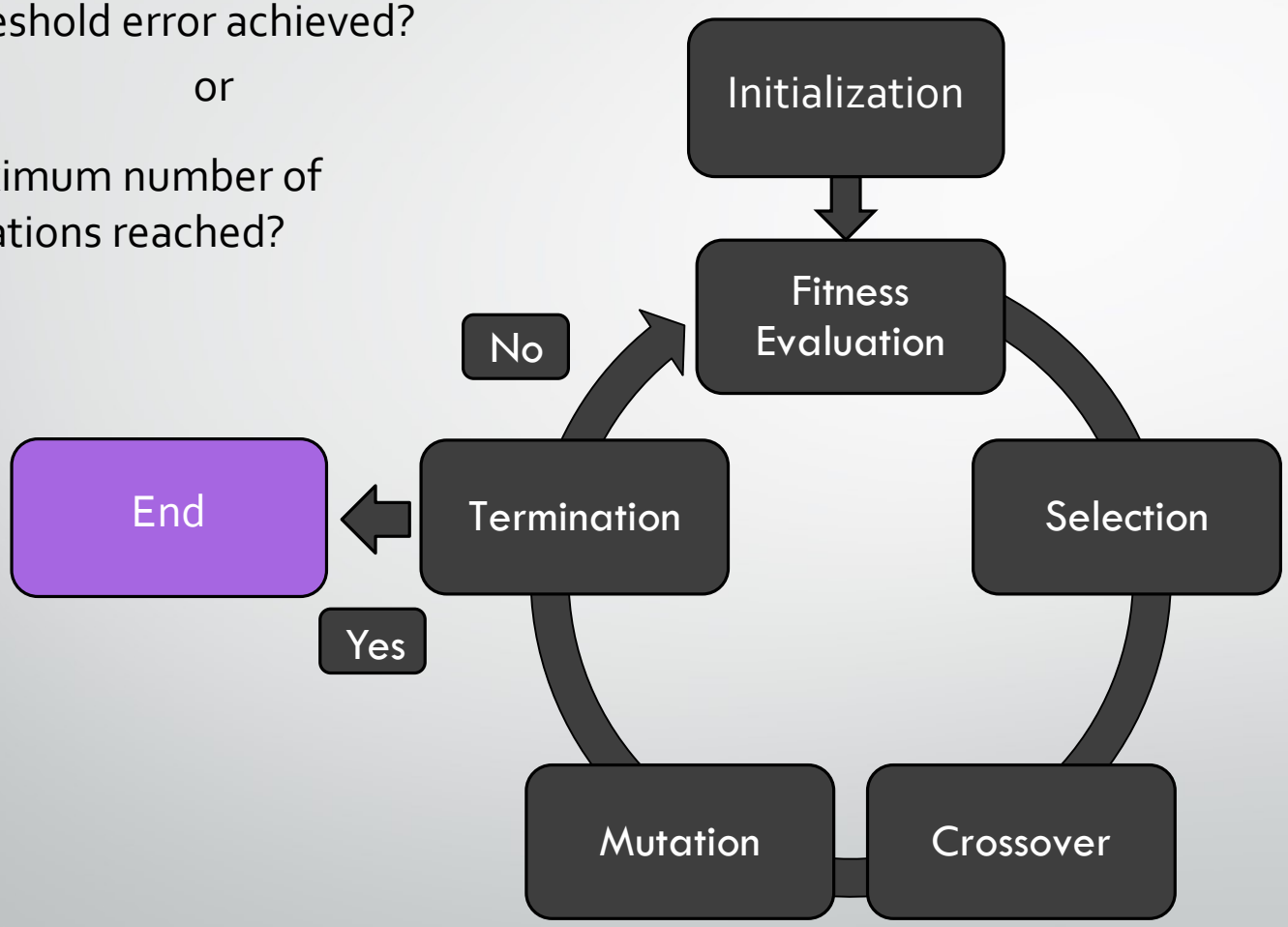
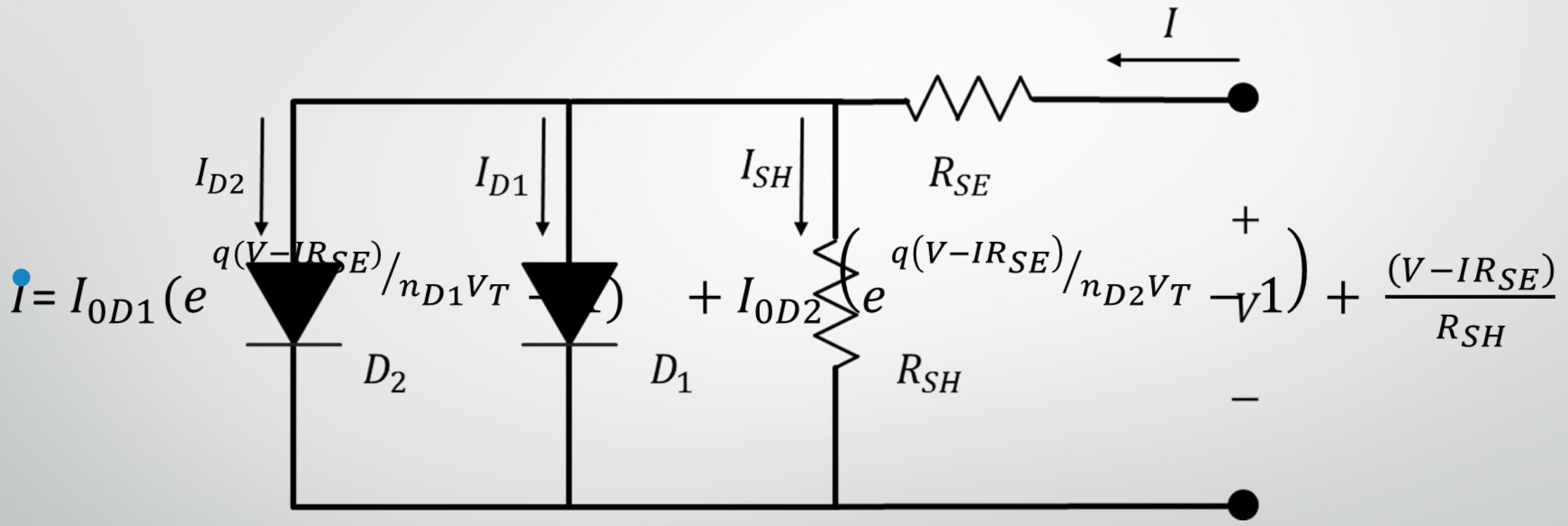


Applied Model

Two-Diode Model

- Diode 1: SRH-diode
- Diode 2: “Diode-like” shunt
- Shunt: Alternate current pathway

Current Model: Two Diode

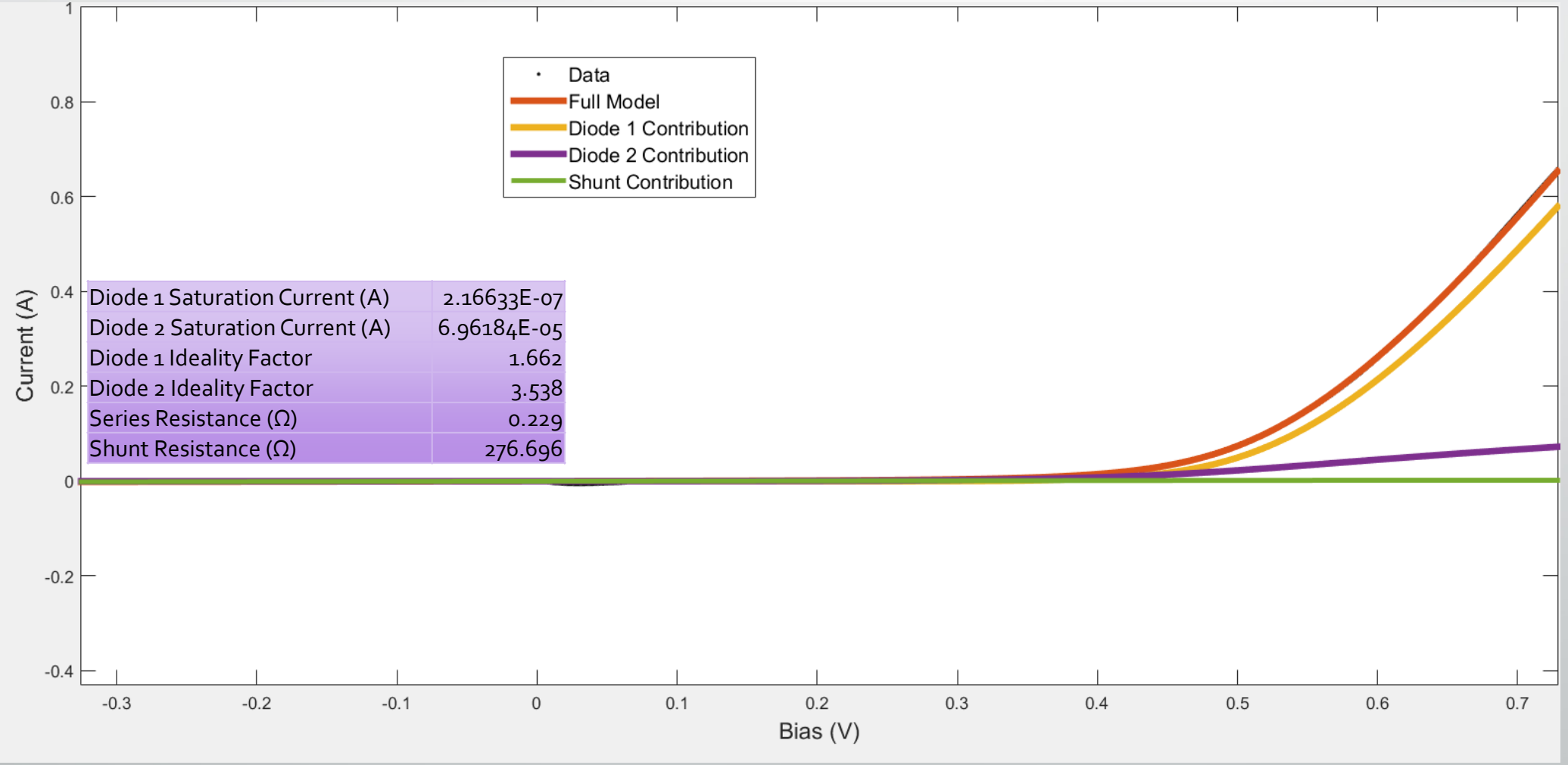


$$I = I_{0D1}\left(e^{q(V-IR_{SE})/n_{D1}V_T} - 1\right) + I_{0D2}\left(e^{q(V-IR_{SE})/n_{D2}V_T} - 1\right) + \frac{(V-IR_{SE})}{R_{SH}}$$

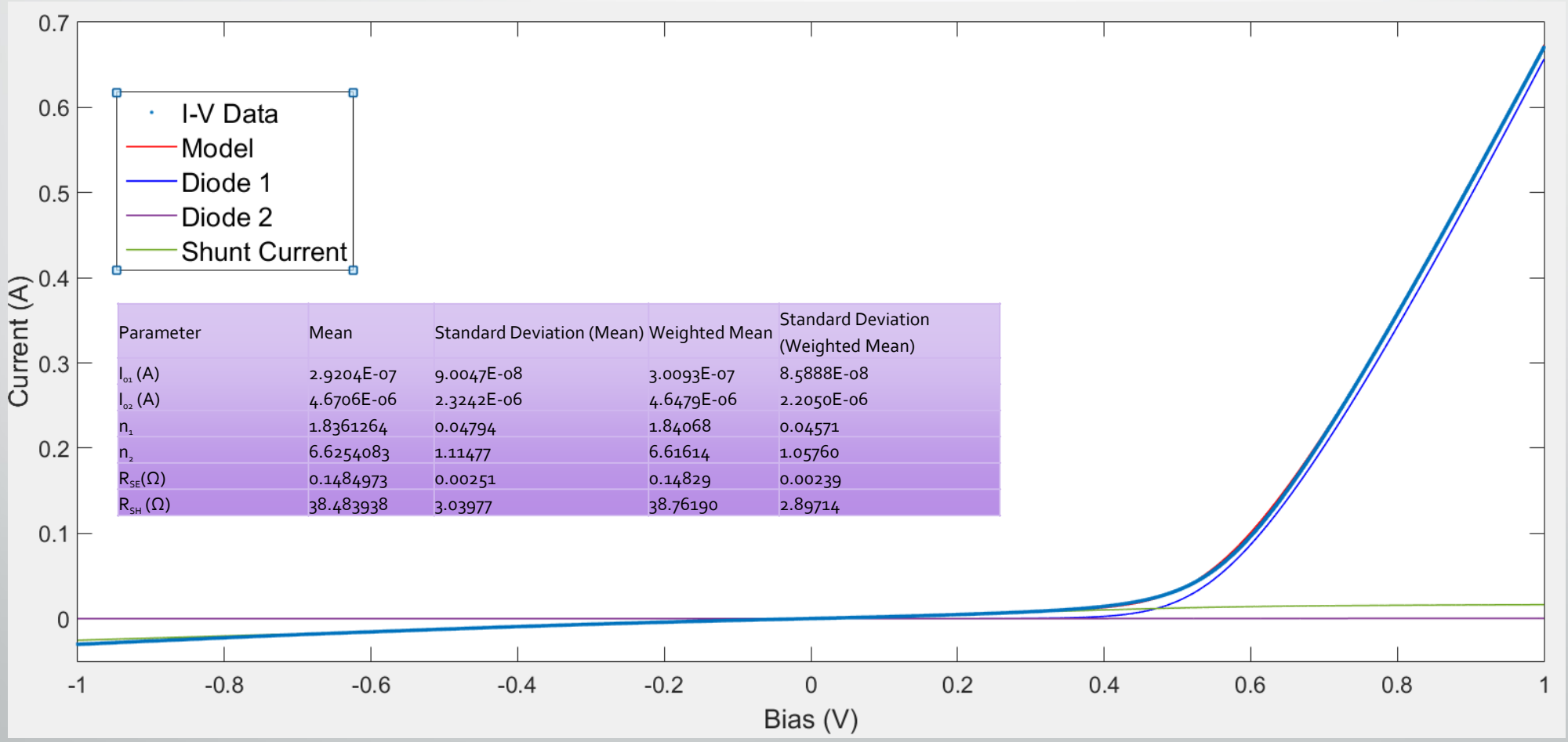
Current Model: Two Diode

Parameter	interpretation
I_{0D1}	Dark saturation current of PN junction
I_{0D2}	Dark saturation current of "Diode-like" shunt
R_{SE}	Series resistance
R_{SH}	Shunt resistance
n_{D1}	Diode 1 ideality factor
n_{D2}	Diode 2 ideality factor

Results: Cleaved Sample

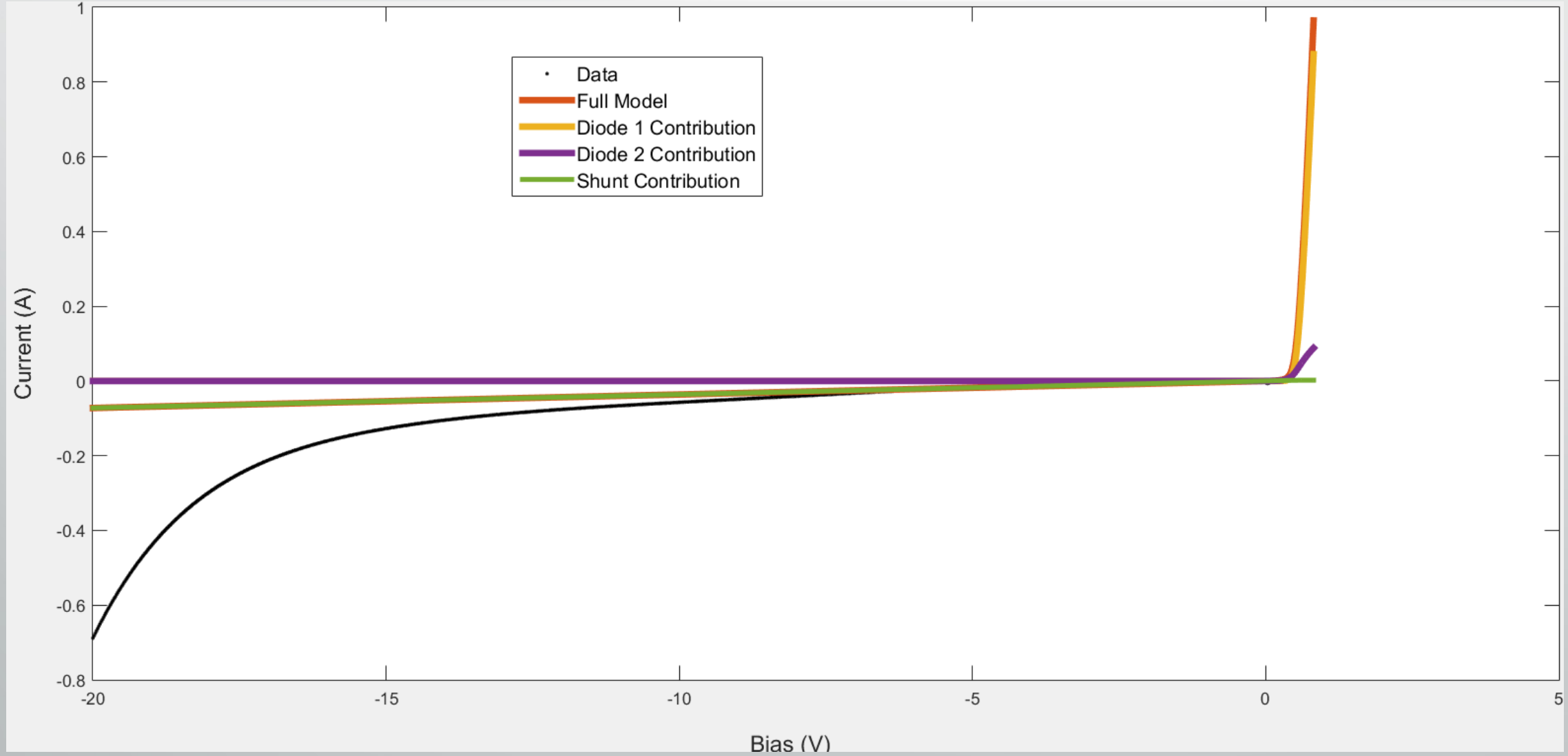


Results: Laser Scribed Sample

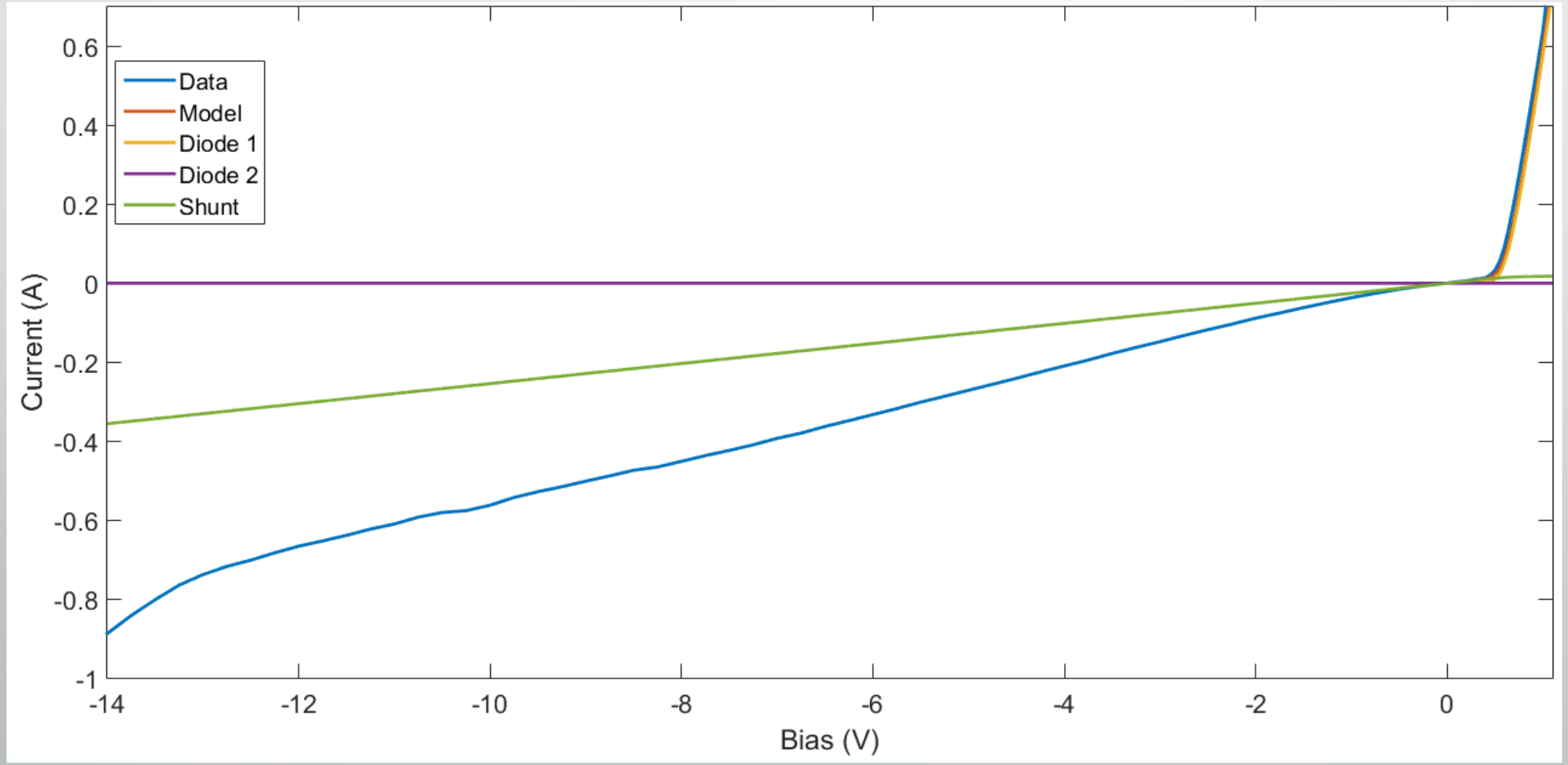


Parameter	Mean	Standard Deviation (Mean)	Weighted Mean	Standard Deviation (Weighted Mean)
I_{01} (A)	2.9204E-07	9.0047E-08	3.0093E-07	8.5888E-08
I_{02} (A)	4.6706E-06	2.3242E-06	4.6479E-06	2.2050E-06
n_1	1.8361264	0.04794	1.84068	0.04571
n_2	6.6254083	1.11477	6.61614	1.05760
$R_{SE}(\Omega)$	0.1484973	0.00251	0.14829	0.00239
$R_{SH}(\Omega)$	38.483938	3.03977	38.76190	2.89714

Results: Cleaved Sample



Results: Laser Scribed Sample

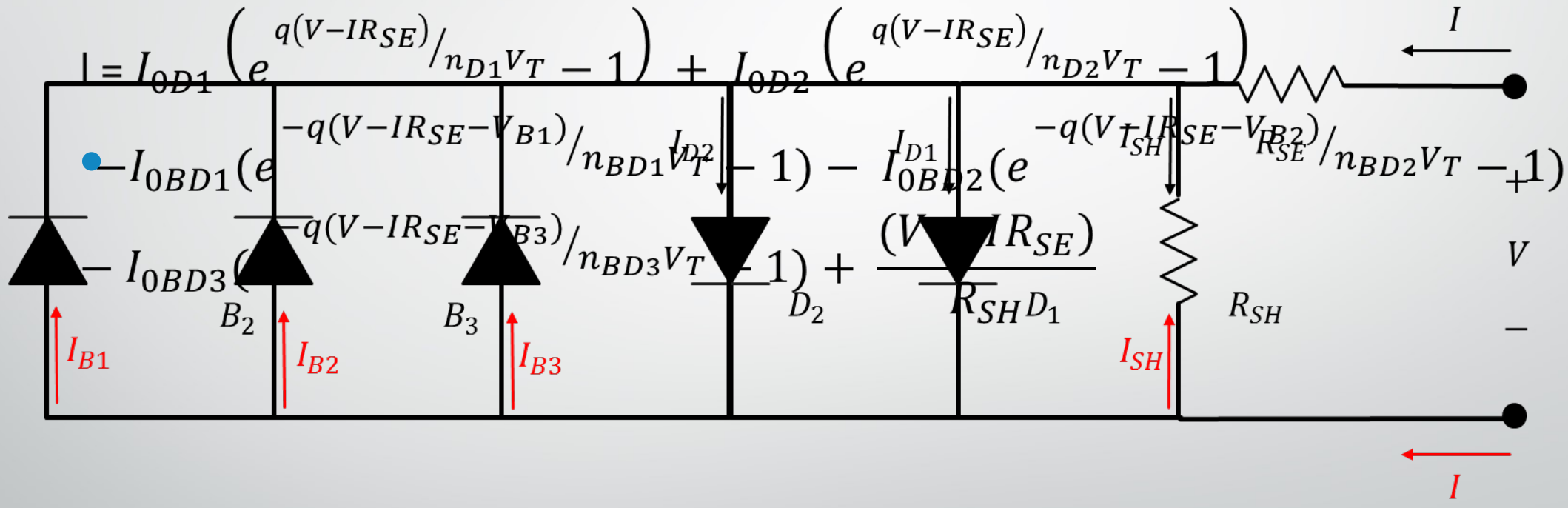


Proposed Model

Five-Diode Model

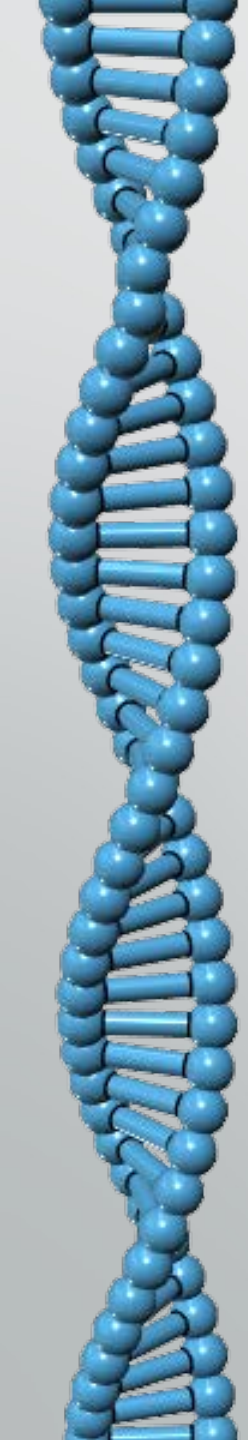
- Diode 1: SRH-diode
- Diode 2: “Diode-like” shunt
- Shunt: Alternate current pathway
- Breakdown diode 1: Type I breakdown – Pre-Breakdown
- Breakdown diode 2: Type II breakdown – Trap assisted tunnelling
- Breakdown diode 3: Type III breakdown – Avalanche breakdown

Current Model: Five Diode



Proposed Model: Five Diode

Parameter	interpretation
I_{0D1}	Dark saturation current of PN junction
I_{0D2}	Dark saturation current of "Diode-like" shunt
R_{SE}	Series resistance
R_{SH}	Shunt resistance
n_{D1}	Diode 1 ideality factor
n_{D2}	Diode 2 ideality factor
I_{0B1}	Dark Saturation current breakdown diode 1
I_{0B2}	Dark Saturation current breakdown diode 2
I_{0B3}	Dark Saturation current breakdown diode 3
n_{B1}	Breakdown diode 1: ideality factor
n_{B2}	Breakdown diode 2: ideality factor
n_{B3}	Breakdown diode 3: ideality factor
V_{B1}	Breakdown voltage – breakdown diode 1
V_{B2}	Breakdown voltage – breakdown diode 2
V_{B3}	Breakdown voltage – breakdown diode 3



Conclusion

- Forward Bias
  - Parameters of a mc-Si solar cells can be optimized using an Genetic Algorithm.
  - Bulk response: Shockley-Reed-Hall model of recombination mechanism.
  - Secondary diode response: likely due to defect recombination mechanisms.
  - The remainder of the response is due to the contribution of the shunt current.
- Reverse Bias
  - Two-diode module is not appropriate
  - Proposed five-diode model
    - Pre-breakdown
    - IFE- through trap assisted tunneling
    - Avalanche breakdown

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- Financial Support

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- Financial Support

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- Financial Support

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NMMU
- Financial support