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Bio-inspiration from Spider's silks

Principles and Development of Bio-Inspired Materials

Vienna, April 14th 2010

Motivation: Production of silk bioinspired fibers

Tunability of spider silk fibers

Synthesis of tunable bio-inspired fibers

Conclusions

Motivation: Production of silk bioinspired fibers

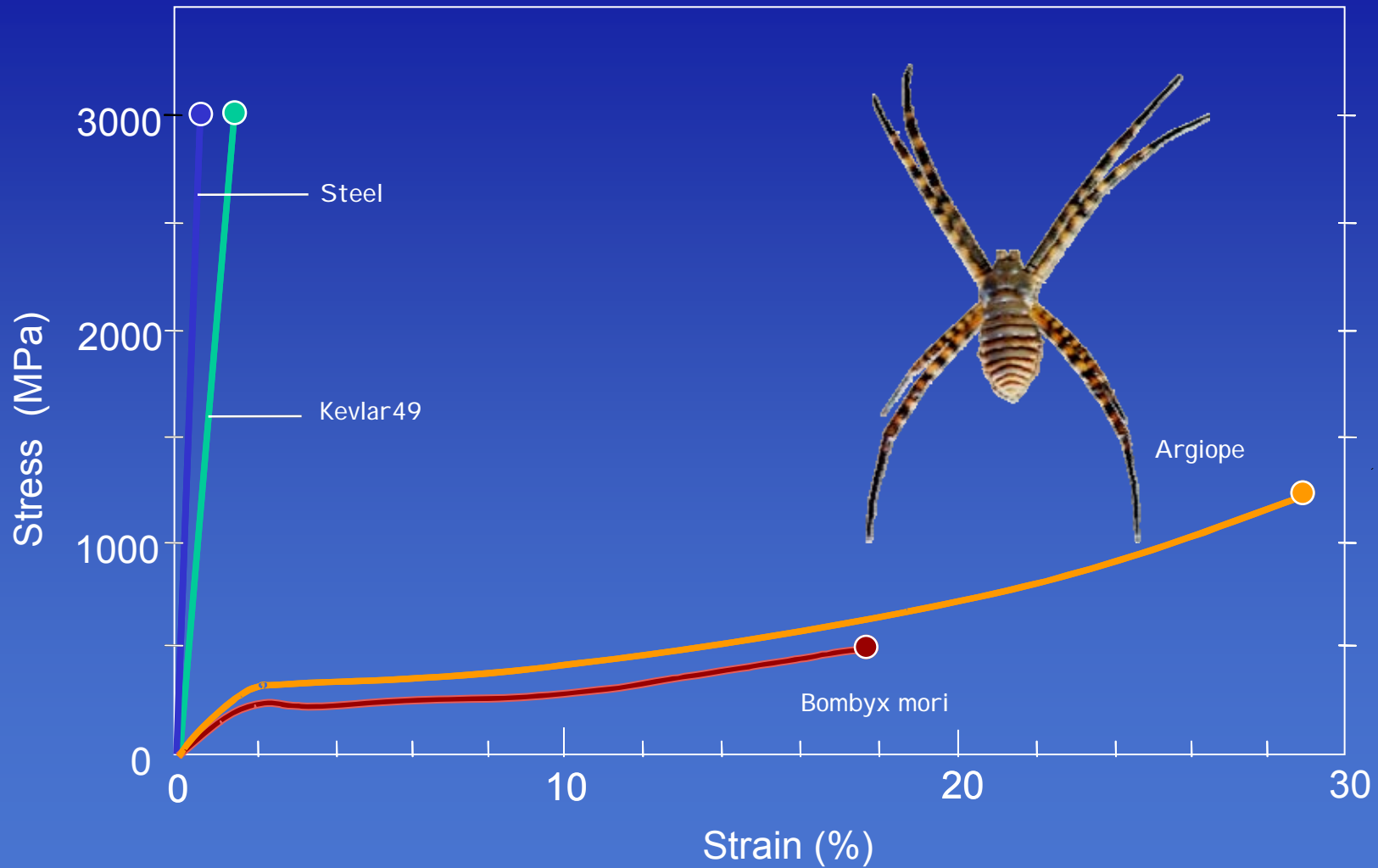
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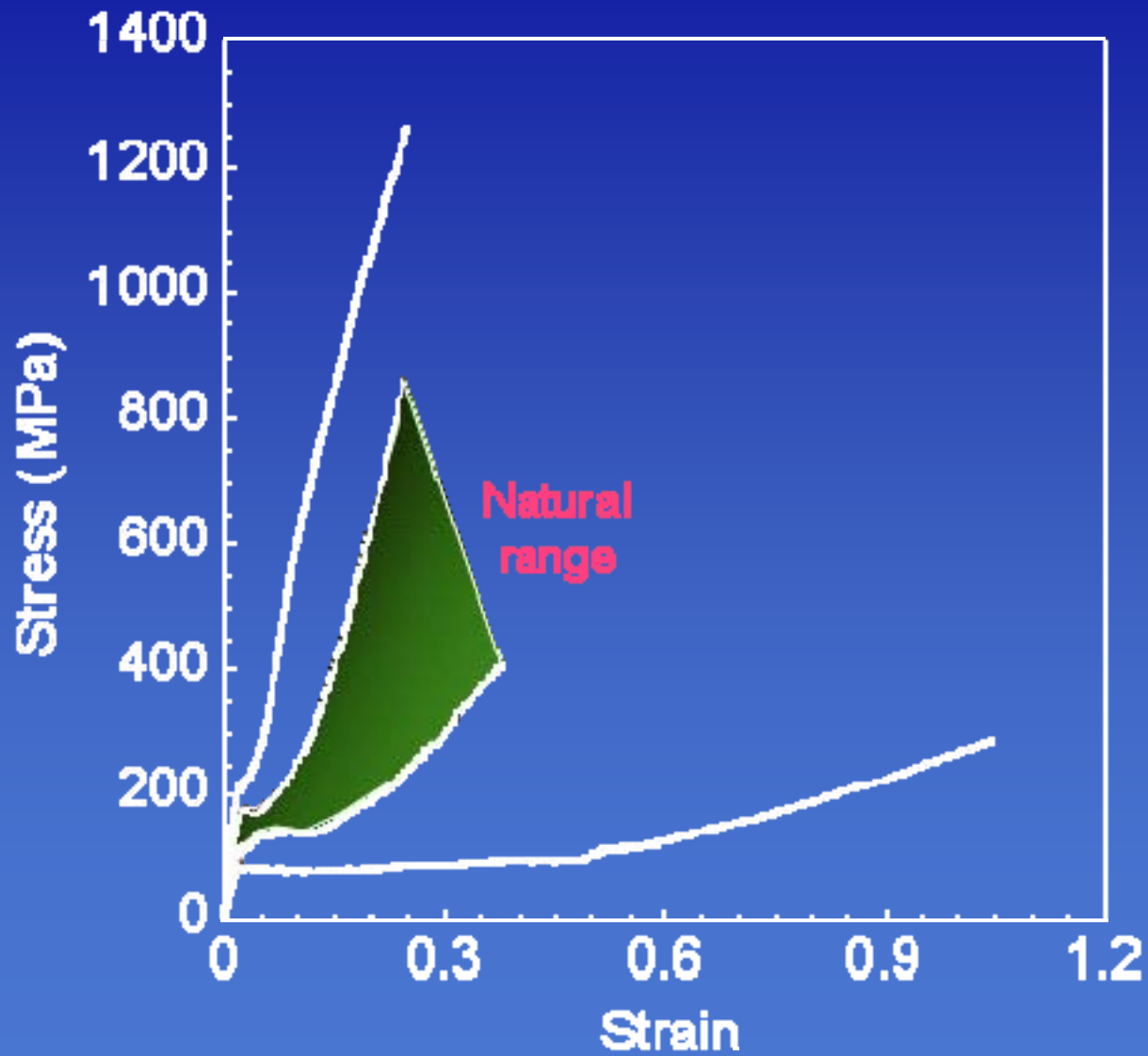
Mechanical properties



Spider silk combines large tensile strength and strain at breaking

Motivation

The many faces of spider silk



Motivation: Production of silk bioinspired fibers

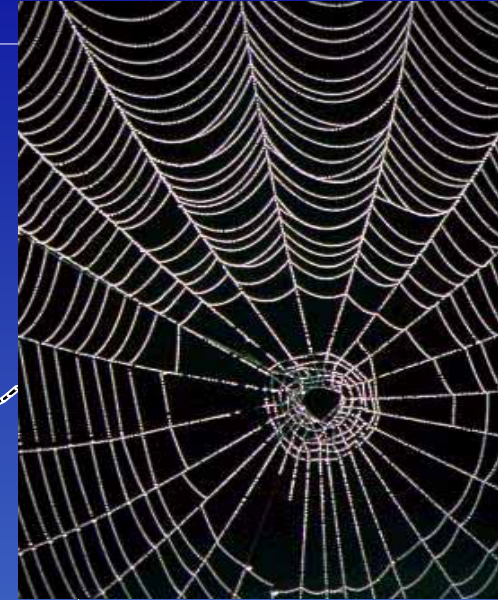
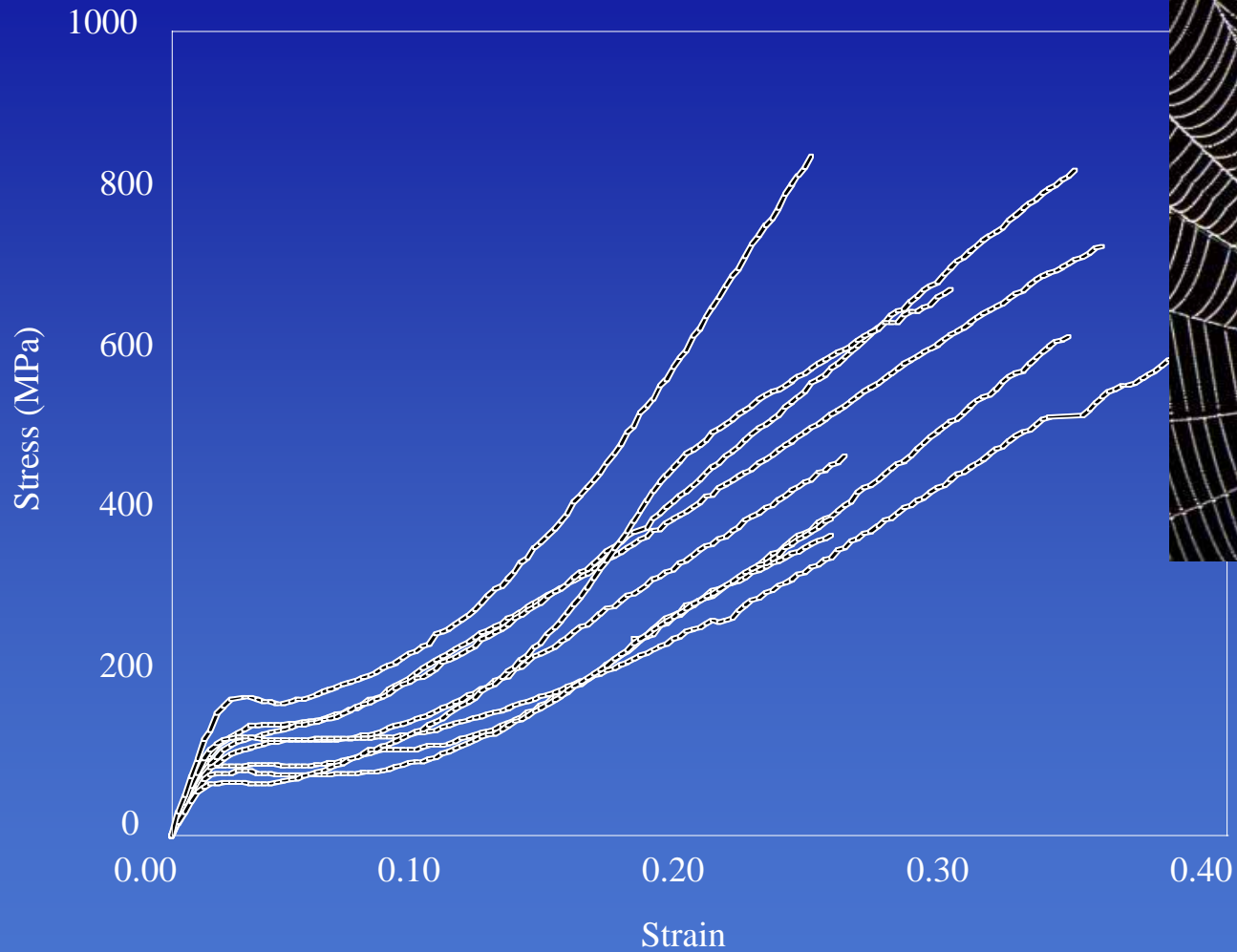
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Tunability of spider silk

Variability of spider silk in the web



Silk fibers retrieved from the web show a large variability

Tunability of spider silk

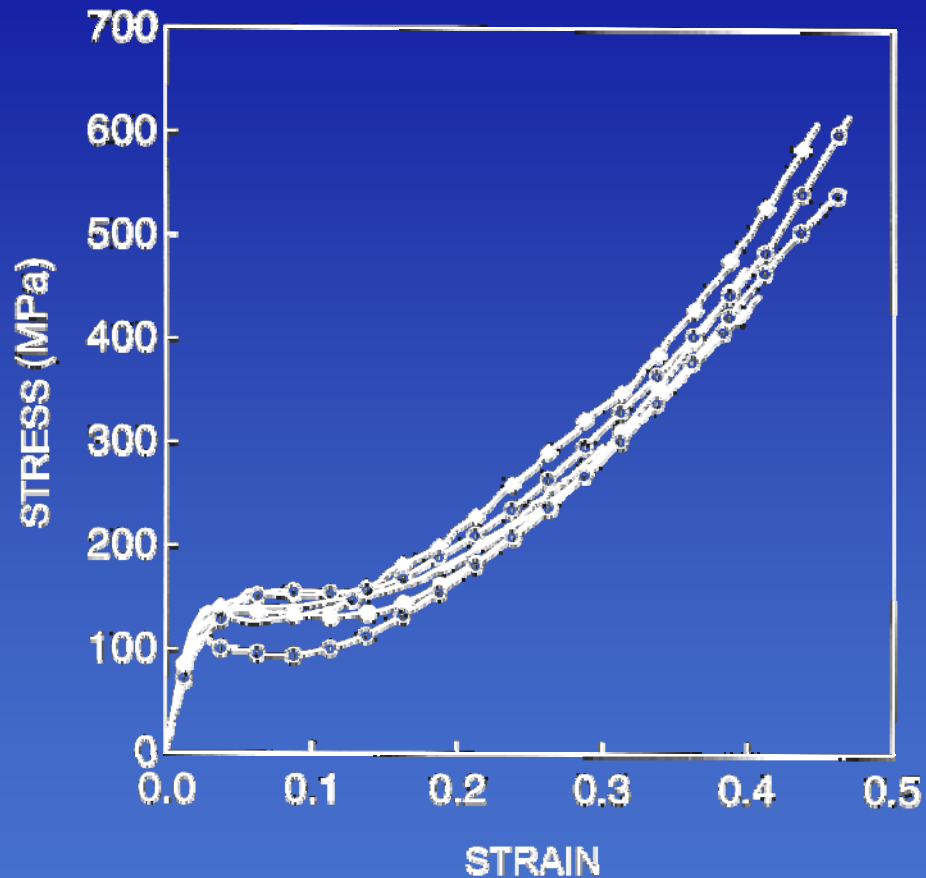
Adapting silk's properties



Spinning of the safety line

Tunability of spider silk

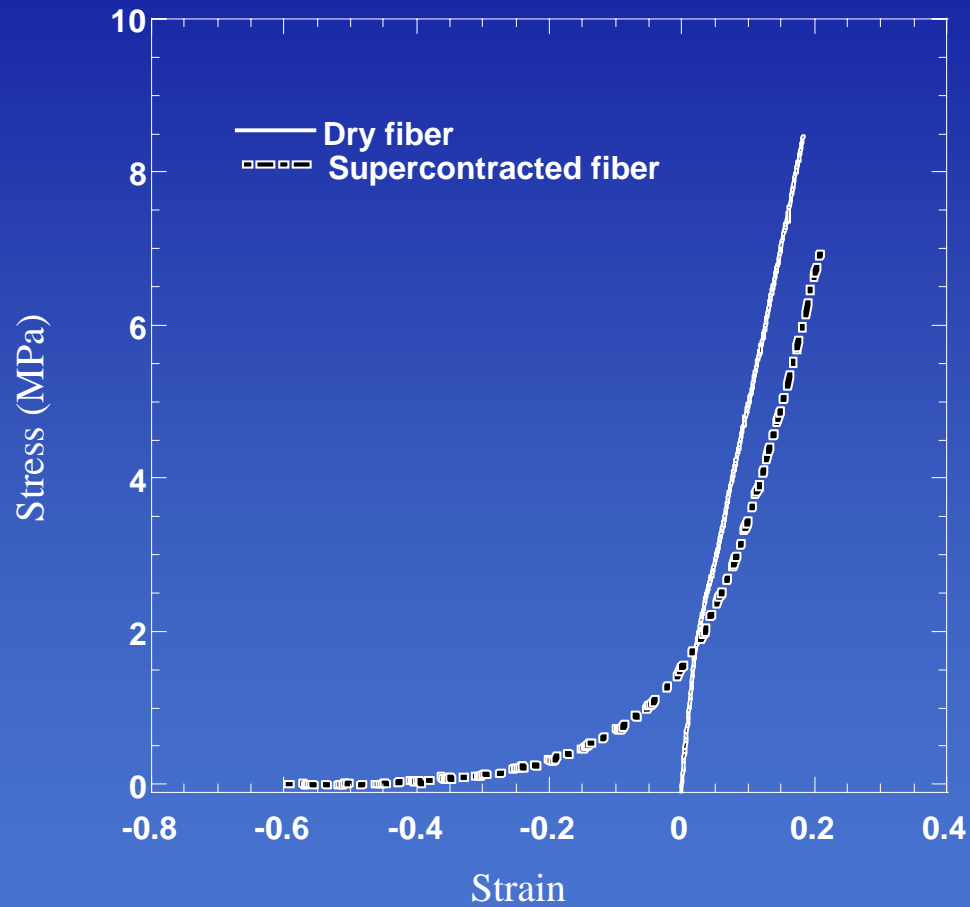
Adapting silk's properties



Reproducibility of spider silk spun during undisturbed climbing

Tunability of spider silk

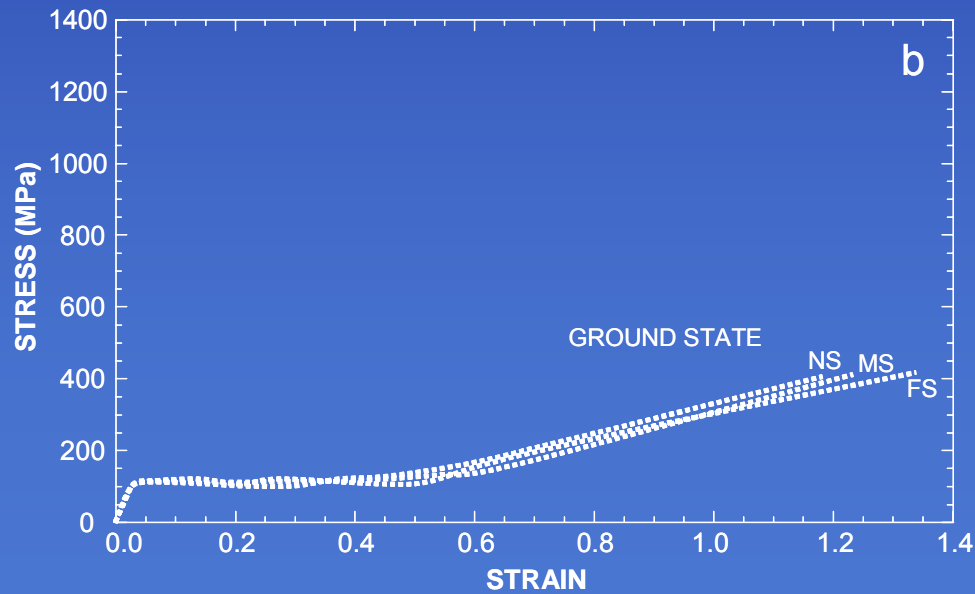
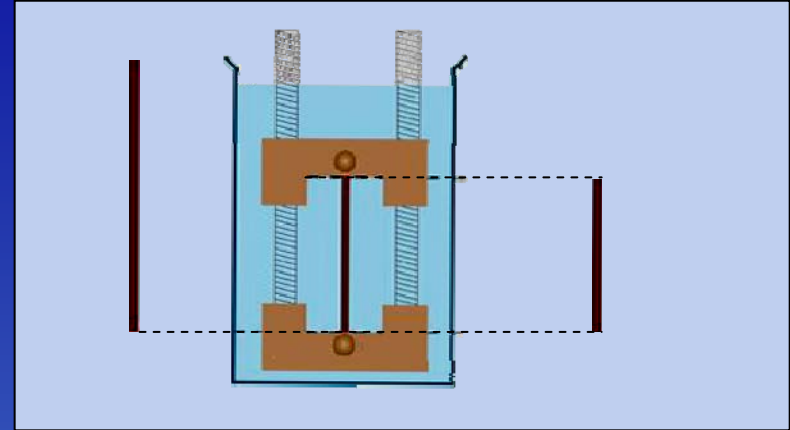
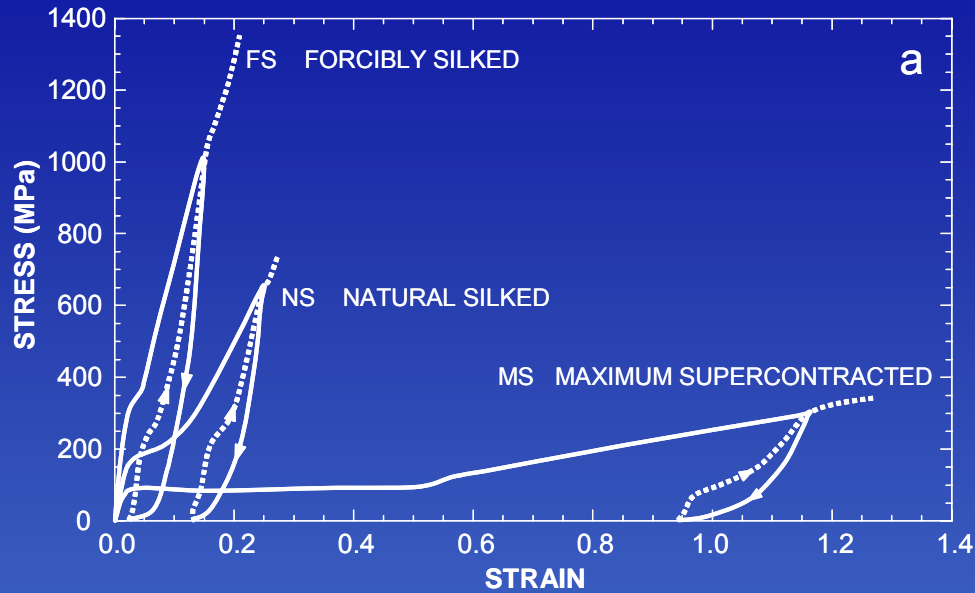
Supercontraction



Immersion in water reduces the length of the fiber down to a 50 % of its initial value

Tunability of spider silk

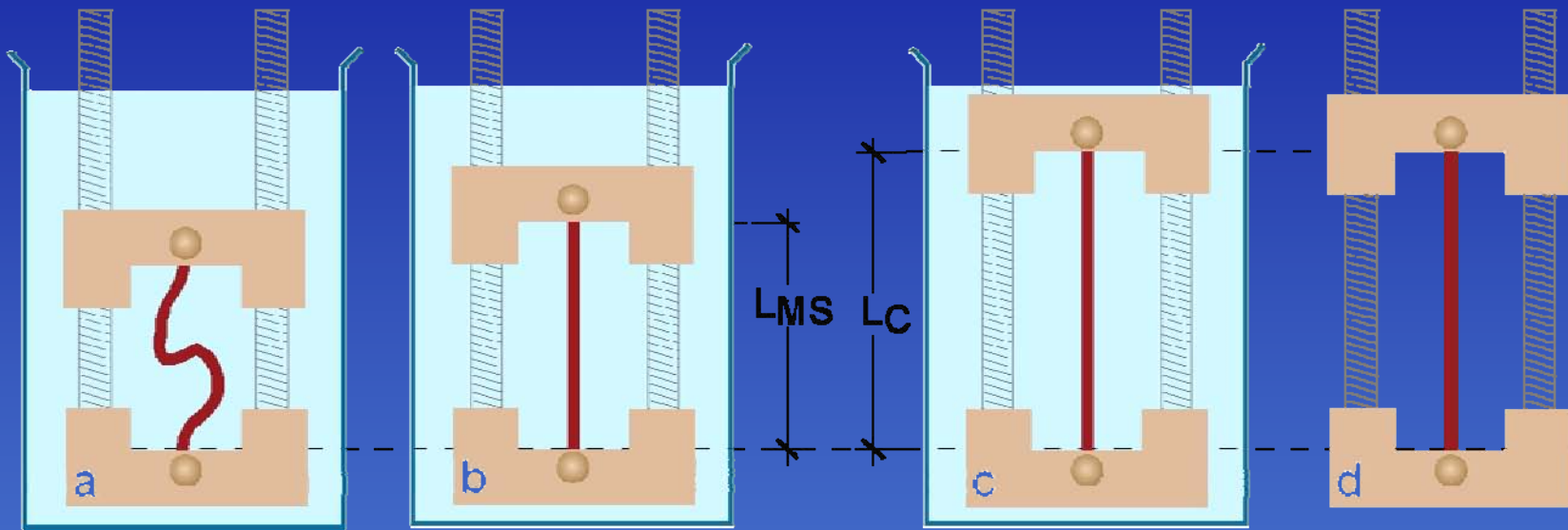
Existence of a ground state



Maximum supercontraction allows reaching a ground state

Tunability of spider silk

Wet stretching process

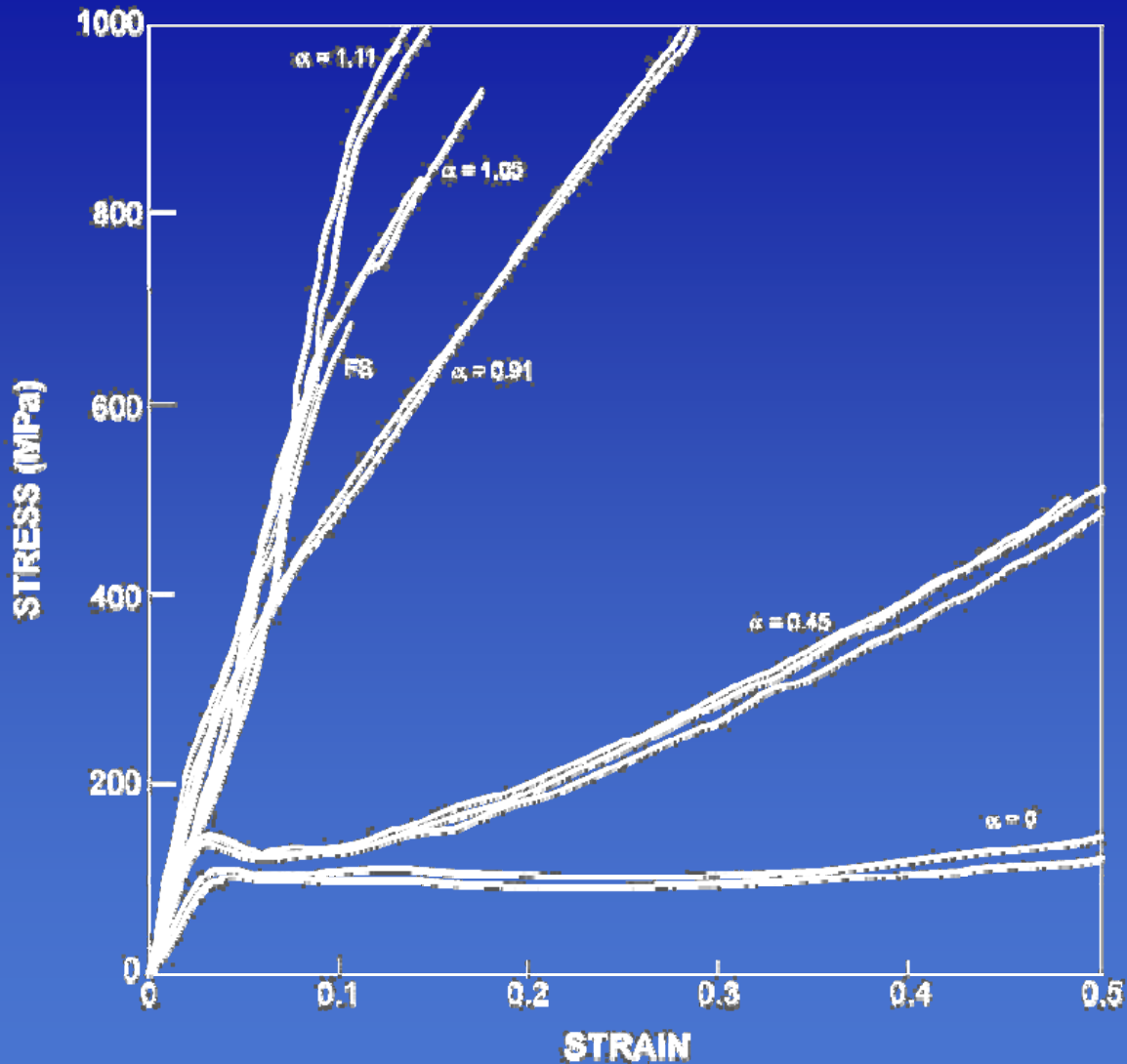


$$\alpha = L_C / L_{SC} - 1$$

The wet stretching process allows modifying the properties of spider silk in a predictable and reproducible way

Tunability of spider silk

Wet stretching process

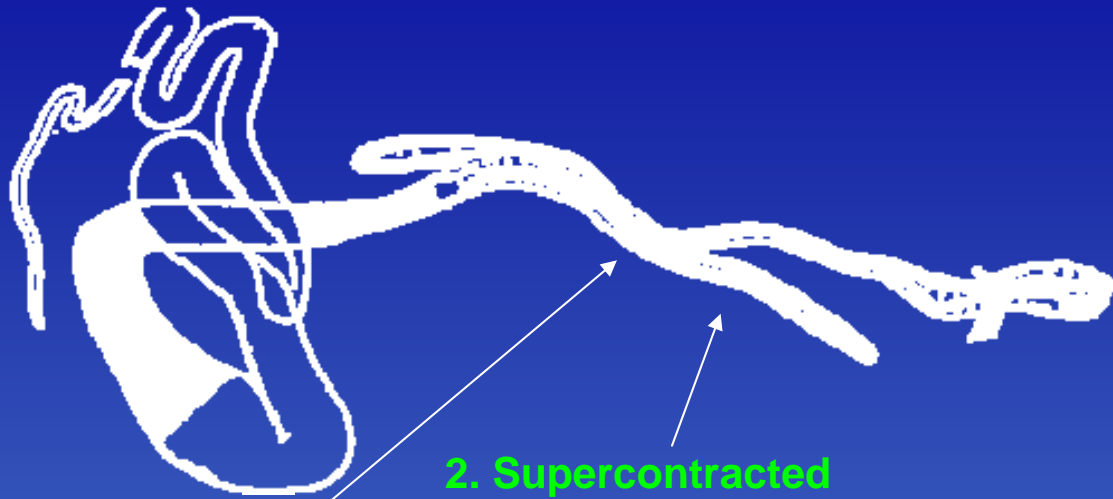


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Tunability of spider silk

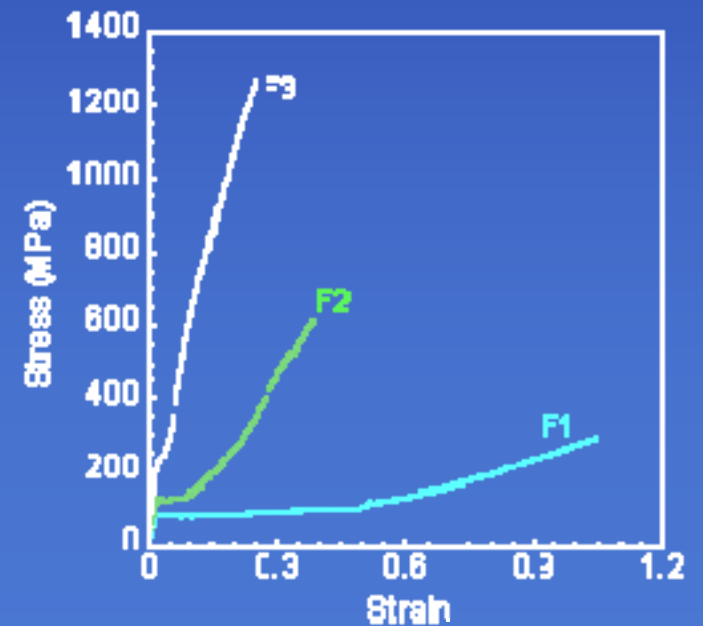
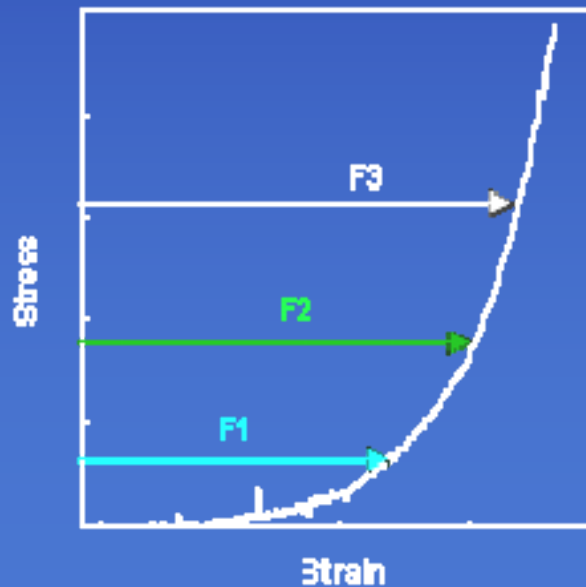
Supercontraction and processing



1. Solidification of the fiber (β microcrystals)

2. Supercontracted (Elastomeric) state

3. Fibers subjected to variable silking stress



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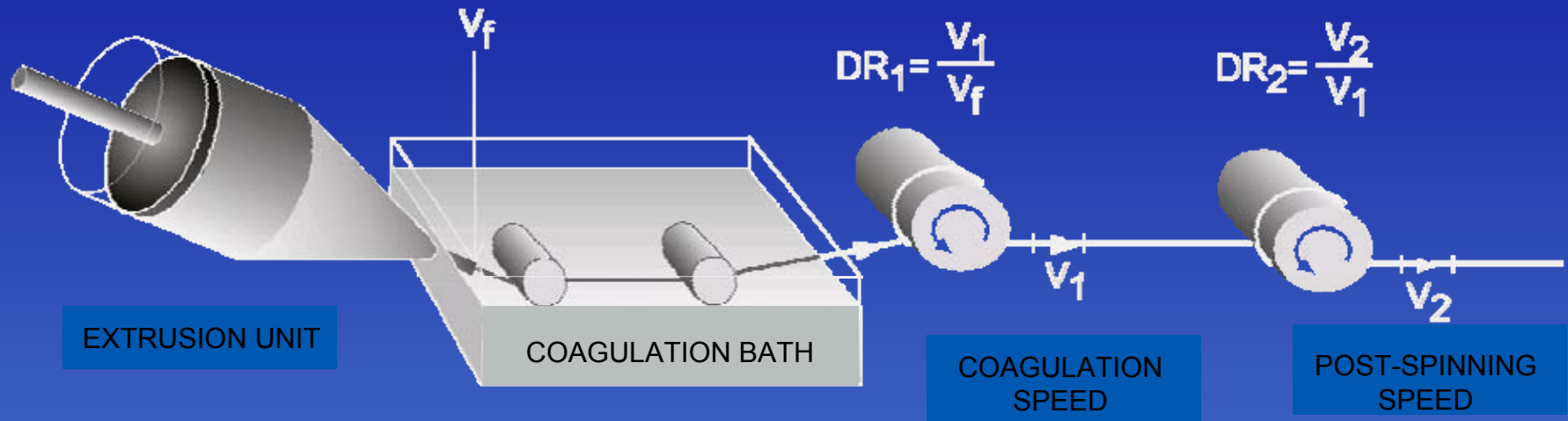
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Wet spinning process



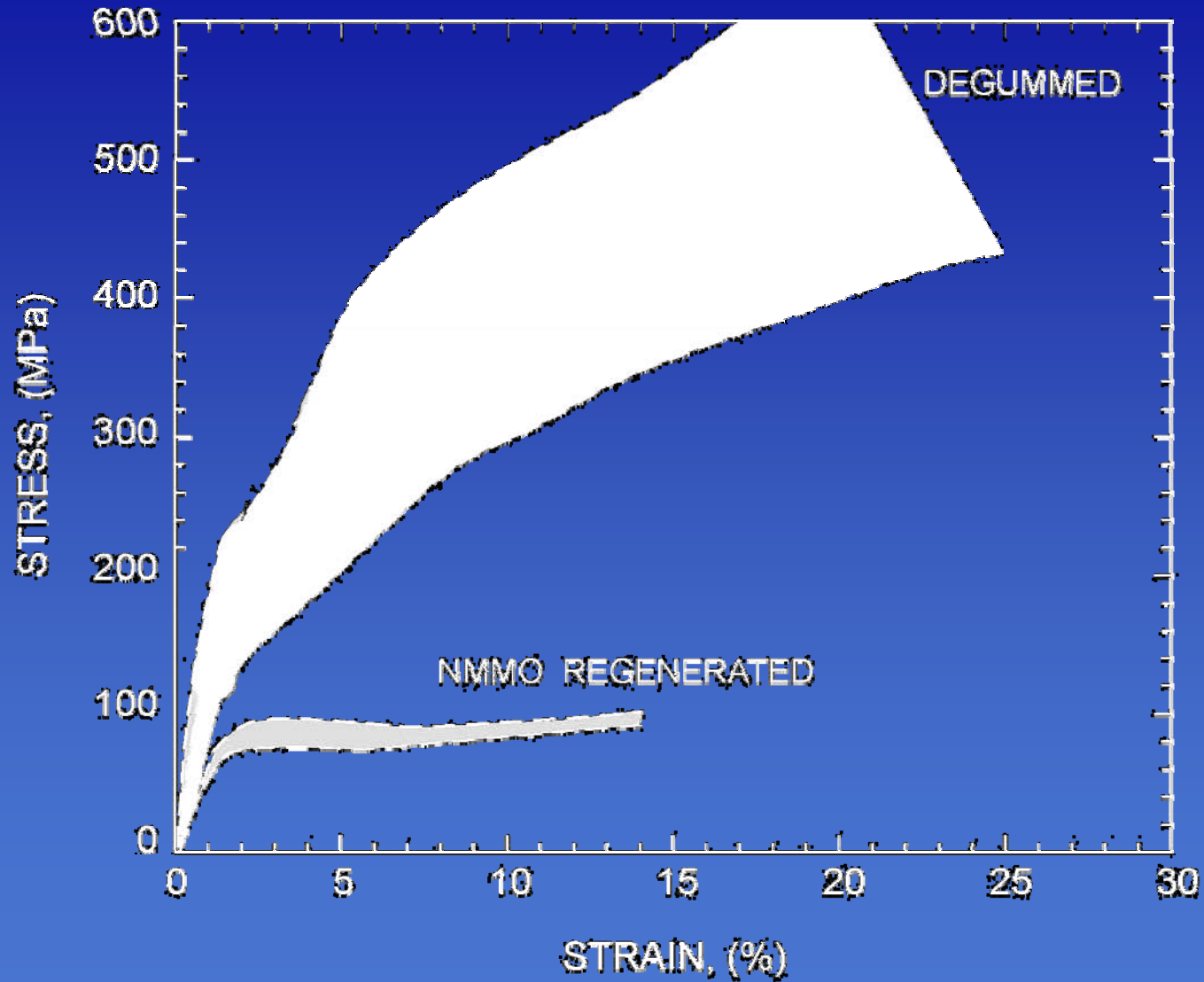
Variables of the process:

Composition of the dope: silk fibroin in NMMO·H₂O

Composition of the coagulating bath: Ethanol

Take up speed

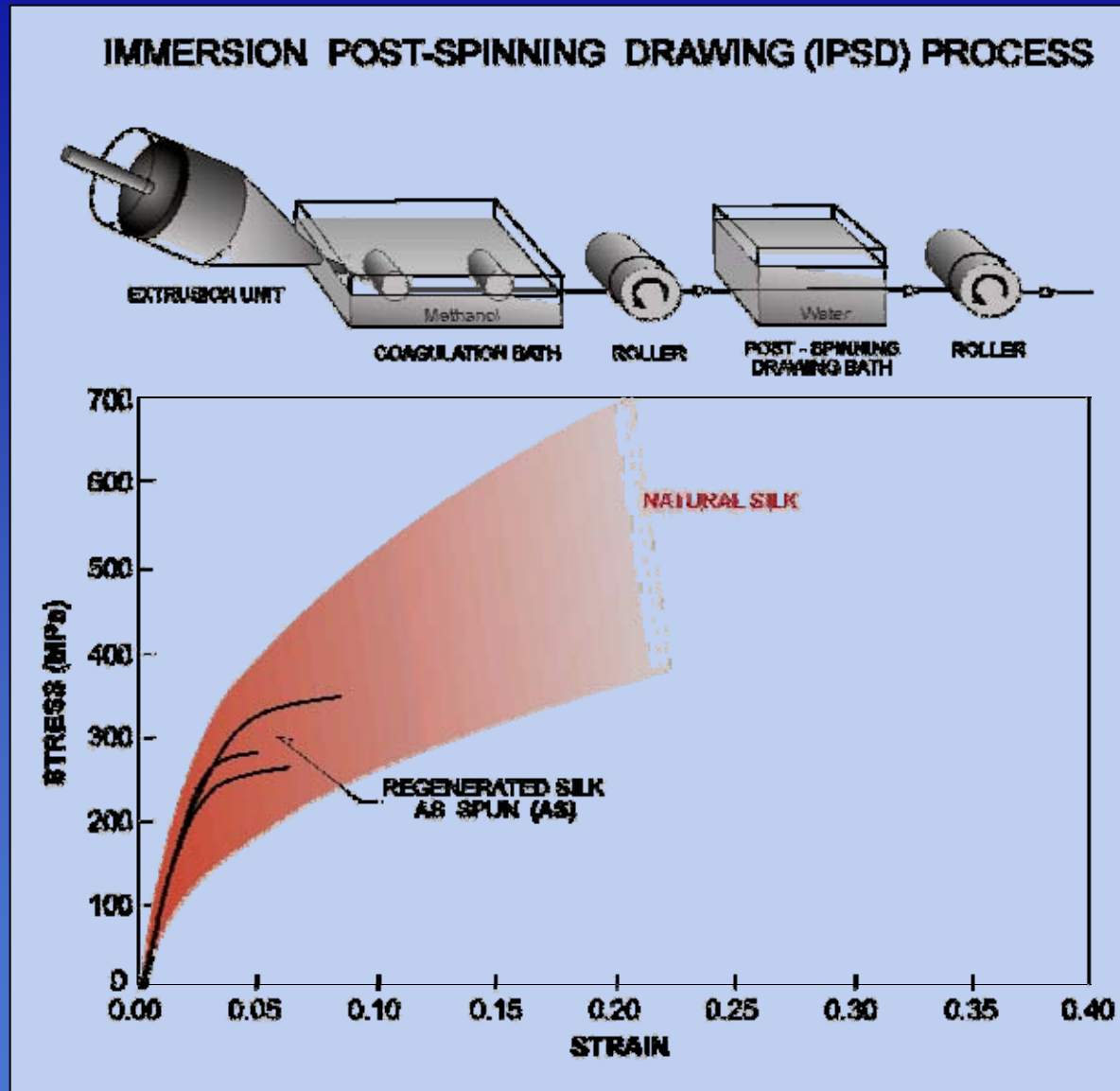
Post-spinning drawing



Silkworm silk fibers do not show supercontraction

Synthesis of bio-inspired fibers

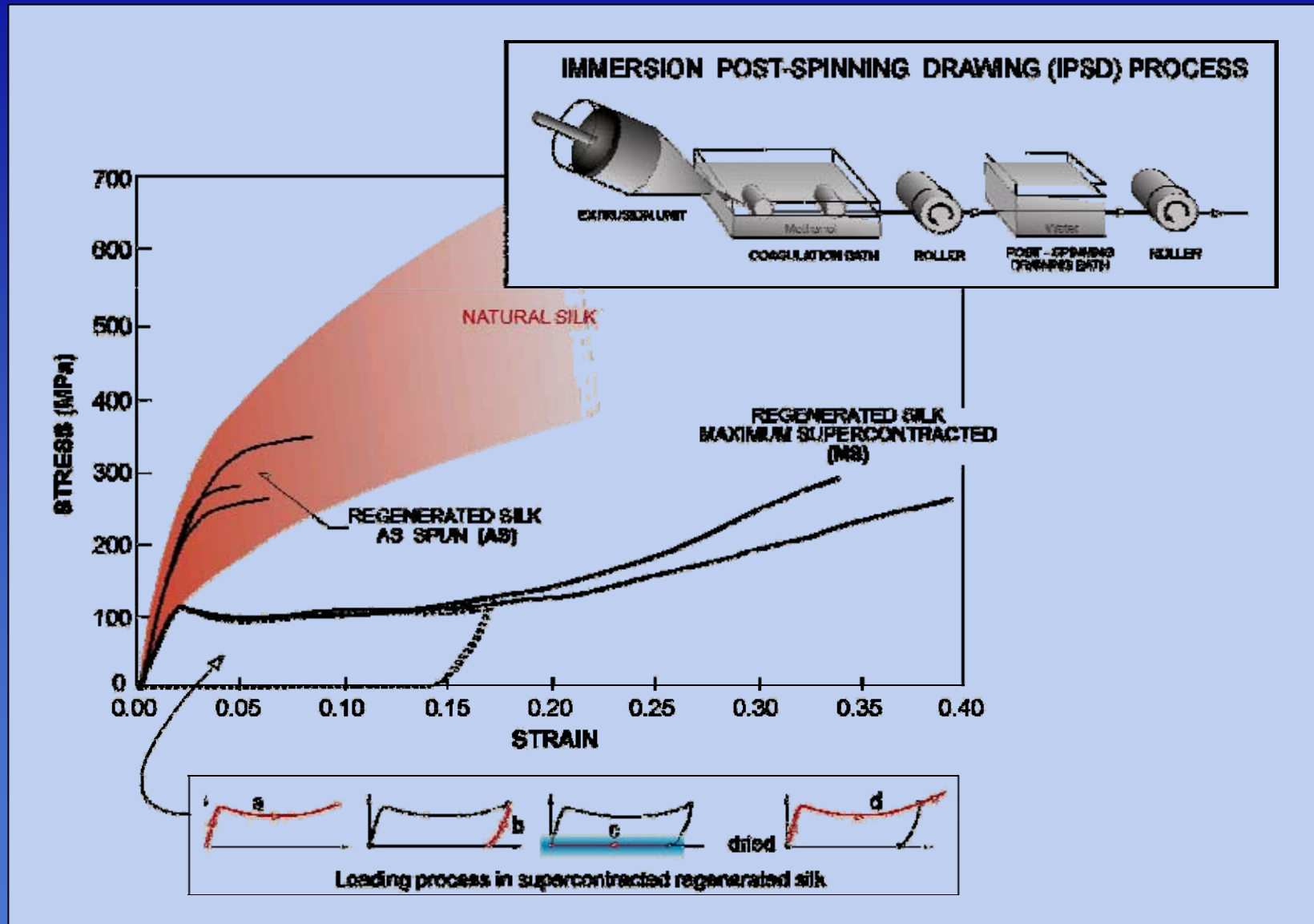
Immersion drawing RSF



Immersion post-spinning drawing (IPSD) improves the tensile behaviour, and...

Synthesis of bio-inspired fibers

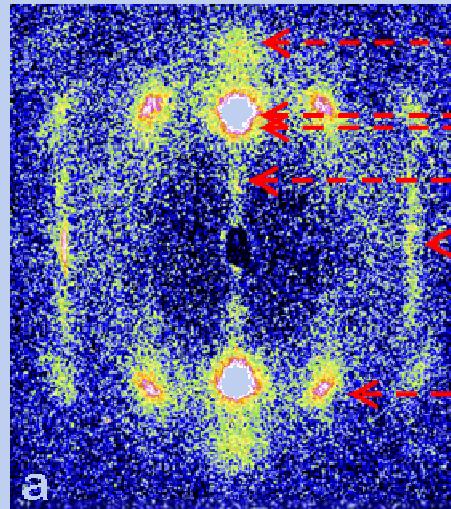
Immersion drawing RSF



...IPSD fibers supercontract exhibiting a ground state

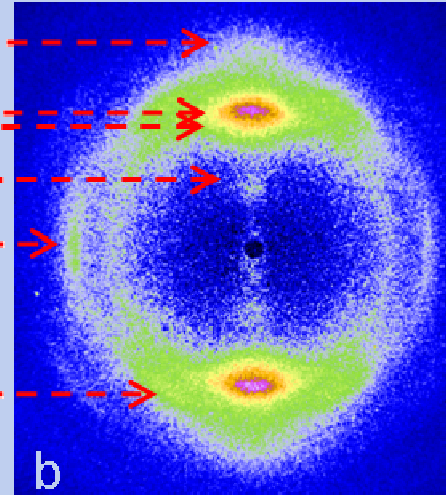
Synthesis of bio-inspired fibers

Microstructure: XRD

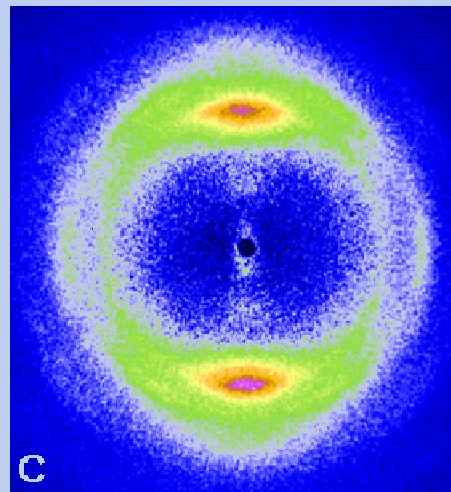


Bombyx mori silk
degummed

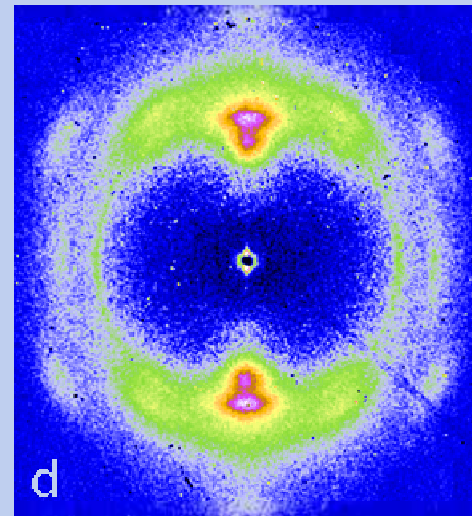
030
210
020
010
002
211



regenerated silk
as spun (AS)



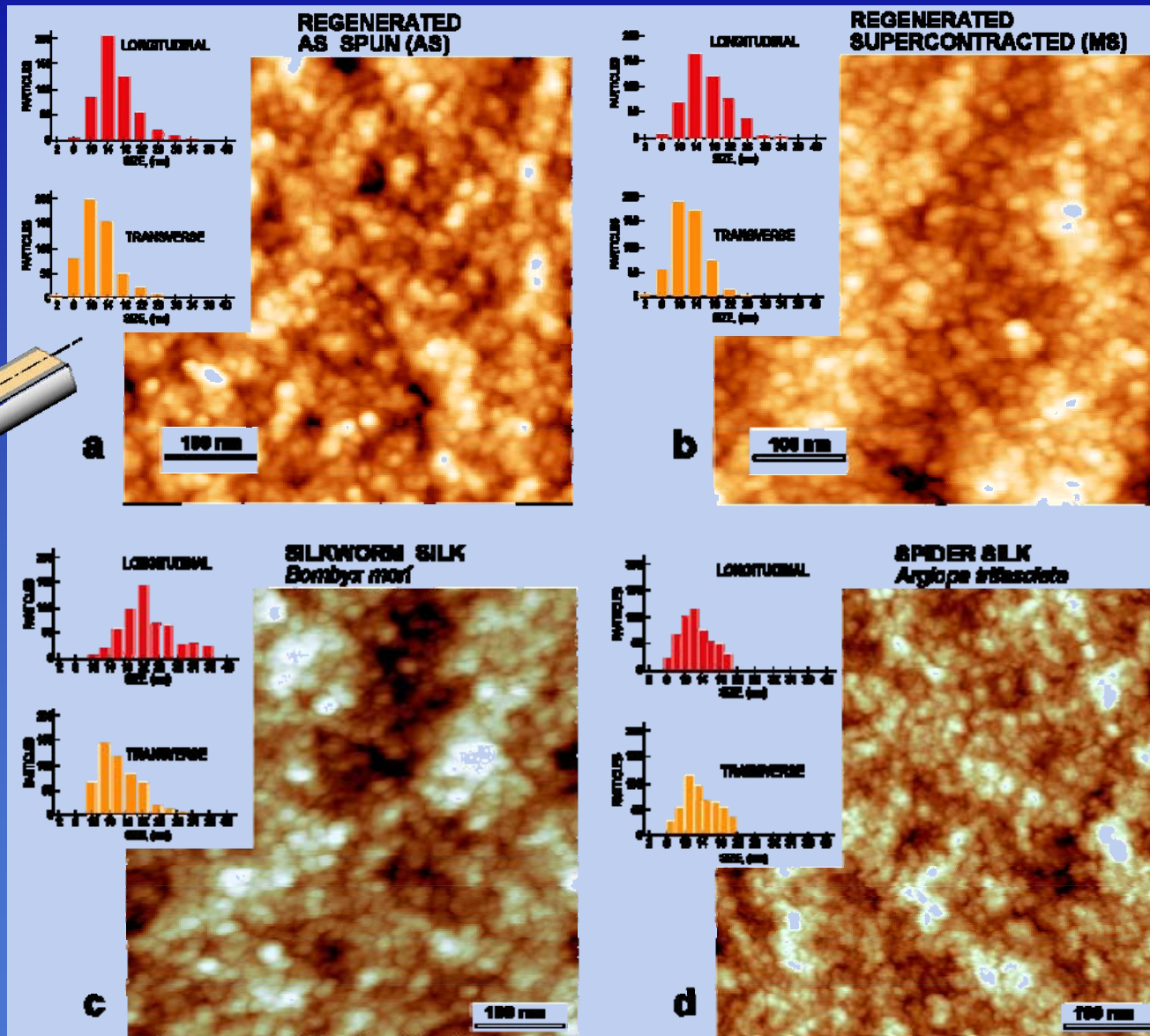
regenerated silk
maximum supercontracted (MS)



Nephila dragline spider silk

Synthesis of bio-inspired fibers

Microstructure: AFM



IPSD fibers: an intermediate microstructure between silkworm and spider silk

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Tunability allows adapting spider silk's properties to its intended use

IPSD silkworm silk regenerated fibers exhibit a ground state and recovery → Tunability

The differences in the sequence between regenerated silkworm silk and natural spider silk fibers highlight the importance of processing



**THANK YOU FOR YOUR
ATTENTION**

“Development of bioinspired scaffolds for tendon repairing”

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