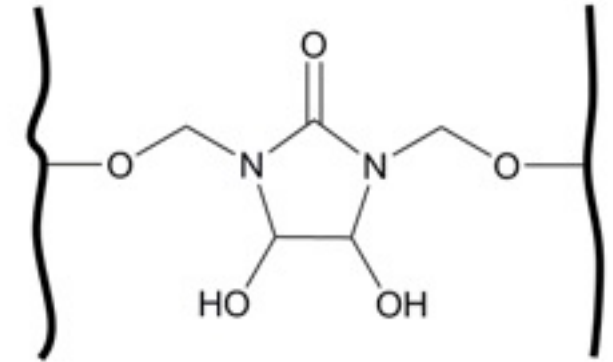
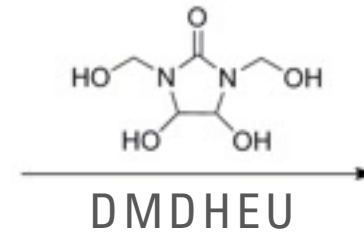
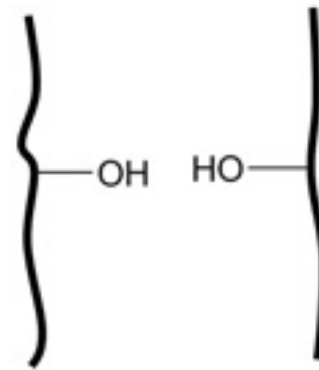
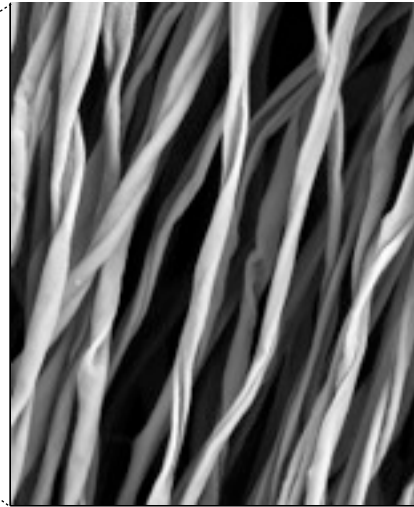
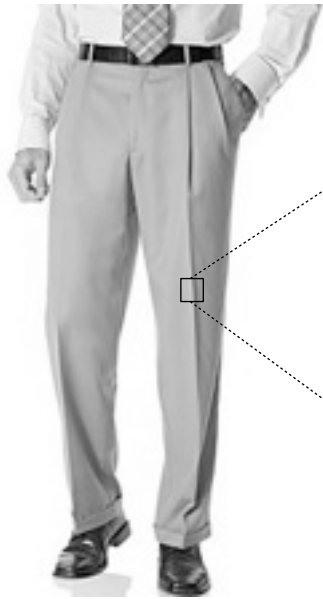


NEW APPROACHES IN COTTON CROSSLINKING

GREENER SOLUTIONS 2013

JOE CHARBONNET
JEN LAWRENCE
LEAH RUBIN
SARA TEPPER

CURRENT TECHNOLOGY: WRINKLE RESISTANCE



WRINKLES ARE CREATED BY DISORDERLY HYDROGEN BONDS BETWEEN WATER AND COTTON

DMDHEU CROSSLINKS COTTON FIBERS IN ORDERED, WRINKLE FREE PATTERN

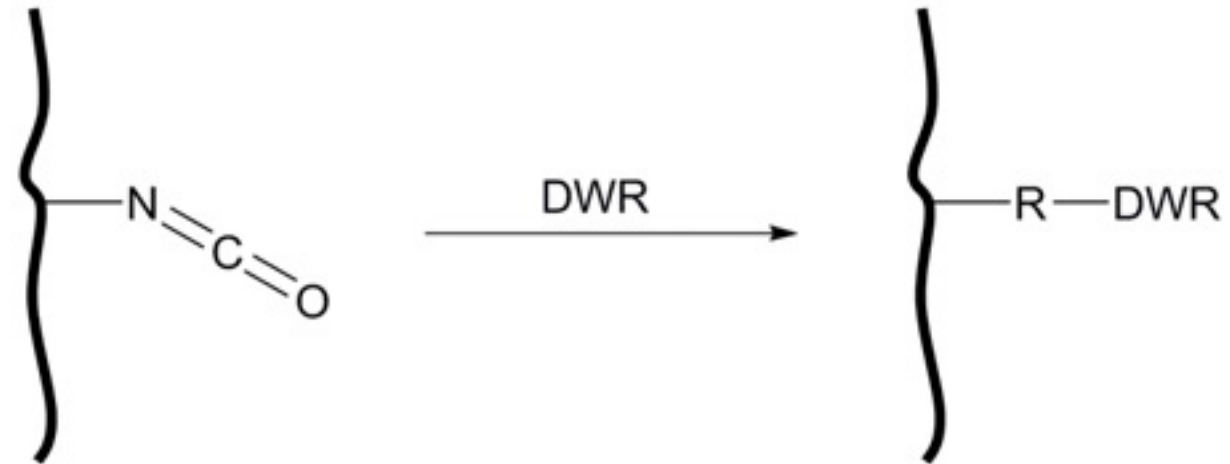
VARIETY OF NAMES: PERMANENT PRESS, WRINKLE-FREE, EASY CARE, NEVER-IRON

CONTRIBUTES TO FREE FORMALDEHYDE IN FABRICS

CURRENT TECHNOLOGY: WATER REPELLENCY



WATER REPELLENCY ACHIEVED
THROUGH CROSSLINKING TO A
DURABLE WATER REPELLENT [DWR]



LEVI'S COMMUTER JEANS
CROSSLINK A PARAFFIN-BASED
DWR, ECOREPEL, WITH
DIISOCYANATES

HEALTH IMPACTS

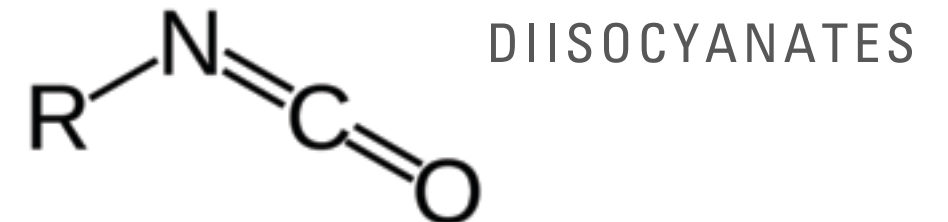


EXPOSURE ROUTES

- INHALATION OF FUMES
- ABSORPTION THROUGH SKIN

SEVERE HEALTH ISSUES

- NERVOUS SYSTEM DAMAGE
- ENDOCRINE DISRUPTION
- NASAL CANCER
- NASOPHARYNGEAL CANCER
- LEUKEMIA
- SKIN SENSITIZER
- RESPIRATORY SENSITIZER



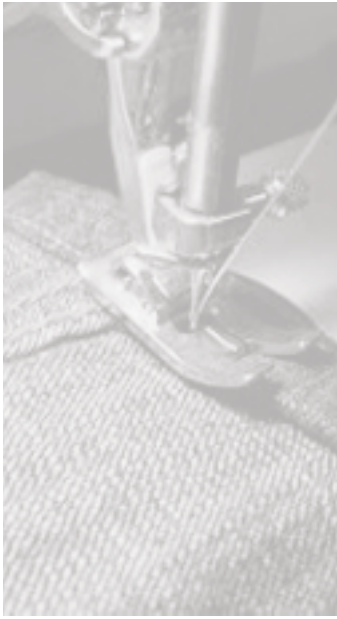
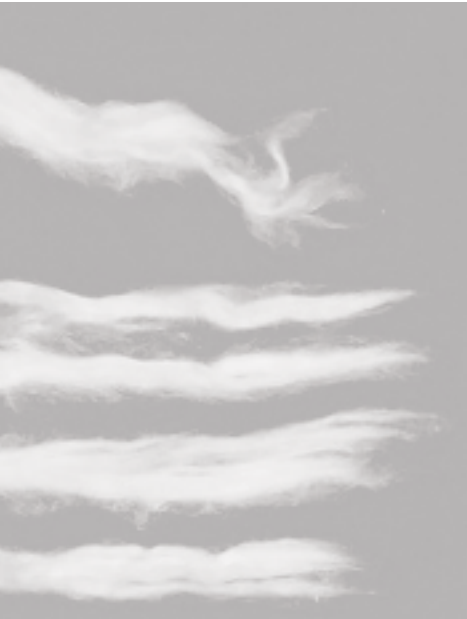
EXPOSURE ROUTES

- MAY BE APPLIED IN GARMENT FORM
- INCREASES EXPOSURE

SEVERE HEALTH ISSUES

- SKIN, EYE, AND RESPIRATORY IRRITANT
- RESPIRATORY SENSITIZER
- PRODUCES ASTHMA
- POSSIBLE CARCINOGEN

GOALS



CONTEXT

METHODS

CROSSLINKING STRATEGIES

TECHNICAL
FEASIBILITY

HEALTH
IMPACTS

CONCLUSIONS

GOALS



TO DETERMINE WHAT BIOLOGICALLY INSPIRED OPPORTUNITIES EXIST FOR LEVI STRAUSS & CO. TO MODIFY CURRENT CROSSLINKING TECHNOLOGIES USED TO IMPART WRINKLE-RESISTANCE AND WATER-REPELLENCY.

TO EVALUATE SOLUTIONS' HEALTH AND ENVIRONMENTAL IMPACTS RELATIVE TO CURRENT TECHNOLOGIES.

CONTEXT

METHODS

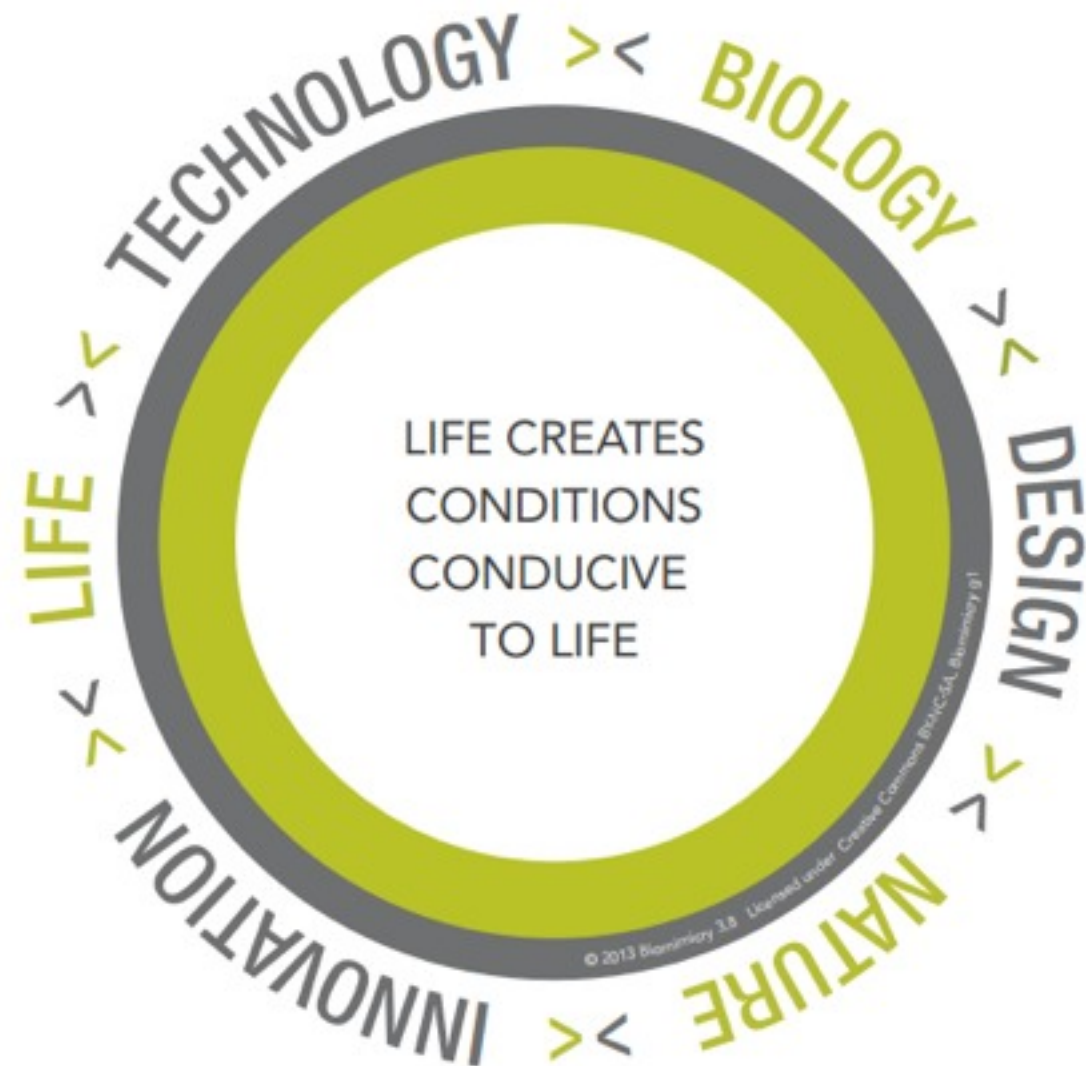
CROSSLINKING STRATEGIES

TECHNICAL
FEASIBILITY

HEALTH
IMPACTS

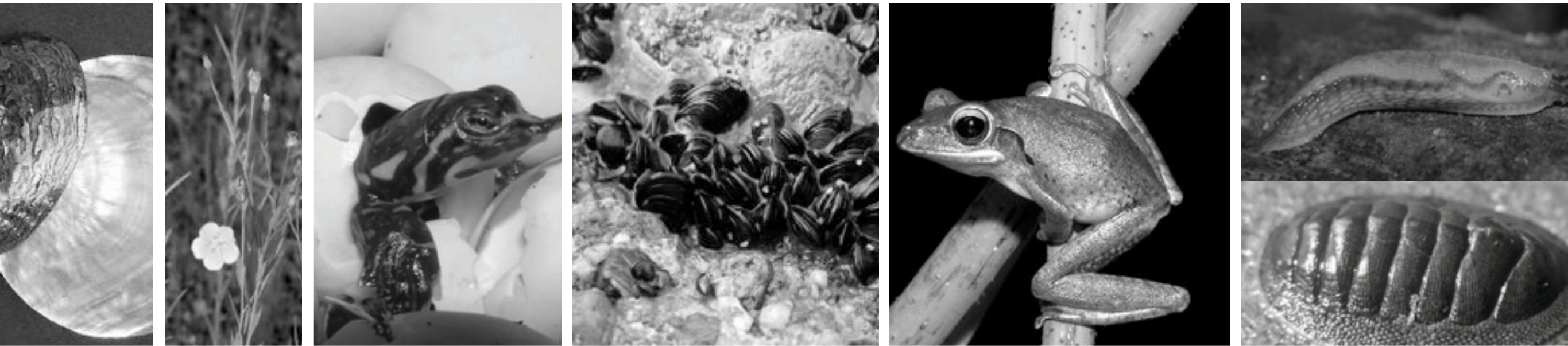
CONCLUSIONS

WHAT IS BIOMIMICRY?



BIOMIMICRY IS LEARNING FROM AND THEN EMULATING NATURAL FORMS, PROCESSES, AND ECOSYSTEMS TO CREATE MORE SUSTAINABLE DESIGNS

TRANSLATING BIOLOGY TO TEXTILES



CONTEXT

METHODS

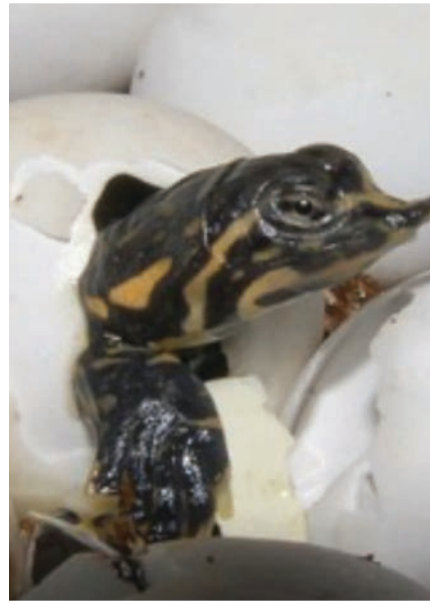
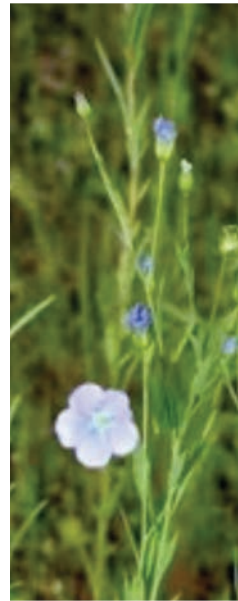
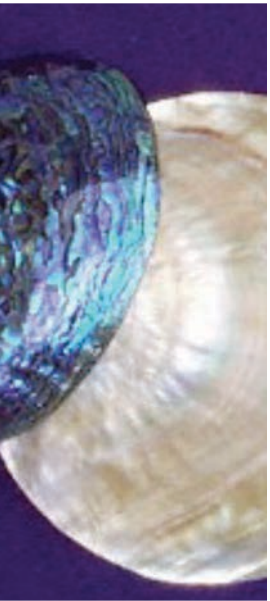
CROSSLINKING STRATEGIES

TECHNICAL
FEASIBILITY

HEALTH
IMPACTS

CONCLUSIONS

TRANSLATING BIOLOGY TO TEXTILES



COVALENT INTERACTIONS

CONTEXT

METHODS

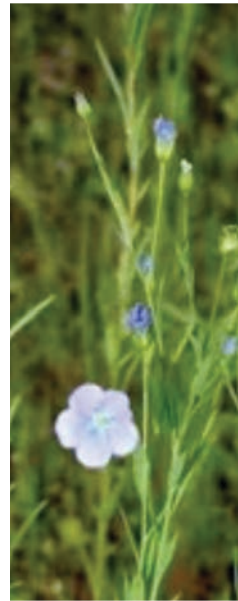
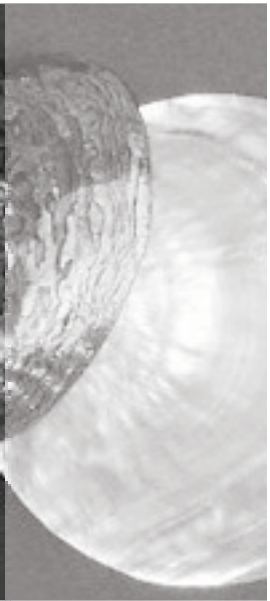
CROSSLINKING STRATEGIES

TECHNICAL
FEASIBILITY

HEALTH
IMPACTS

CONCLUSIONS

TRANSLATING BIOLOGY TO TEXTILES



NON-COVALENT INTERACTIONS

CONTEXT

METHODS

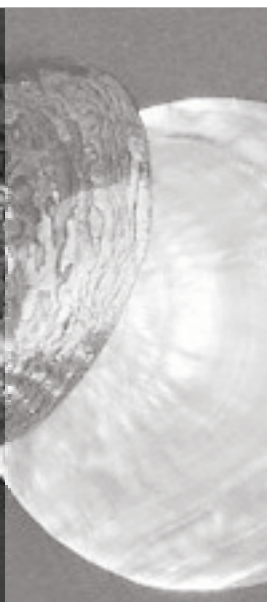
CROSSLINKING STRATEGIES

TECHNICAL
FEASIBILITY

HEALTH
IMPACTS

CONCLUSIONS

TRANSLATING BIOLOGY TO TEXTILES



COORDINATION WITH METALS

CONTEXT

METHODS

CROSSLINKING STRATEGIES

TECHNICAL
FEASIBILITY

HEALTH
IMPACTS

CONCLUSIONS

TRANSLATING BIOLOGY TO TEXTILES



STRUCTURAL FEATURES

CONTEXT

METHODS

CROSSLINKING STRATEGIES

TECHNICAL
FEASIBILITY

HEALTH
IMPACTS

CONCLUSIONS

TRANSLATING BIOLOGY TO TEXTILES

12 EXAMPLES

COMMON THEMES
MULTIPLE BONDING
TYPES

COVALENT + NONCOVALENT
CROSSLINKING + BONDS
WITH CELLULOSE

STRATEGIES

SOLUTIONS

CONTEXT

METHODS

CROSSLINKING STRATEGIES

TECHNICAL
FEASIBILITY

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TRANSLATING BIOLOGY TO TEXTILES

12 EXAMPLES

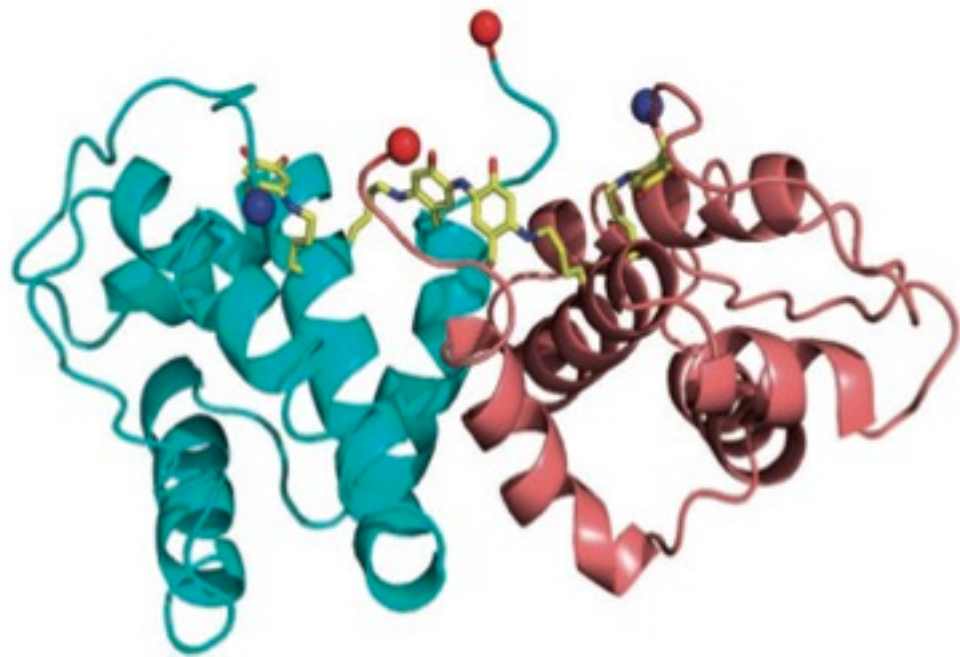
COMMON THEMES
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CROSSLINKING + BONDS
WITH CELLULOSE

STRATEGIES

SOLUTIONS

RANASMURFIN



Oke, et al, 2008.

CONTEXT

METHODS

CROSSLINKING STRATEGIES

TECHNICAL
FEASIBILITY

HEALTH
IMPACTS

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TRANSLATING BIOLOGY TO TEXTILES

12 EXAMPLES

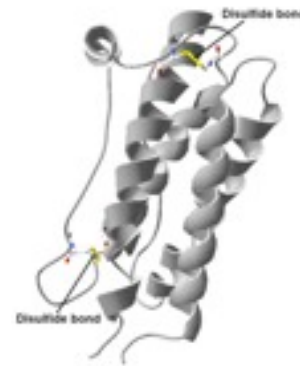
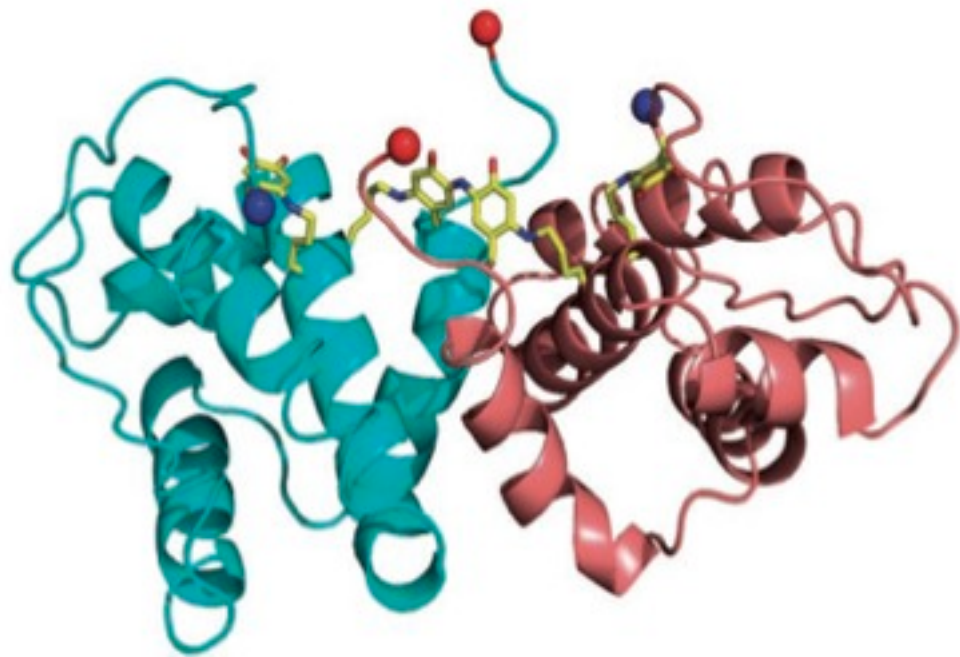
COMMON THEMES
MULTIPLE BONDING
TYPES

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CROSSLINKING + BONDS
WITH CELLULOSE

STRATEGIES

SOLUTIONS

RANASMURFIN



COVALENT INTERACTIONS
DISULFIDE BONDS

Oke, et al, 2008.

CONTEXT

METHODS

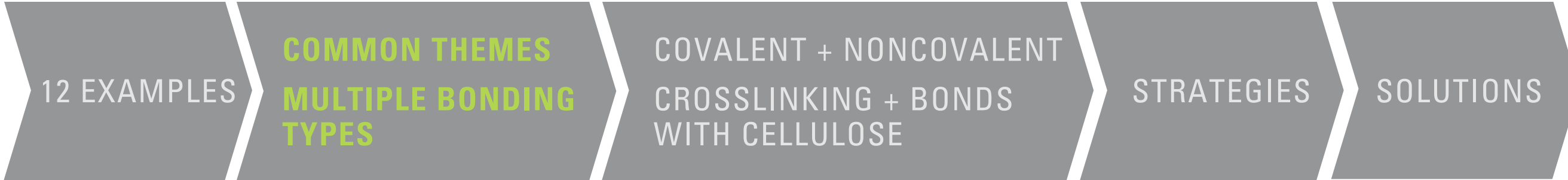
CROSSLINKING STRATEGIES

TECHNICAL
FEASIBILITY

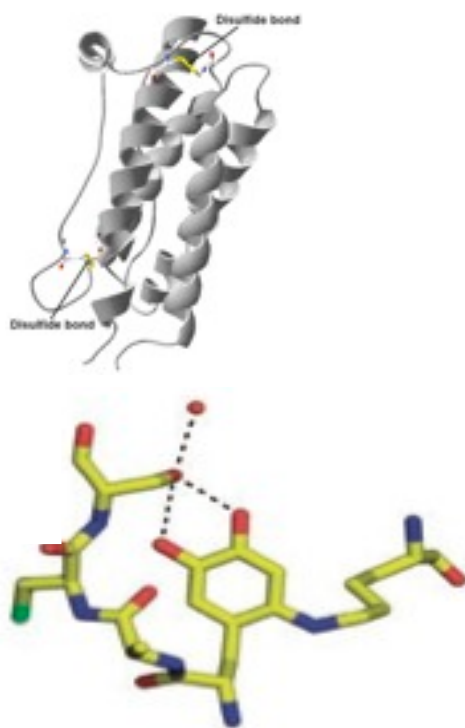
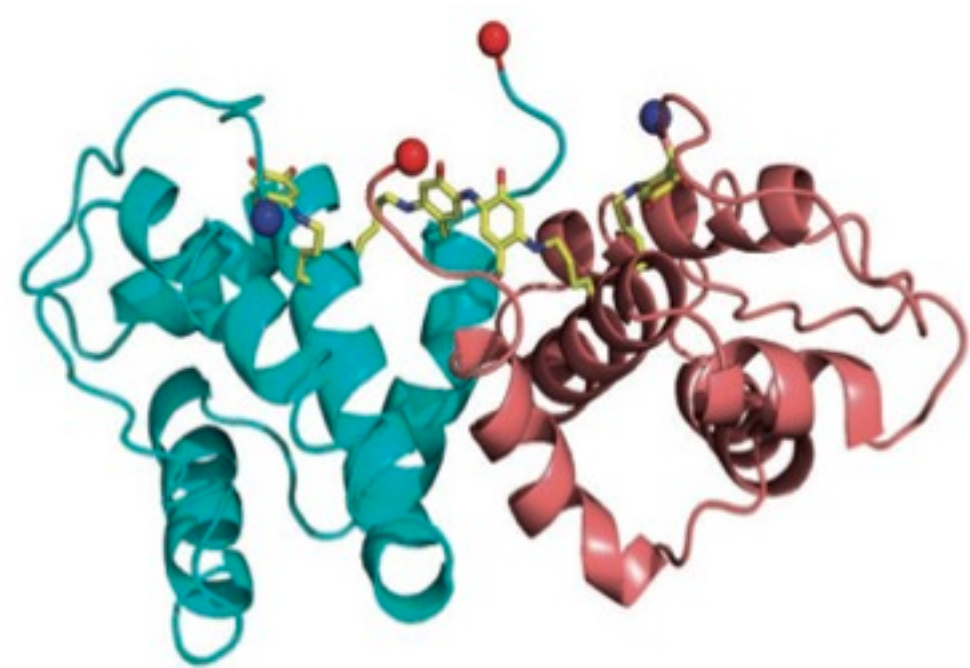
HEALTH
IMPACTS

CONCLUSIONS

TRANSLATING BIOLOGY TO TEXTILES



RANASMURFIN

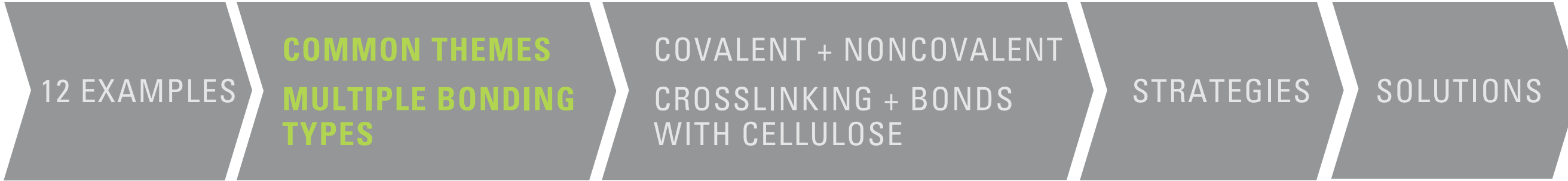


COVALENT INTERACTIONS
DISULFIDE BONDS

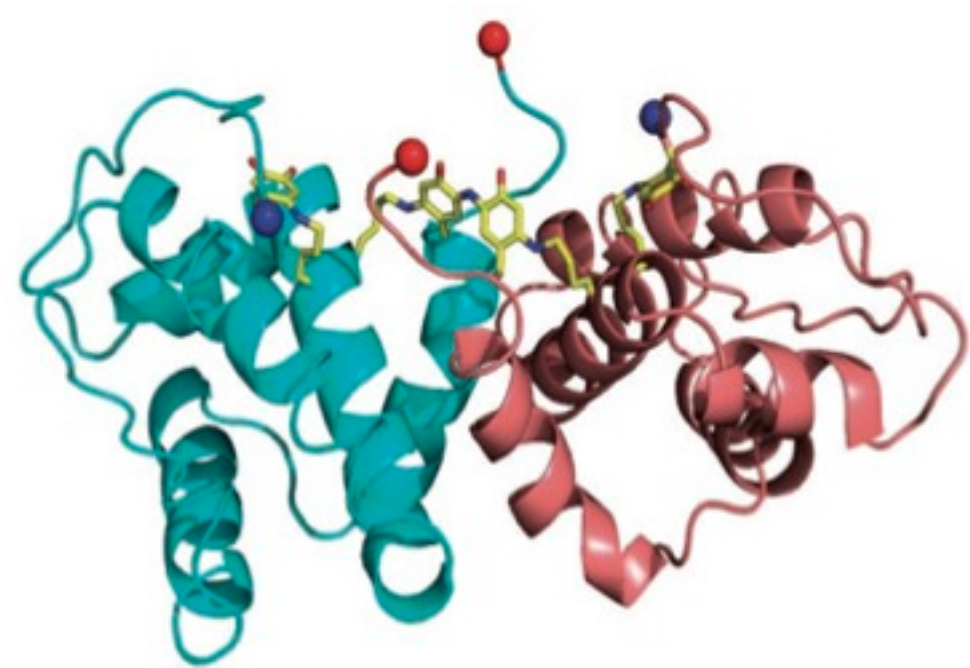
NON-COVALENT INTERACTIONS
HYDROGEN BONDS

Oke, et al, 2008.

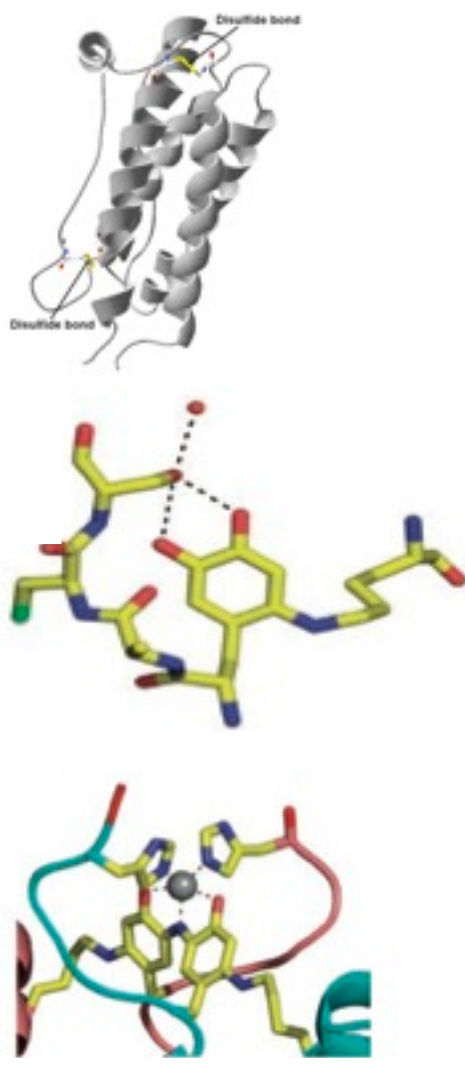
TRANSLATING BIOLOGY TO TEXTILES



RANASMURFIN



Oke, et al, 2008.

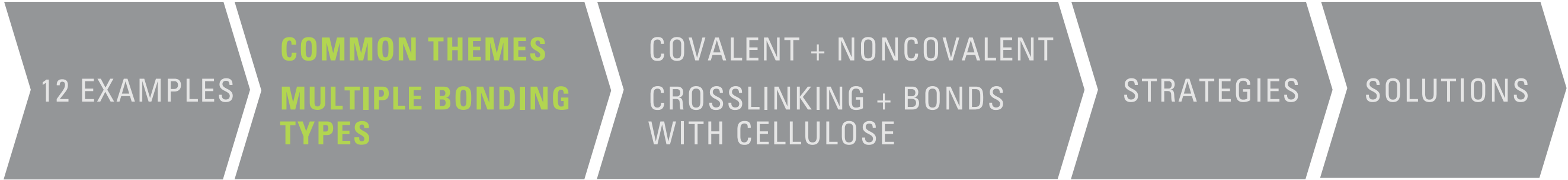


COVALENT INTERACTIONS
DISULFIDE BONDS

NON-COVALENT INTERACTIONS
HYDROGEN BONDS

ANCILLARY METALS
COORDINATION COMPLEXES

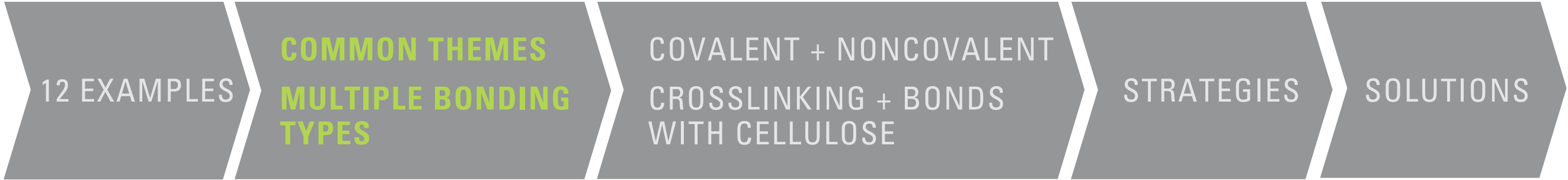
TRANSLATING BIOLOGY TO TEXTILES



BIOLOGICAL CROSSLINKING

TEXTILE CROSSLINKING

TRANSLATING BIOLOGY TO TEXTILES



BIOLOGICAL CROSSLINKING

MULTIPLE BONDING STRUCTURES

- COVALENT INTERACTIONS
- NON-COVALENT INTERACTIONS
- COORDINATION WITH METALS
- STRUCTURAL FEATURES

TEXTILE CROSSLINKING

TRANSLATING BIOLOGY TO TEXTILES

12 EXAMPLES

COMMON THEMES
MULTIPLE BONDING
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COVALENT + NONCOVALENT
CROSSLINKING + BONDS
WITH CELLULOSE

STRATEGIES

SOLUTIONS

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MULTIPLE BONDING STRUCTURES

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TEXTILE CROSSLINKING

MULTIPLE BONDING STRUCTURES

- COVALENT INTERACTIONS
- NON-COVALENT INTERACTIONS +
STRUCTURAL FEATURES

CONTEXT

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TRANSLATING BIOLOGY TO TEXTILES

12 EXAMPLES

COMMON THEMES
MULTIPLE BONDING
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CROSSLINKING + BONDS
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BIOLOGICAL CROSSLINKING

MULTIPLE BONDING STRUCTURES

- COVALENT INTERACTIONS
- NON-COVALENT INTERACTIONS
- COORDINATION WITH METALS
- STRUCTURAL FEATURES

MULTIPLE BONDING POINTS

TEXTILE CROSSLINKING

MULTIPLE BONDING STRUCTURES

- COVALENT INTERACTIONS
- NON-COVALENT INTERACTIONS +
STRUCTURAL FEATURES

CONTEXT

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TRANSLATING BIOLOGY TO TEXTILES

12 EXAMPLES

COMMON THEMES
MULTIPLE BONDING
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CROSSLINKING + BONDS
WITH CELLULOSE

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BIOLOGICAL CROSSLINKING

MULTIPLE BONDING STRUCTURES

- COVALENT INTERACTIONS
- NON-COVALENT INTERACTIONS
- COORDINATION WITH METALS
- STRUCTURAL FEATURES

MULTIPLE BONDING POINTS

TEXTILE CROSSLINKING

MULTIPLE BONDING STRUCTURES

- COVALENT INTERACTIONS
- NON-COVALENT INTERACTIONS +
STRUCTURAL FEATURES

MULTIPLE BONDING POINTS

- TWO BONDING POINTS

CONTEXT

METHODS

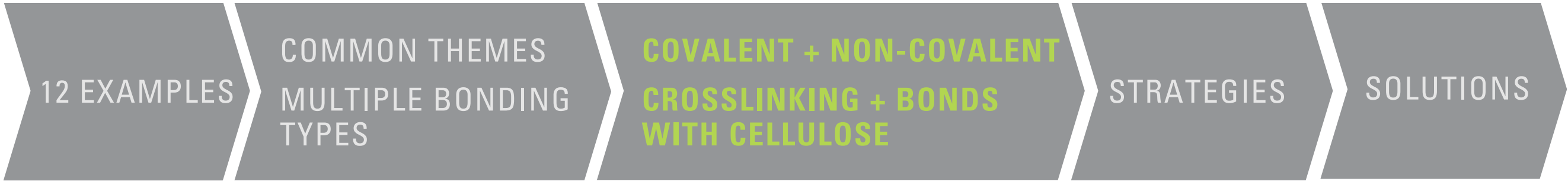
CROSSLINKING STRATEGIES

TECHNICAL
FEASIBILITY

HEALTH
IMPACTS

CONCLUSIONS

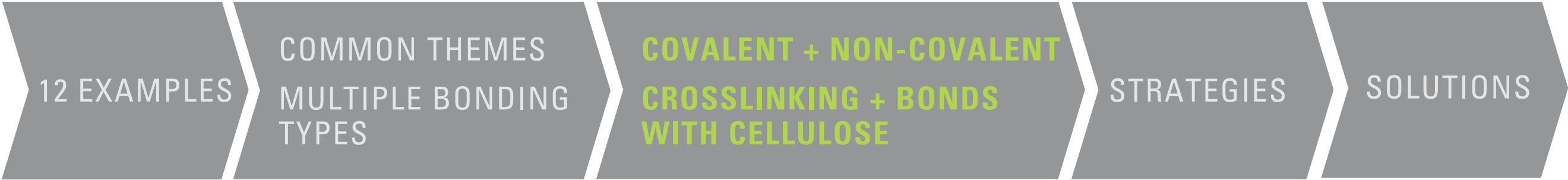
TRANSLATING BIOLOGY TO TEXTILES



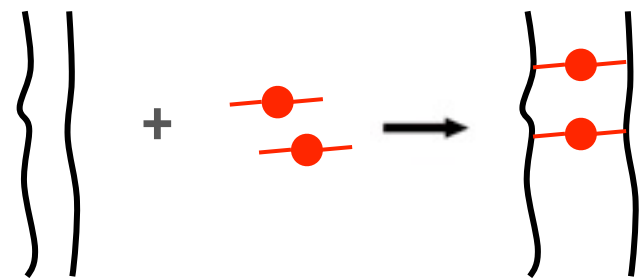
TRADITIONAL CROSSLINKING

BIOMIMETIC CROSSLINKING

TRANSLATING BIOLOGY TO TEXTILES

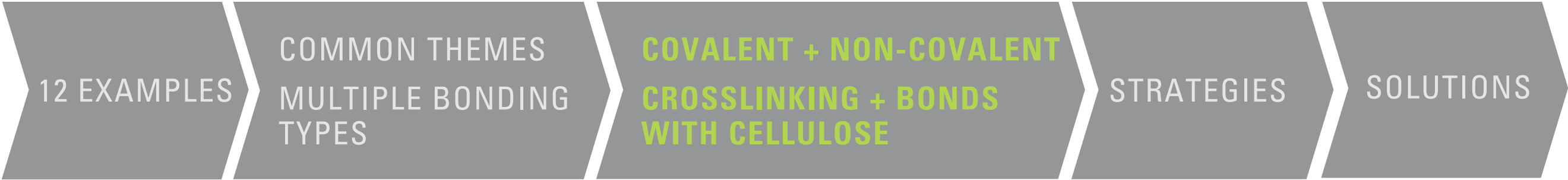


TRADITIONAL CROSSLINKING

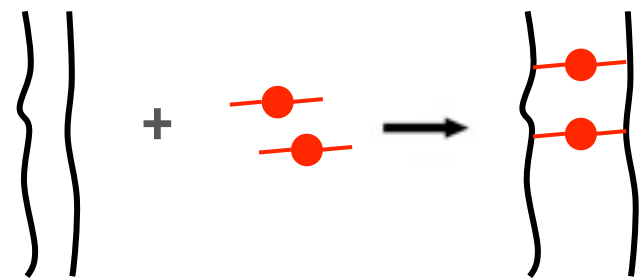


BIOMIMETIC CROSSLINKING

TRANSLATING BIOLOGY TO TEXTILES

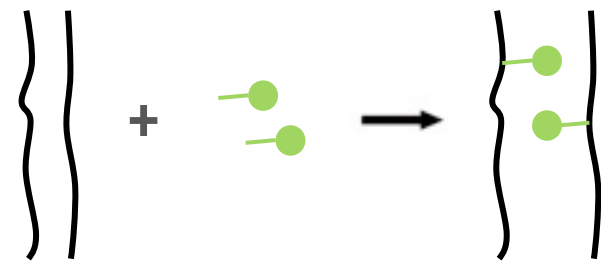


TRADITIONAL CROSSLINKING

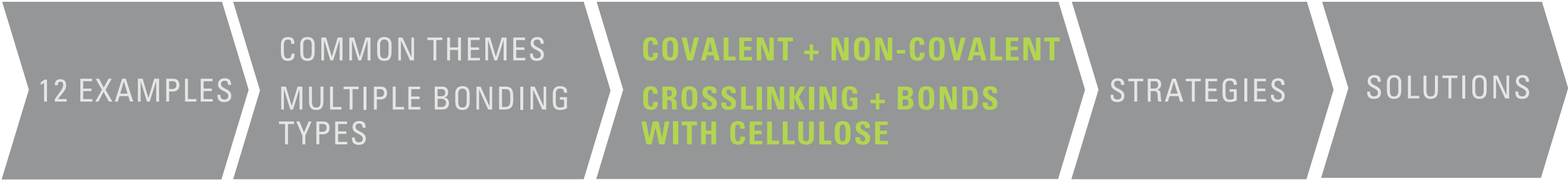


BIOMIMETIC CROSSLINKING

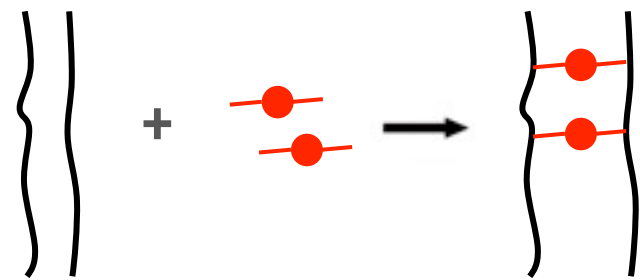
[1] BIND TO CELLULOSE



TRANSLATING BIOLOGY TO TEXTILES

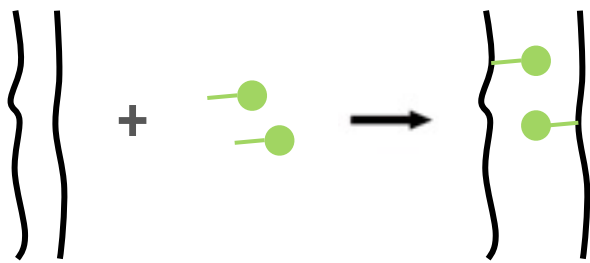


TRADITIONAL CROSSLINKING



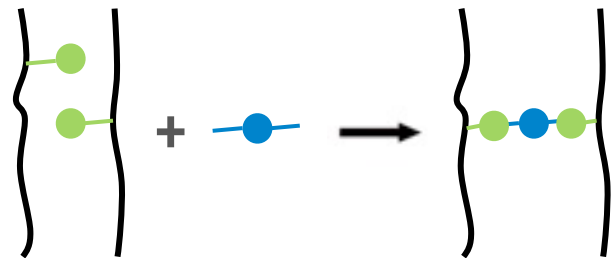
BIOMIMETIC CROSSLINKING

[1] BIND TO CELLULOSE

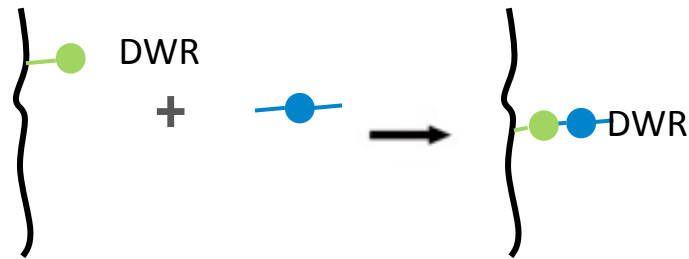


[2] PERFORM CROSSLINK

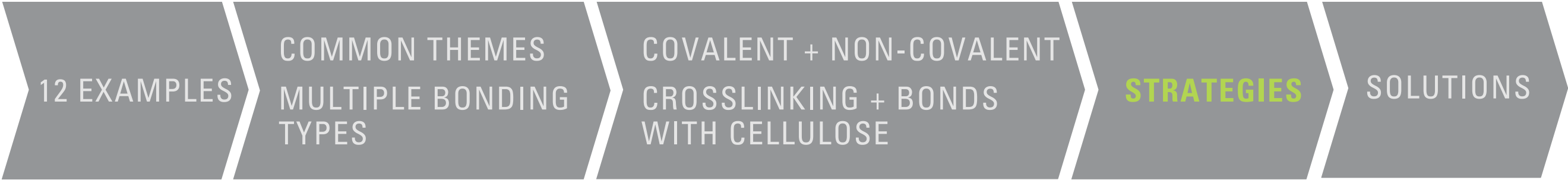
WRINKLE
RESISTANCE



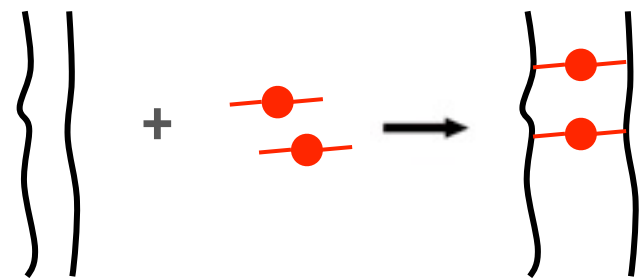
WATER
REPELLENCY



TRANSLATING BIOLOGY TO TEXTILES

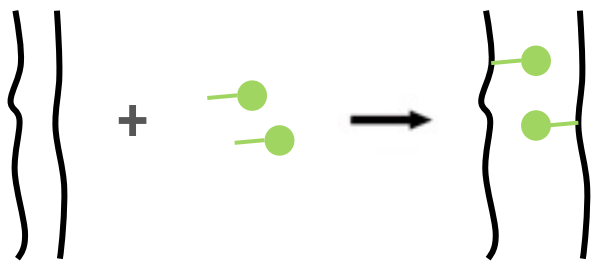


TRADITIONAL CROSSLINKING



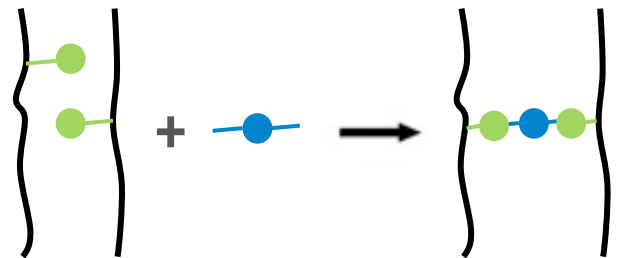
BIOMIMETIC CROSSLINKING

[1] BIND TO CELLULOSE

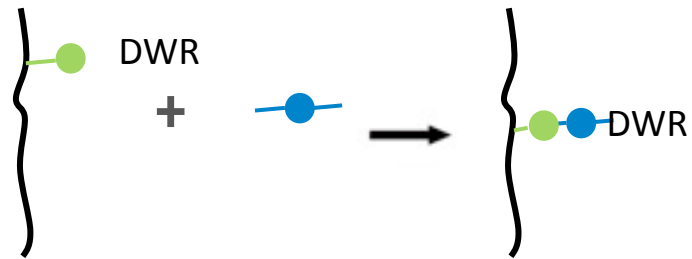


[2] PERFORM CROSSLINK

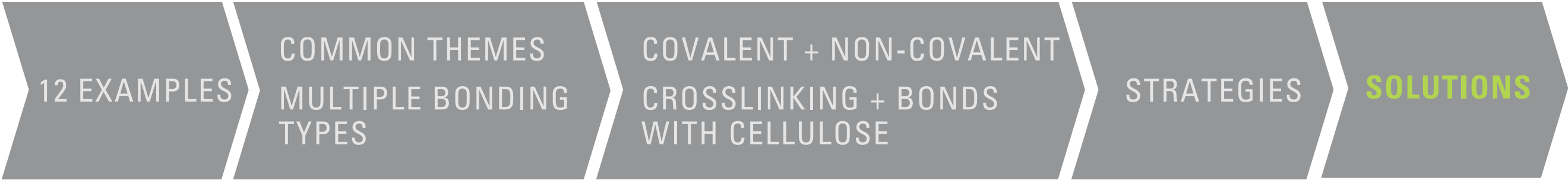
WRINKLE
RESISTANCE



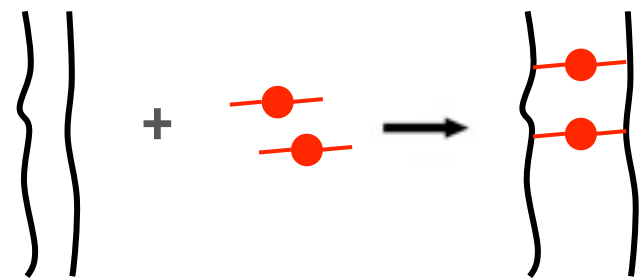
WATER
REPELLENCY



TRANSLATING BIOLOGY TO TEXTILES

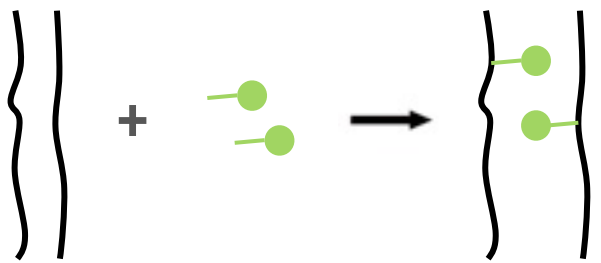


TRADITIONAL CROSSLINKING



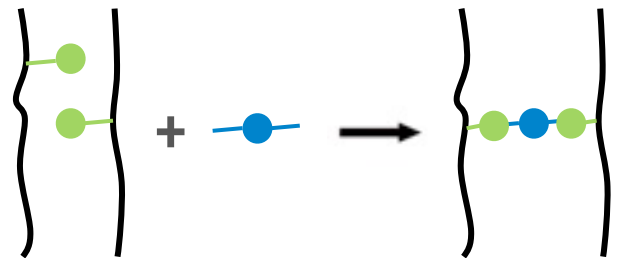
BIOMIMETIC CROSSLINKING

[1] BIND TO CELLULOSE

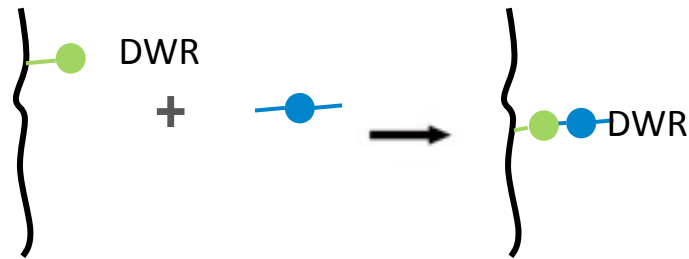


[2] PERFORM CROSSLINK





WRINKLE
RESISTANCE



WATER
REPELLENCY

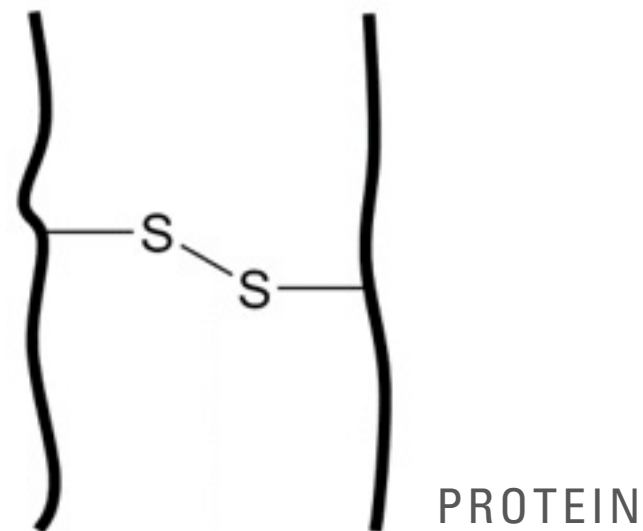
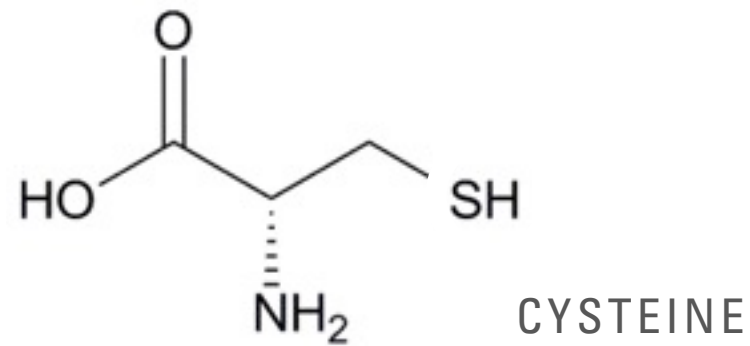


PROCESS

 <div>YARN FORMATION</div>	RAW COTTON FIBER PREPARATION SPINNING
 <div>FABRIC FORMATION</div>	WARPING SIZING → polyvinyl alcohol polyacrylic acid carboxymethyl cellulose WEAVING
 <div>WET PROCESSING</div>	PREPARATION DYEING/PRINTING FINISHING → may include DMDHEU, diisocyanates, perfluorinated acids, fluoropolymers, paraffin-based DWRs
 <div>FINISHING</div>	CUTTING SEWING → for Levi's: DWR properties imparted here [garment form] CURING FINISHED GOODS

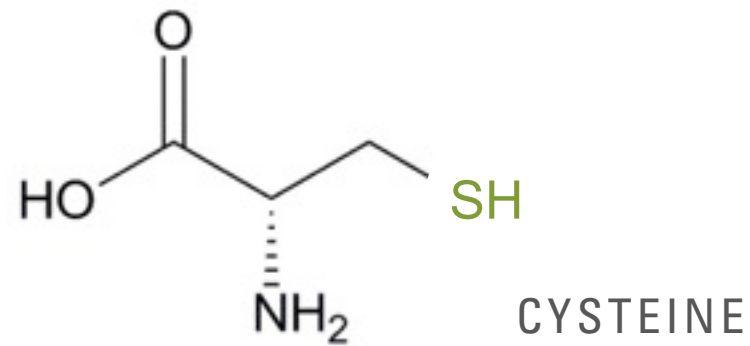
CROSSLINKING: DISULFIDE BONDS

DISULFIDE BONDS STABILIZE
PROTEIN STRUCTURE BY
CROSSLINKING PEPTIDE CHAINS

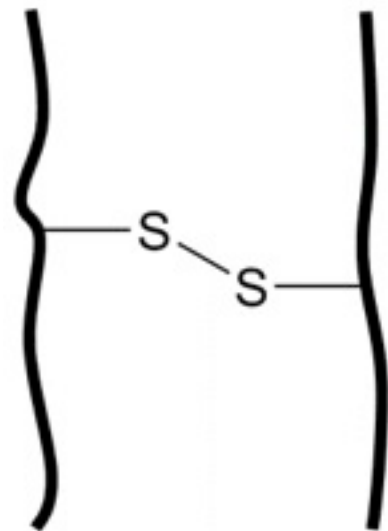


CROSSLINKING: DISULFIDE BONDS

DISULFIDE BONDS STABILIZE
PROTEIN STRUCTURE BY
CROSSLINKING PEPTIDE CHAINS



CYSTEINE

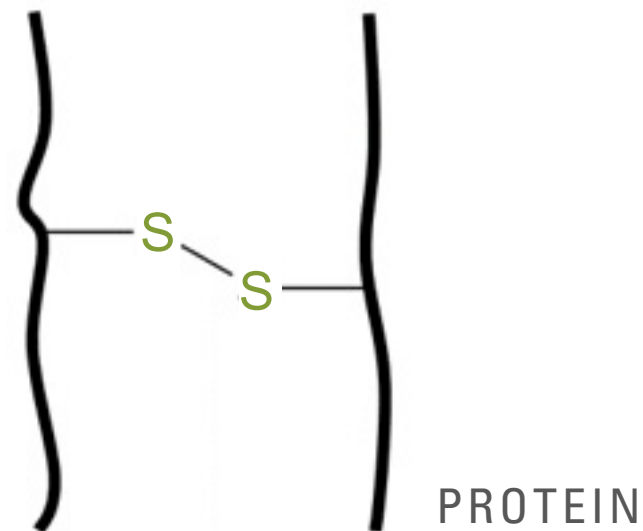
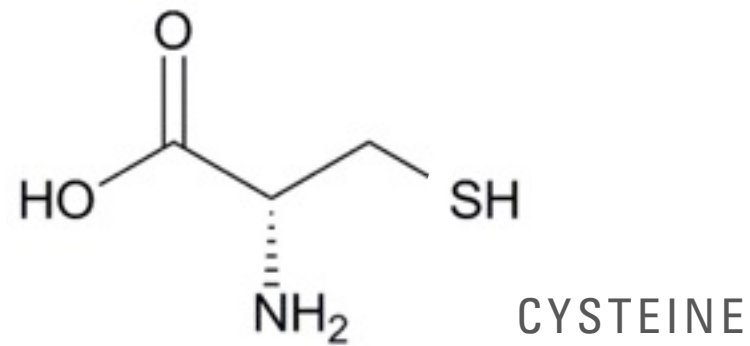


PROTEIN



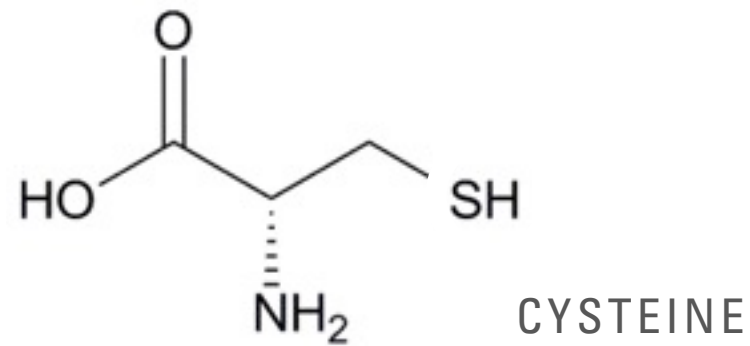
CROSSLINKING: DISULFIDE BONDS

DISULFIDE BONDS STABILIZE
PROTEIN STRUCTURE BY
CROSSLINKING PEPTIDE CHAINS

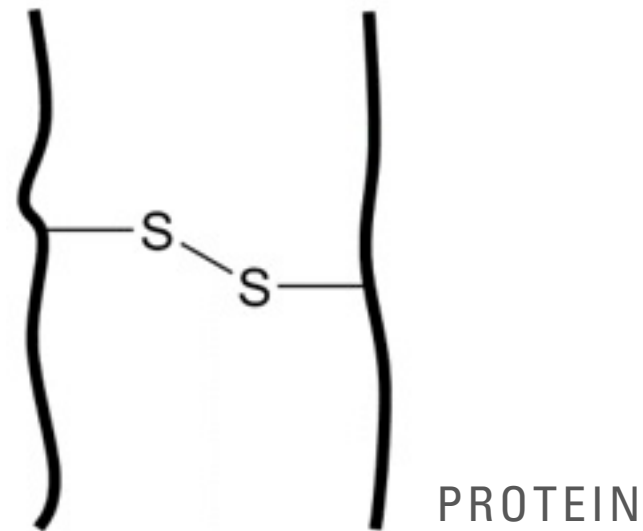


CROSSLINKING: DISULFIDE BONDS

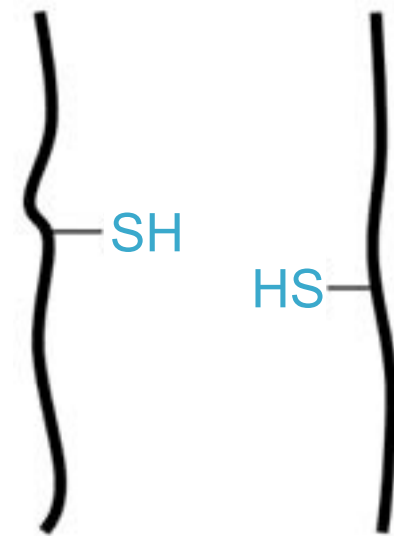
DISULFIDE BONDS STABILIZE
PROTEIN STRUCTURE BY
CROSSLINKING PEPTIDE CHAINS



CYSTEINE

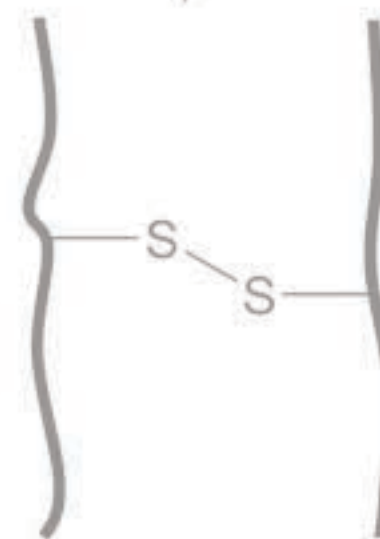


PROTEIN



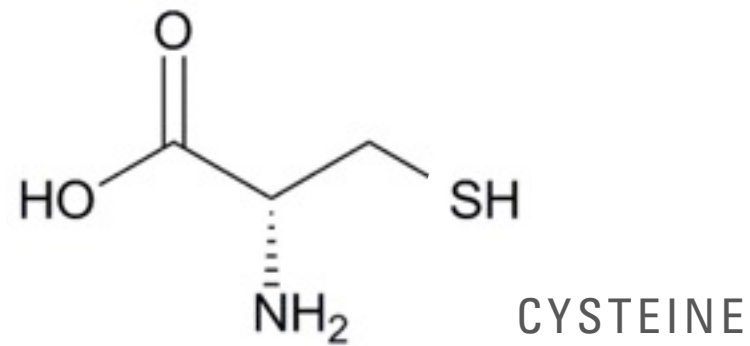
ATTACH THIOL GROUPS
TO CELLULOSE FIBER

OXIDANT,
CATALYST

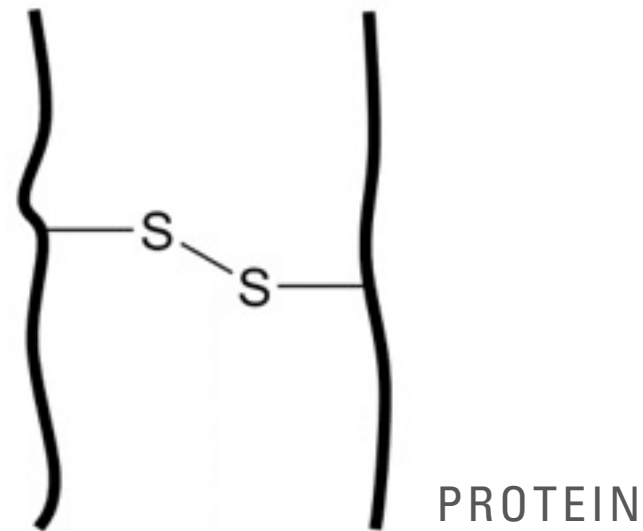


CROSSLINKING: DISULFIDE BONDS

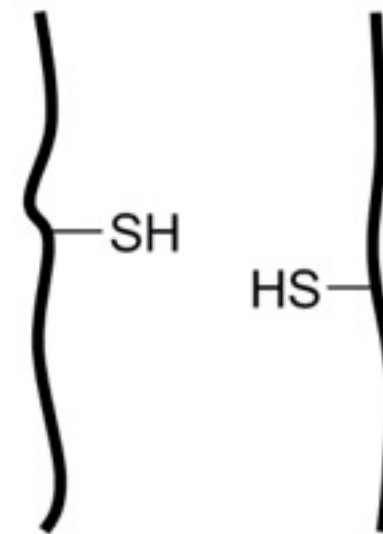
DISULFIDE BONDS STABILIZE
PROTEIN STRUCTURE BY
CROSSLINKING PEPTIDE CHAINS



CYSTEINE

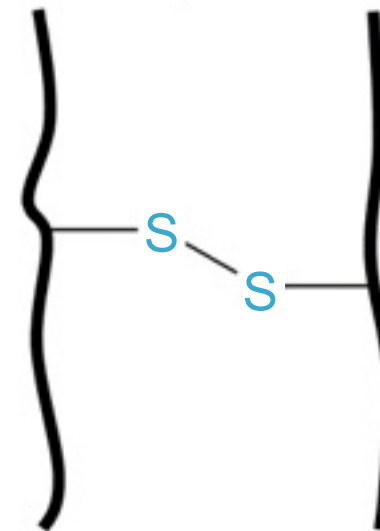


PROTEIN



ATTACH THIOL GROUPS
TO CELLULOSE FIBER

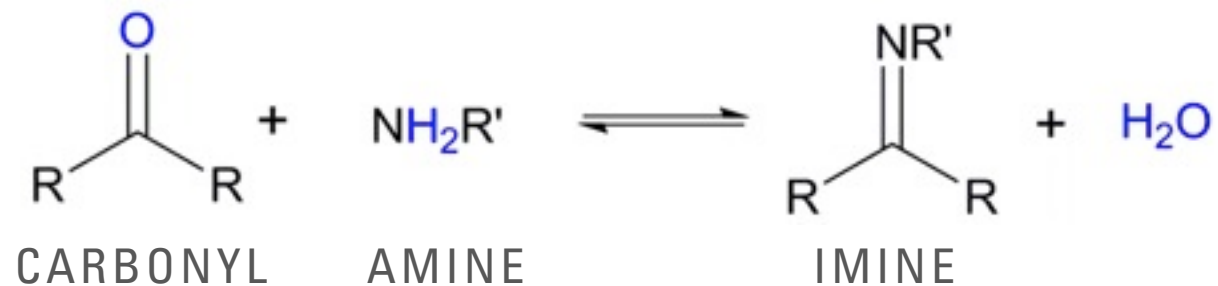
OXIDANT,
CATALYST



OXIDIZE TO FORM
DISULFIDE BOND

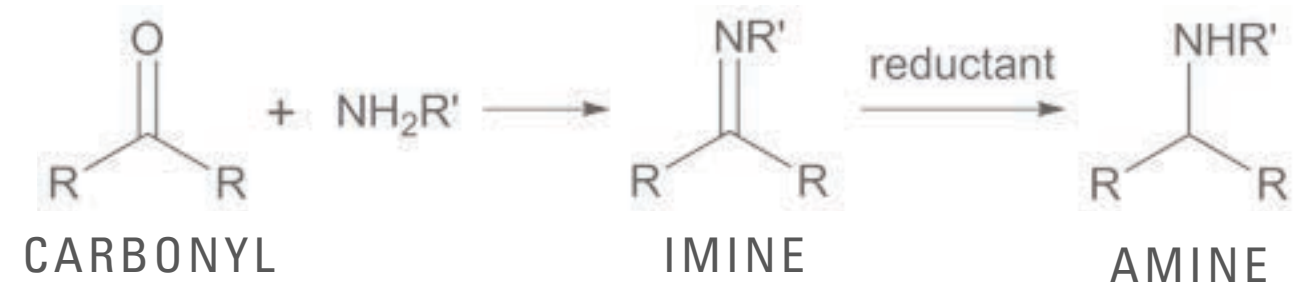
CROSSLINKING: IMINE + AMINE BONDS

INSPIRED BY THE SLUG, ARION
SUBFUSCUS

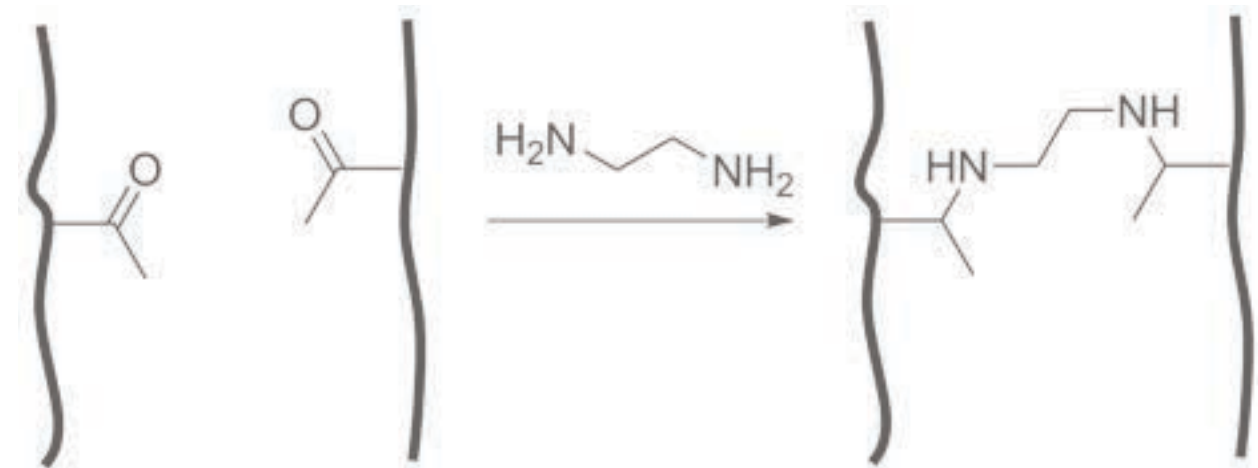


IMINE BOND CONTRIBUTES TO
STIFFNESS OF MUCUS
SECRETIONS

REDUCTIVE AMINATION PRODUCES A MORE
STABLE BOND

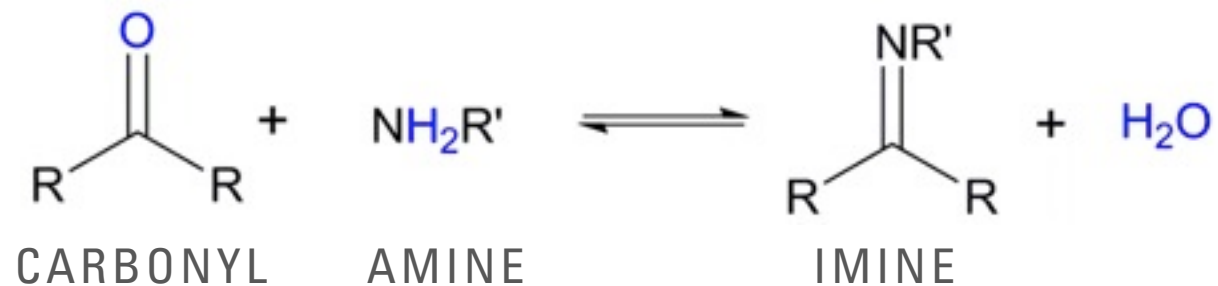


ATTACH CARBONYL GROUPS
CROSSLINK WITH DIAMINE



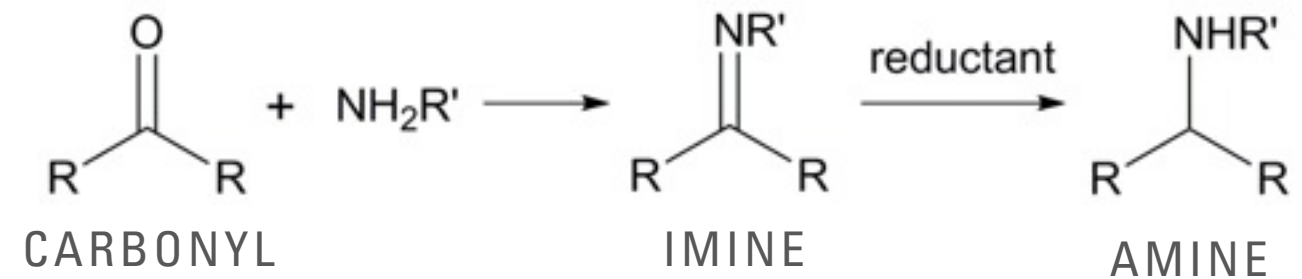
CROSSLINKING: IMINE + AMINE BONDS

INSPIRED BY THE SLUG, ARION
SUBFUSCUS

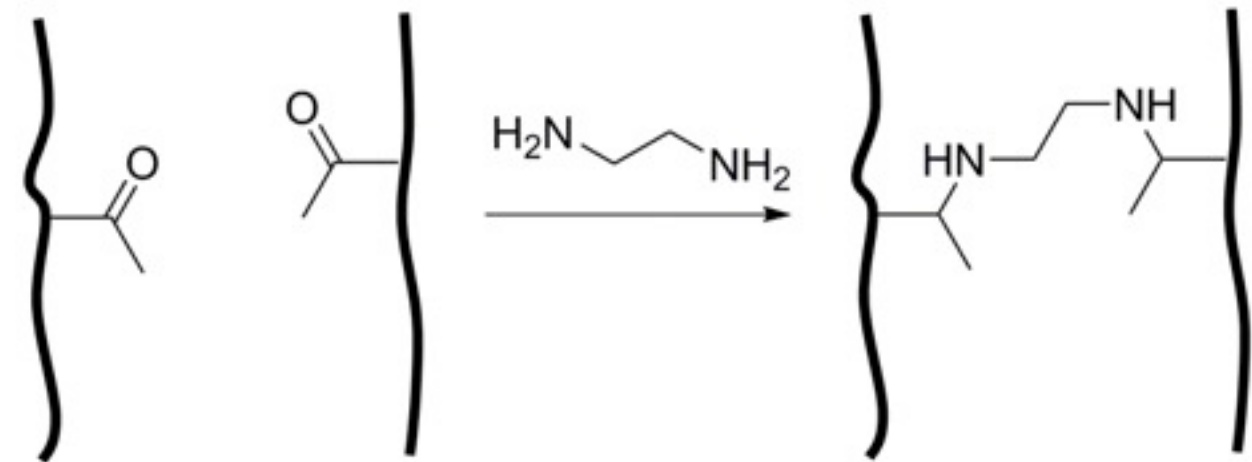


IMINE BOND CONTRIBUTES TO
STIFFNESS OF MUCUS
SECRETIONS

REDUCTIVE AMINATION PRODUCES A MORE
STABLE BOND

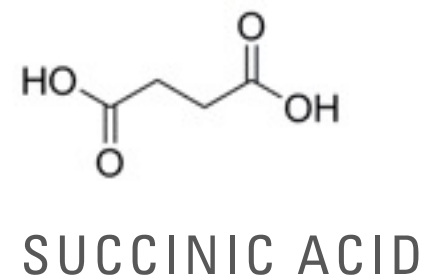
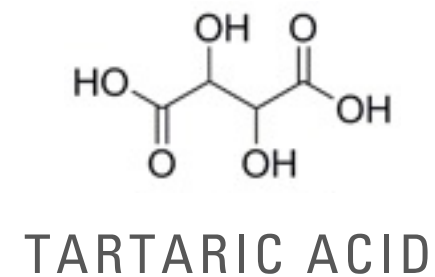
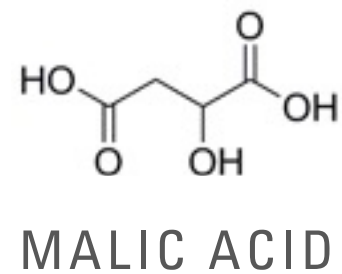
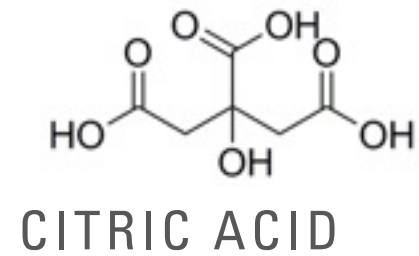


ATTACH CARBONYL GROUPS
CROSSLINK WITH DIAMINE

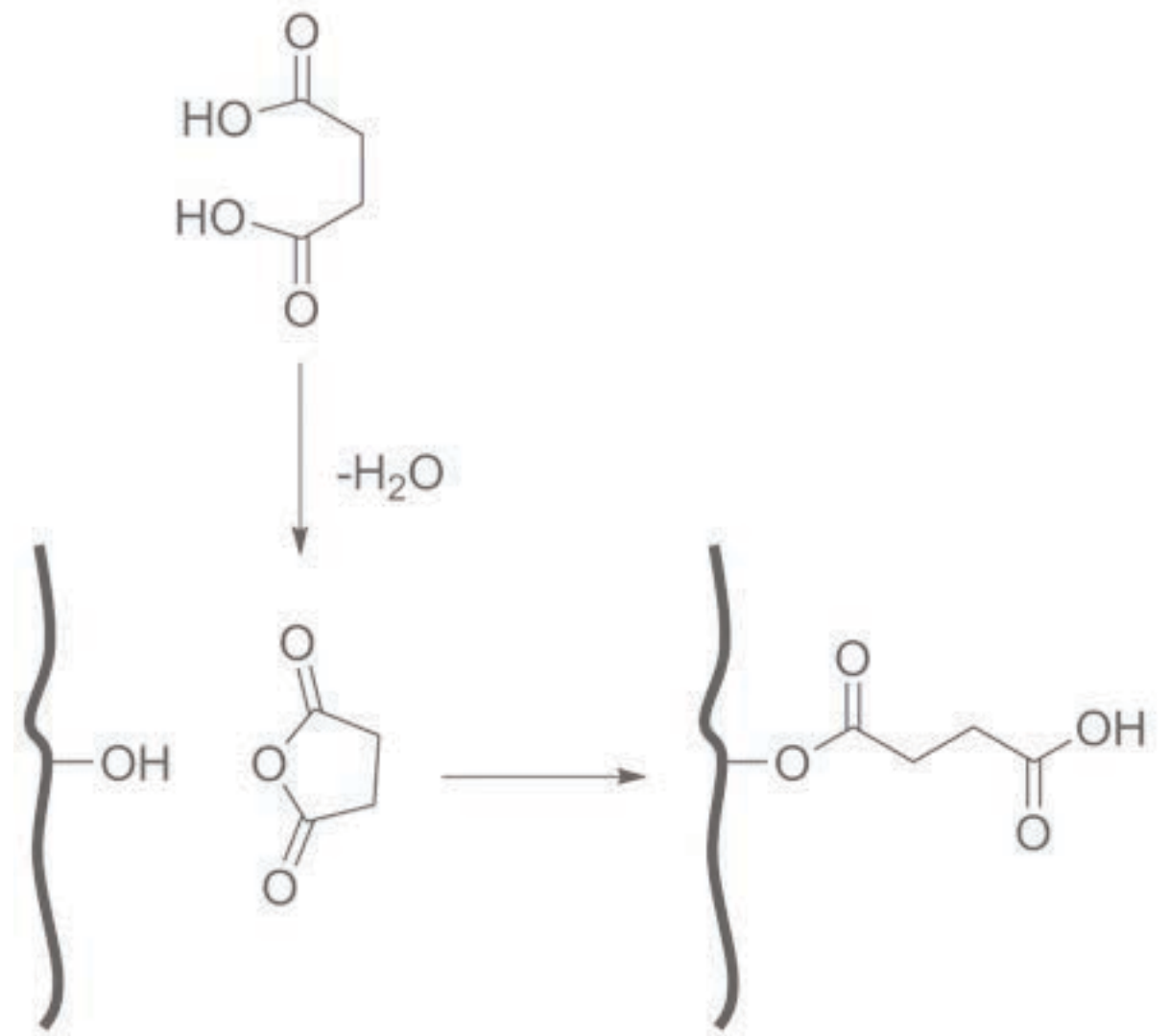


LINKING TO COTTON: POLY[CARBOXYLIC ACIDS]

POLY[CARBOXYLIC ACIDS] ARE COMMONLY FOUND IN NATURE

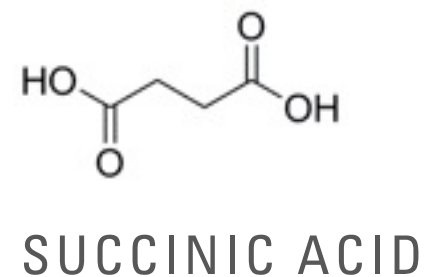
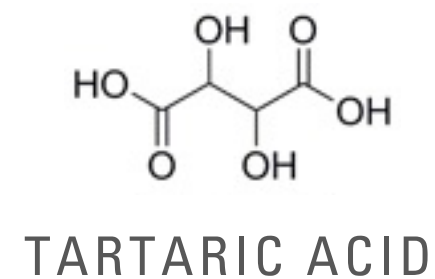
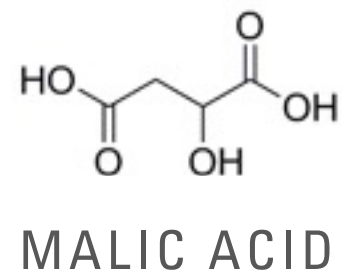
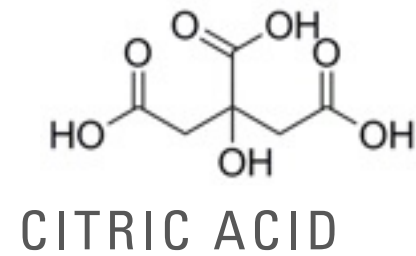


POLY[CARBOXYLIC ACIDS] HAVE BEEN SHOWN TO BIND TO CELLULOSE THROUGH CYCLIC ANHYDRIDE INTERMEDIATE

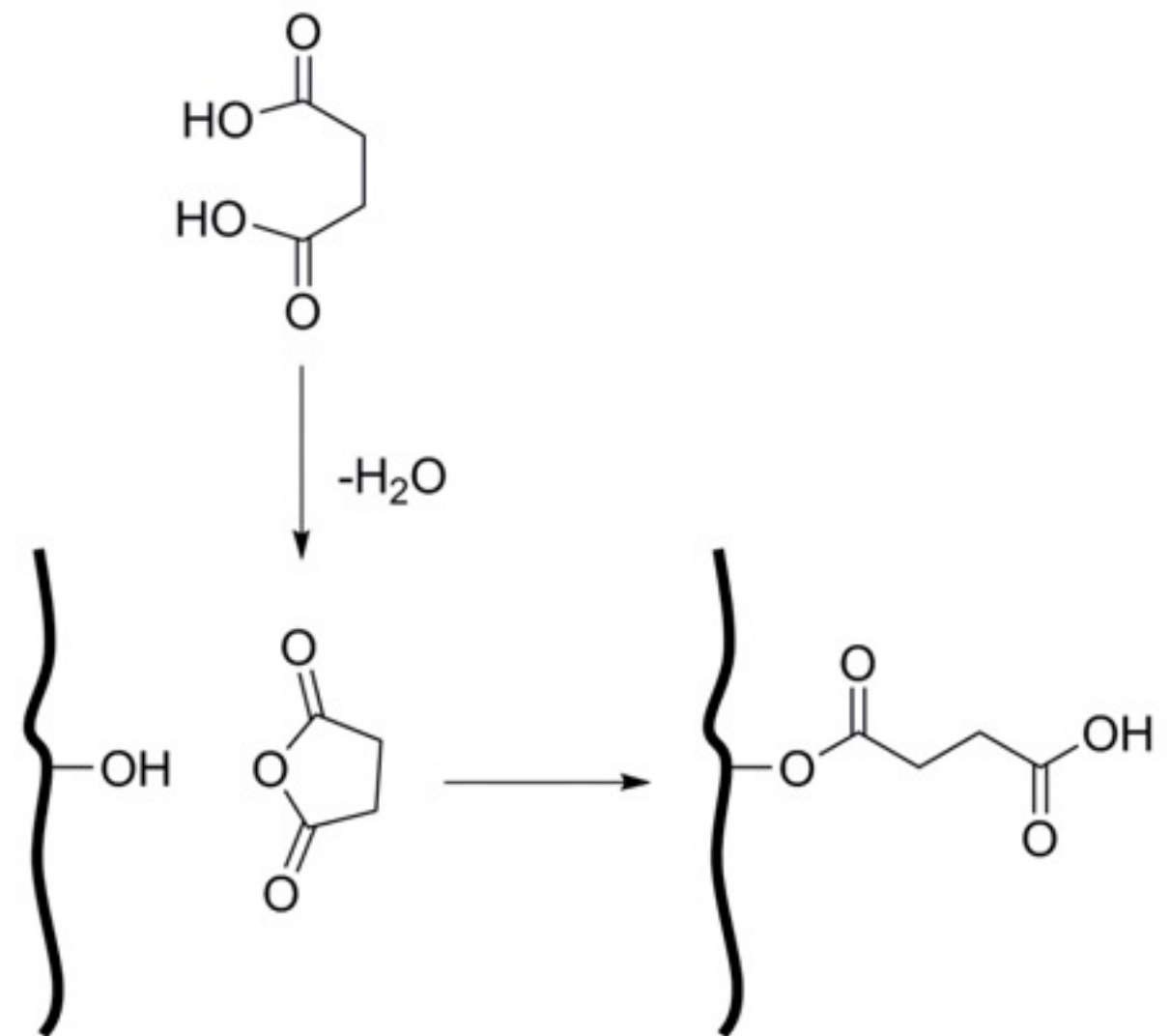


LINKING TO COTTON: POLY[CARBOXYLIC ACIDS]

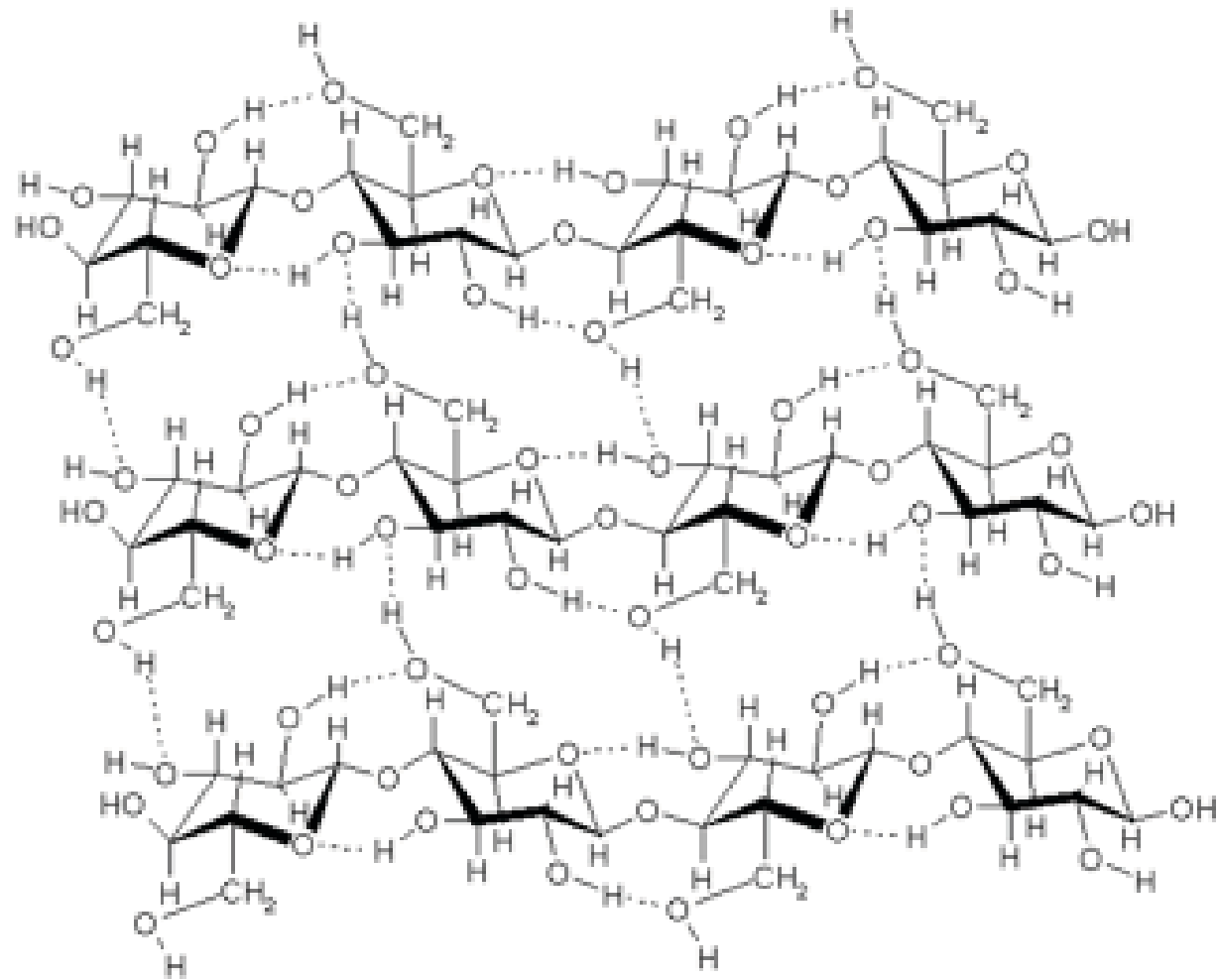
POLY[CARBOXYLIC ACIDS] ARE COMMONLY FOUND IN NATURE



POLY[CARBOXYLIC ACIDS] HAVE BEEN SHOWN TO BIND TO CELLULOSE THROUGH CYCLIC ANHYDRIDE INTERMEDIATE



LINKING TO COTTON



BIOLOGICAL ORIGINS

WOOD CELL WALL

- HIGH NUMBER OF HYDROGEN BONDS
- STRUCTURAL INTEGRATION

INDUSTRY PRECEDENT

USE OF POLYMERS

- CURRENTLY COAT FIBERS AND BLEND POLYESTERS

MOTIVATION

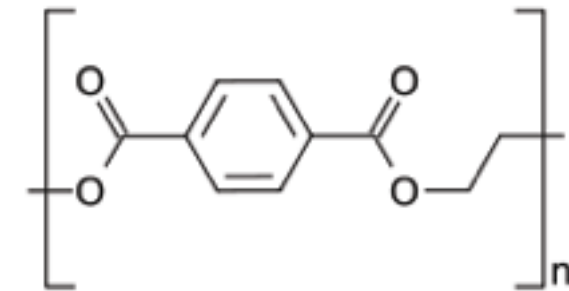
FUNCTIONALIZE CELLULOSE

- BETTER CROSSLINKING HANDLES
- COATING PROCESS
- COAT FIBER OR FABRIC WITH NON-COVALENTLY BOUND POLYMER FOR BETTER CROSSLINKING

LINKING TO COTTON: POLYMER WEAVE

CROSSLINK TO BLENDED POLYESTER

- LS & CO. OFTEN USES PET
- BLENDED POLYESTER MAY PROVIDE CROSSLINKING SITES

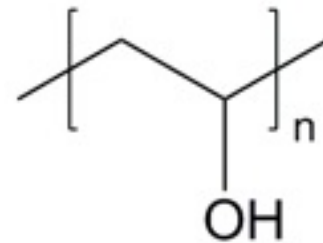


POLYETHYLENE
TEREPHTHALATE, THE MOST
COMMON POLYESTER IN
TEXTILES

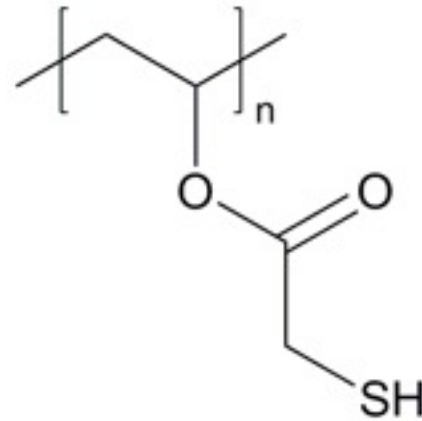
LINKING TO COTTON: POLYMER COATING

COAT FIBERS OR FABRIC WITH MORE CROSS-LINKABLE POLYMER

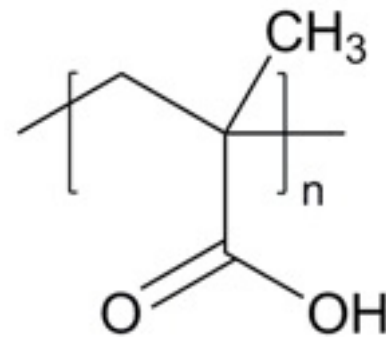
- POLYMERS ALREADY COATED ON FIBERS DURING SIZING
- MODIFIED SIZES OR NEW POLYMERS MAY PROVIDE CROSSLINKING SITES



POLY[VINYL ALCOHOL]



THIOLATED PVA

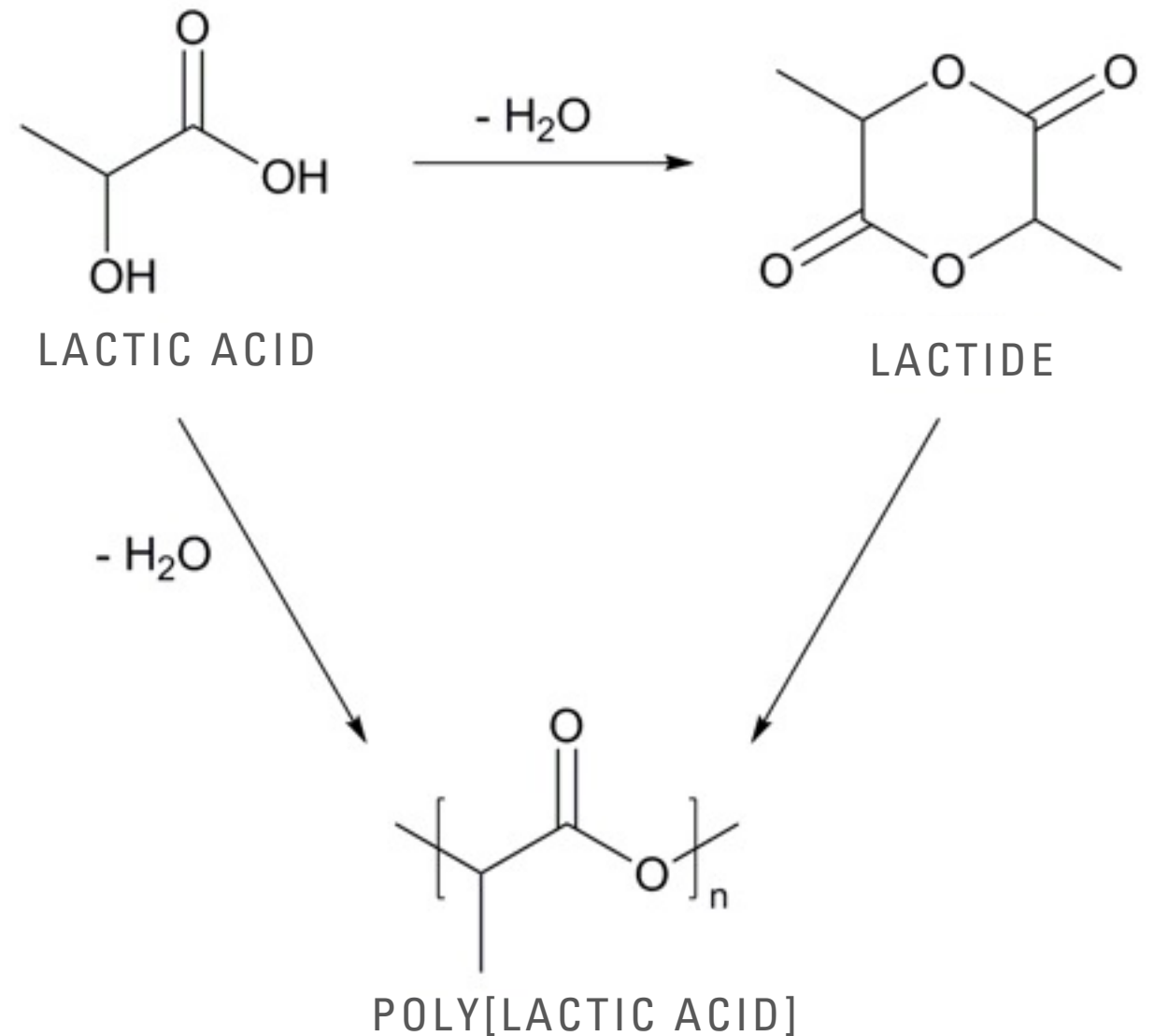


POLY[METHACRYLIC ACID]

LINKING TO COTTON: IN SITU POLYMERIZATION

COAT FIBERS OR FABRIC WITH MORE CROSS-LINKABLE POLYMER

- ENABLES APPLICATION IN FABRIC OR GARMENT FORM
- PREVIOUS USE IN TEXTILE INDUSTRY FOR DIFFERENT FUNCTIONALITIES [EG. LEVI'S REVEL LINE, CONDUCTIVE FABRICS, ETC.]



TECHNICAL EVALUATION FRAMEWORK

CONTEXT

METHODS

CROSSLINKING STRATEGIES

**TECHNICAL
FEASIBILITY**

HEALTH
IMPACTS

CONCLUSIONS

TECHNICAL EVALUATION FRAMEWORK

INNOVATION	ADDITIONAL RESEARCH NEEDED	MAJOR HURDLES ANTICIPATED	MINOR HURDLES ANTICIPATED	OPTIMIZATION ONLY
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TECHNICAL EVALUATION FRAMEWORK

INNOVATION	ADDITIONAL RESEARCH NEEDED	MAJOR HURDLES ANTICIPATED	MINOR HURDLES ANTICIPATED	OPTIMIZATION ONLY
DISRUPTION OF INFRASTRUCTURE	CHEMICAL SUPPLY	SPECIAL MANUFACTURE	LIMITED AVAILABILITY	WIDE AVAILABILITY

TECHNICAL EVALUATION FRAMEWORK

INNOVATION	ADDITIONAL RESEARCH NEEDED	MAJOR HURDLES ANTICIPATED	MINOR HURDLES ANTICIPATED	OPTIMIZATION ONLY
DISRUPTION OF INFRASTRUCTURE	CHEMICAL SUPPLY	SPECIAL MANUFACTURE	LIMITED AVAILABILITY	WIDE AVAILABILITY
	FABRIC APPLICATION	NEW PROCESS	MODIFY EXISTING PROCESS	USES EXISTING PROCESS

TECHNICAL EVALUATION FRAMEWORK

INNOVATION	ADDITIONAL RESEARCH NEEDED	MAJOR HURDLES ANTICIPATED	MINOR HURDLES ANTICIPATED	OPTIMIZATION ONLY
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	FABRIC APPLICATION	NEW PROCESS	MODIFY EXISTING PROCESS	USES EXISTING PROCESS
	CROSSLINKING STEP	NEW EQUIPMENT	NEW CHEMICALS, SOLVENTS	HEAT OR AIR CURED

TECHNICAL EVALUATION FRAMEWORK

INNOVATION	ADDITIONAL RESEARCH NEEDED	MAJOR HURDLES ANTICIPATED	MINOR HURDLES ANTICIPATED	OPTIMIZATION ONLY
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	CROSSLINKING STEP	NEW EQUIPMENT	NEW CHEMICALS, SOLVENTS	HEAT OR AIR CURED
ROBUSTNESS	CONTROLLABLE CROSSLINKING	TOO REACTIVE OR UNREACTIVE	SPECIAL CONDITIONS OR EXTRA CHEMICALS	ADD CATALYST, REAGENT, HEAT

TECHNICAL EVALUATION FRAMEWORK

INNOVATION	ADDITIONAL RESEARCH NEEDED	MAJOR HURDLES ANTICIPATED	MINOR HURDLES ANTICIPATED	OPTIMIZATION ONLY
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	RESILIENCE DURING MANUFACTURING	LIKELY PROBLEMS	POSSIBLE PROBLEMS	NO FORESEEABLE PROBLEMS

TECHNICAL EVALUATION FRAMEWORK

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	RESILIENCE DURING MANUFACTURING	LIKELY PROBLEMS	POSSIBLE PROBLEMS	NO FORESEEABLE PROBLEMS
	RESILIENCE DURING CONSUMER USE	LIKELY PROBLEMS	POSSIBLE PROBLEMS	NO FORESEEABLE PROBLEMS

TECHNICAL EVALUATION FRAMEWORK

INNOVATION	ADDITIONAL RESEARCH NEEDED	MAJOR HURDLES ANTICIPATED	MINOR HURDLES ANTICIPATED	OPTIMIZATION ONLY
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	RESILIENCE DURING CONSUMER USE	LIKELY PROBLEMS	POSSIBLE PROBLEMS	NO FORESEEABLE PROBLEMS
SIDE EFFECTS	EFFECTS ON FABRIC	REQUIRES PROBLEM CHEMICALS	POSSIBLE NEED FOR PROBLEM CHEMICALS	NO FORESEEABLE PROBLEMS

TECHNICAL EVALUATION COMPARISON

	INNOVATION	DISRUPTION			ROBUSTNESS			SIDE EFFECTS
	ADD'L RESEARCH NEEDED	CHEMICAL SUPPLY DISRUPTION	FABRIC APPLICATION DISRUPTION	CROSSLINK STEP DISRUPTION	CONTROLLED CROSSLINK	PROCESS DURABILITY	USE PHASE DURABILITY	PROCESS EFFECTS
DISULFIDE BONDS								
IMINE/AMINE BONDS								
POLY[CARBOXYLIC ACIDS]								
POLYMER WEAVE								
FIBER COATING								
FABRIC COATING								
IN SITU POLYMERIZATION								

TECHNICAL EVALUATION COMPARISON

	INNOVATION	DISRUPTION			ROBUSTNESS			SIDE EFFECTS
	ADD'L RESEARCH NEEDED	CHEMICAL SUPPLY DISRUPTION	FABRIC APPLICATION DISRUPTION	CROSSLINK STEP DISRUPTION	CONTROLLED CROSSLINK	PROCESS DURABILITY	USE PHASE DURABILITY	PROCESS EFFECTS
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TECHNICAL EVALUATION COMPARISON

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	INNOVATION	DISRUPTION			ROBUSTNESS			SIDE EFFECTS
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HEALTH EVALUATION FRAMEWORK

CONTEXT

METHODS

CROSSLINKING STRATEGIES

TECHNICAL
FEASIBILITY

**HEALTH
IMPACTS**

CONCLUSIONS

HEALTH EVALUATION FRAMEWORK

	SCOPE			DATA COLLECTION + PRIORITIZATION				OUTCOME
	INPUTS	USE	DEGREDAATION	LISTS	PRIMARY LIT	ANALOGS	MODELED DATA	
GREENSCREEN				2	1 [comprehensive]	3	3	benchmark score
ADAPTED EVAL				1	2 [as needed]	3	3	relative rank

HEALTH EVALUATION FRAMEWORK

SINGLE CHEMICAL
EVALUATION

GROUP I HUMAN					GROUP II + II* HUMAN								E TOX		FATE		PHYS		
C	M	R	D	E	AT	ST		N		SnS	SnR	IrS	IrE	AA	CA	P	B	Rx	F
						sgl	rep	sgl	rep										

HEALTH EVALUATION FRAMEWORK

SINGLE CHEMICAL
EVALUATION

GROUP I HUMAN					GROUP II + II* HUMAN								E TOX		FATE		PHYS		
C	M	R	D	E	AT	ST		N		SnS	SnR	IrS	IrE	AA	CA	P	B	Rx	F
						sgl	rep	sgl	rep										

CHEMICAL HAZARD
COMPARISON

GROUP I HUMAN					GROUP II + II* HUMAN								E TOX		FATE		PHYS		
C	M	R	D	E	AT	ST		N		SnS	SnR	IrS	IrE	AA	CA	P	B	Rx	F
						sgl	rep	sgl	rep										

HEALTH EVALUATION FRAMEWORK

SINGLE CHEMICAL EVALUATION

GROUP I HUMAN					GROUP II + II* HUMAN								E TOX		FATE		PHYS		
C	M	R	D	E	AT	ST		N		SnS	SnR	IrS	IrE	AA	CA	P	B	Rx	F
						sgl	rep	sgl	rep										
↘																			

CHEMICAL HAZARD COMPARISON

[illegible]

SYSTEMS HAZARD COMPARISON

The image displays a 4x4 grid of 16 square grids. Each grid contains a 10x10 sub-grid. The top-right grid is partially cut off by a diagonal dotted line. The sub-grids are arranged in a 4x4 pattern, with the top-right grid being the only one that is not fully visible.

CONTEXT

METHODS

CROSSLINKING STRATEGIES

TECHNICAL FEASIBILITY

HEALTH IMPACTS

CONCLUSIONS

HEALTH EVALUATION FRAMEWORK

CONTEXT

METHODS

CROSSLINKING STRATEGIES

TECHNICAL
FEASIBILITY

HEALTH
IMPACTS

CONCLUSIONS

HEALTH EVALUATION FRAMEWORK


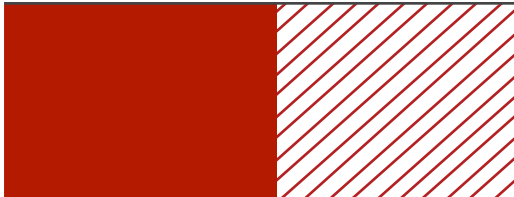
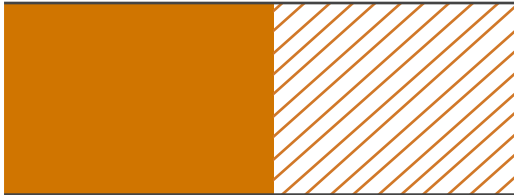
BM 1

MEETS GREENSCREEN BENCHMARK 1 CRITERIA FOR AT LEAST ONE
ENDPOINT; MUST BE ELIMINATED.


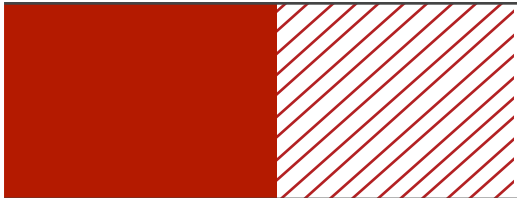
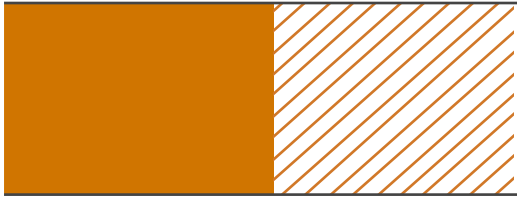
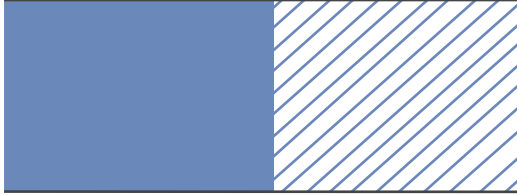
HEALTH EVALUATION FRAMEWORK

BM 1	MEETS GREENSCREEN BENCHMARK 1 CRITERIA FOR AT LEAST ONE ENDPOINT; MUST BE ELIMINATED.
	PROBABLE HIGH HAZARD FOR GROUP 1 HUMAN AND ECOTOXICITY ENDPOINTS; VERY HIGH GROUP II/II* ENDPOINTS; AVOID.

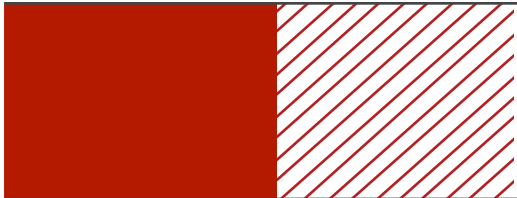
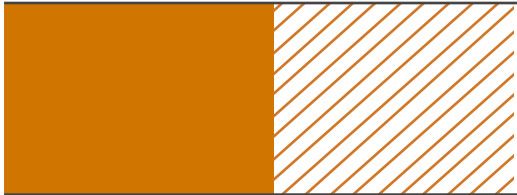
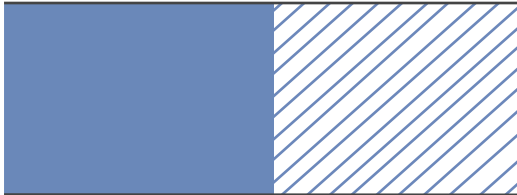
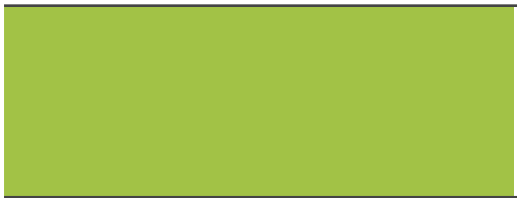
HEALTH EVALUATION FRAMEWORK

 BM 1	MEETS GREENSCREEN BENCHMARK 1 CRITERIA FOR AT LEAST ONE ENDPOINT; MUST BE ELIMINATED.
	PROBABLE HIGH HAZARD FOR GROUP 1 HUMAN AND ECOTOXICITY ENDPOINTS; VERY HIGH GROUP II/II* ENDPOINTS; AVOID.
	POTENTIAL HAZARD FOR GRP I HUMAN AND ECOTOX ENDPOINTS; KNOWN HIGH HAZARD FOR GRP II/II* HUMAN ENDPOINTS; HIGH PHYSICAL HAZARD.

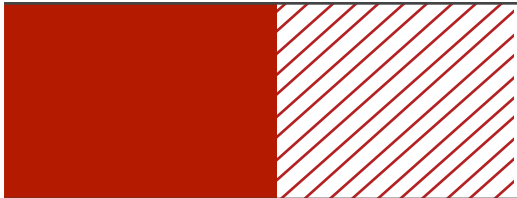
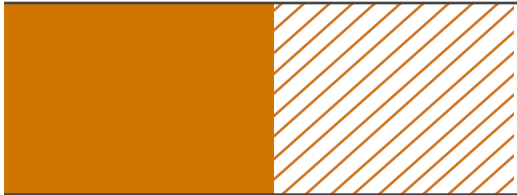

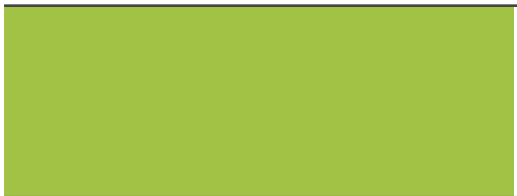

HEALTH EVALUATION FRAMEWORK

 BM 1	MEETS GREENSCREEN BENCHMARK 1 CRITERIA FOR AT LEAST ONE ENDPOINT; MUST BE ELIMINATED.
	PROBABLE HIGH HAZARD FOR GROUP 1 HUMAN AND ECOTOXICITY ENDPOINTS; VERY HIGH GROUP II/II* ENDPOINTS; AVOID.
	POTENTIAL HAZARD FOR GRP I HUMAN AND ECOTOX ENDPOINTS; KNOWN HIGH HAZARD FOR GRP II/II* HUMAN ENDPOINTS; HIGH PHYSICAL HAZARD.
	REASONABLE SUSPICION FOR CONCERN; MORE RESEARCH IS NECESSARY.

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	SUITABLE SUBSTITUTION BASED ON AVAILABLE DATA.

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	REASONABLE SUSPICION FOR CONCERN; MORE RESEARCH IS NECESSARY.
	SUITABLE SUBSTITUTION BASED ON AVAILABLE DATA.
	NO DATA AVAILABLE.

HEALTH EVALUATION FRAMEWORK

SINGLE CHEMICAL EVALUATION

GROUP I HUMAN					GROUP II + II* HUMAN								E TOX		FATE		PHYS		
C	M	R	D	E	AT	ST		N		SnS	SnR	IrS	IrE	AA	CA	P	B	Rx	F
						sgl	rep	sgl	rep										

[illegible]

SYSTEMS HAZARD COMPARISON

CONTEXT

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HEALTH IMPACTS

CONCLUSIONS

HEALTH EVALUATION FRAMEWORK

SINGLE CHEMICAL EVALUATION

GROUP I HUMAN					GROUP II + II* HUMAN								E TOX		FATE		PHYS		
C	M	R	D	E	AT	ST		N		SnS	SnR	IrS	IrE	AA	CA	P	B	Rx	F
						sgl	rep	sgl	rep										

[illegible]

SYSTEMS HAZARD COMPARISON

The image displays a 4x4 grid of 16 identical 10x10 grids. Each 10x10 grid contains a 2x2 grid of smaller squares in the top-left corner, with the top-left square of the 2x2 grid shaded gray.

HEALTH EVALUATION FRAMEWORK

SINGLE CHEMICAL EVALUATION

GROUP I HUMAN					GROUP II + II* HUMAN								E TOX		FATE		PHYS		
C	M	R	D	E	AT	ST		N		SnS	SnR	IrS	IrE	AA	CA	P	B	Rx	F
						sgl	rep	sgl	rep										

GROUP I HUMAN					GROUP II + II* HUMAN									E TOX		FATE		PHYS	
C	M	R	D	E	AT	ST		N		SnS	SnR	IrS	IrE	AA	CA	P	B	Rx	F
						sgl	rep	sgl	rep										

SYSTEMS HAZARD COMPARISON

The image contains four identical empty 10x10 grids arranged vertically. Each grid is designed for a drawing exercise. The first three grids have a small 2x2 square drawn in the top-left corner, with its bottom-right corner at the intersection of the 3rd vertical line and the 3rd horizontal line. The fourth grid is completely empty. Each grid has 10 vertical lines and 10 horizontal lines, creating a 9x9 array of squares.Three identical empty 10x10 grids are provided for drawing. Each grid has a small 2x2 square in the top-left corner, which is further divided into four 1x1 squares. The rest of the grid is a single 9x9 square.

The image contains four identical empty 10x10 grids arranged vertically. Each grid has a small coordinate plane in the top-left corner, with the x-axis and y-axis labeled from 1 to 10. The rest of the grid is empty for graphing.

The image contains three identical empty 10x10 grids, each with a 2x2 arrangement of squares in the top-left corner. Each grid is intended for a drawing.

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HEALTH EVALUATION FRAMEWORK

SINGLE CHEMICAL EVALUATION

GROUP I HUMAN					GROUP II + II* HUMAN								E TOX		FATE		PHYS		
C	M	R	D	E	AT	ST		N		SnS	SnR	IrS	IrE	AA	CA	P	B	Rx	F
						sgl	rep	sgl	rep										

	GROUP I HUMAN					GROUP II + II* HUMAN								E TOX		FATE		PHYS		
	C	M	R	D	E	AT	ST		N		SnS	SnR	IrS	IrE	AA	CA	P	B	Rx	F
							sgl	rep	sgl	rep										
CATALYST	Red	Gray	Gray	Red	Gray	Green	Gray	Gray	Gray	Gray	Green	Blue	Green	Gray	Orange	Blue/White Stripes	Orange	Orange	Green	Green
CATALYST	Gray	Gray	Gray	Gray	Red	Green	Orange	Orange	Gray	Orange	Blue	Blue	Green	Gray	Gray	Gray	Green	Gray	Orange	Green
OXIDANT	Gray	Orange/White Stripes	Orange	Gray	Orange/White Stripes	Orange	Blue	Blue	Gray	Gray	Orange	Red	Orange	Orange	Orange	Orange/White Stripes	Red	Blue/White Stripes	Green	Green
OXIDANT	Gray	Gray	Gray	Gray	Gray	Green	Orange	Orange	Blue	Blue	Green	Green	Green	Green	Gray	Gray	Green	Green	Orange	Green
SOLVENT	Gray	Gray	Gray	Gray	Gray	Gray	Gray	Gray	Orange/White Stripes	Gray	Gray	Gray	Gray	Gray	Gray	Gray	Blue	Blue	Gray	Gray
SOLVENT	Orange/White Stripes	Gray	Gray	Gray	Red	Green	Blue	Blue	Gray	Orange	Blue	Blue	Red	Red	Gray	Gray	Green	Green	Orange	Green

SYSTEMS HAZARD COMPARISON

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HEALTH EVALUATION FRAMEWORK

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GROUP I HUMAN					GROUP II + II* HUMAN								E TOX		FATE		PHYS		
C	M	R	D	E	AT	ST		N		SnS	SnR	IrS	IrE	AA	CA	P	B	Rx	F
						sgl	rep	sgl	rep										

	GROUP I HUMAN					GROUP II + II* HUMAN										E TOX		FATE		PHYS	
	C	M	R	D	E	AT	ST		N		SnS	SnR	IrS	IrE	AA	CA	P	B	Rx	F	
							sgl	rep	sgl	rep											
CATALYST	Red			Red	Gray	Green					Green	Blue	Green	Gray	Orange	Blue/White Stripes	Orange	Orange	Green	Green	
CATALYST				Red	Gray	Green	Orange	Orange		Orange	Blue	Blue	Green	Gray		Gray	Green	Gray	Orange	Green	
OXIDANT		Orange/White Stripes	Orange		Orange/White Stripes	Orange	Blue	Blue			Orange	Red	Orange	Orange	Orange	Orange/White Stripes	Red	Blue/White Stripes	Green	Orange	
OXIDANT						Green	Orange	Orange	Blue	Blue	Green	Green	Green				Green	Green	Orange	Green	
SOLVENT									Orange/White Stripes								Blue	Blue			
SOLVENT	Orange/White Stripes			Red		Green	Blue	Blue		Orange	Blue	Blue	Red	Red			Green	Green	Orange	Green	

SYSTEMS HAZARD COMPARISON

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GROUP I HUMAN					GROUP II + II* HUMAN								E TOX		FATE		PHYS		
C	M	R	D	E	AT	ST		N		SnS	SnR	IrS	IrE	AA	CA	P	B	Rx	F
						sgl	rep	sgl	rep										

GROUP I HUMAN					GROUP II + II* HUMAN								E TOX		FATE		PHYS		
C	M	R	D	E	AT	ST		N		SnS	SnR	IrS	IrE	AA	CA	P	B	Rx	F
						sgl	rep	sgl	rep										

HEALTH EVALUATION FRAMEWORK

SINGLE CHEMICAL
EVALUATION

GROUP I HUMAN					GROUP II + II* HUMAN								E TOX		FATE		PHYS		
C	M	R	D	E	AT	ST		N		SnS	SnR	IrS	IrE	AA	CA	P	B	Rx	F
						sgl	rep	sgl	rep										

CATALYST

GROUP I HUMAN					GROUP II + II* HUMAN								E TOX		FATE		PHYS		
C	M	R	D	E	AT	ST		N		SnS	SnR	IrS	IrE	AA	CA	P	B	Rx	F
						sgl	rep	sgl	rep										

HEALTH EVALUATION FRAMEWORK

SINGLE CHEMICAL
EVALUATION

GROUP I HUMAN					GROUP II + II* HUMAN								E TOX		FATE		PHYS		
C	M	R	D	E	AT	ST		N		SnS	SnR	IrS	IrE	AA	CA	P	B	Rx	F
						sgl	rep	sgl	rep										

CATALYST

GROUP I HUMAN					GROUP II + II* HUMAN								E TOX + FATE				PHYS	

HEALTH EVALUATION FRAMEWORK

SINGLE CHEMICAL
EVALUATION

GROUP I HUMAN					GROUP II + II* HUMAN								E TOX		FATE		PHYS		
C	M	R	D	E	AT	ST		N		SnS	SnR	IrS	IrE	AA	CA	P	B	Rx	F
						sgl	rep	sgl	rep										

CATALYST
CATALYST
OXIDANT
OXIDANT
SOLVENT
SOLVENT

GROUP I HUMAN	GROUP II + II* HUMAN										E TOX + FATE				PHYS	

HEALTH EVALUATION FRAMEWORK

SINGLE CHEMICAL
EVALUATION

GROUP I HUMAN					GROUP II + II* HUMAN								E TOX		FATE		PHYS		
C	M	R	D	E	AT	ST		N		SnS	SnR	IrS	IrE	AA	CA	P	B	Rx	F
						sgl	rep	sgl	rep										

CATALYST
CATALYST
OXIDANT
OXIDANT
SOLVENT
SOLVENT

GROUP I HUMAN	GROUP II + II* HUMAN										E TOX + FATE				PHYS	

STRATEGY A

GROUP I HUMAN	GROUP II + II* HUMAN										E TOX + FATE				PHYS	

HEALTH EVALUATION FRAMEWORK

SINGLE CHEMICAL
EVALUATION

GROUP I HUMAN					GROUP II + II* HUMAN								E TOX		FATE		PHYS		
C	M	R	D	E	AT	ST		N		SnS	SnR	IrS	IrE	AA	CA	P	B	Rx	F
						sgl	rep	sgl	rep										

CATALYST
CATALYST
OXIDANT
OXIDANT
SOLVENT
SOLVENT

GROUP I HUMAN	GROUP II + II* HUMAN										E TOX + FATE				PHYS	

STRATEGY A

GROUP I HUMAN	GROUP II + II* HUMAN										E TOX + FATE				PHYS	

STRATEGY B

GROUP I HUMAN	GROUP II + II* HUMAN										E TOX + FATE				PHYS	

STRATEGY C

GROUP I HUMAN	GROUP II + II* HUMAN										E TOX + FATE				PHYS	

STRATEGY D

GROUP I HUMAN	GROUP II + II* HUMAN										E TOX + FATE				PHYS	

HEALTH EVALUATION GREATEST HITS

BASELINE					
	GRP I	II + II*	E TOX	FATE	PHYS
SIZING					
WRINKLE-FREE XLINK					
DWR XLINK					
FORMALDEHYDE					

HEALTH EVALUATION GREATEST HITS

BASELINE

	GRP I	II + II*	E TOX	FATE	PHYS
SIZING					
WRINKLE-FREE XLINK					
DWR XLINK					
FORMALDEHYDE					

DISULFIDE BONDS

	GRP I	II + II*	E TOX	FATE	PHYS
OXIDANT					
CATALYST					
CATALYST SUPPORT					
HEAT SOURCE					

IMINE BONDS

	GRP I	II + II*	E TOX	FATE	PHYS
XLINK					
REDUCTANT					
CATALYST					

POLY ACIDS

	GRP I	II + II*	E TOX	FATE	PHYS
CARBOXYLIC ACID					
THIOLATING AGENT					
CATALYST					

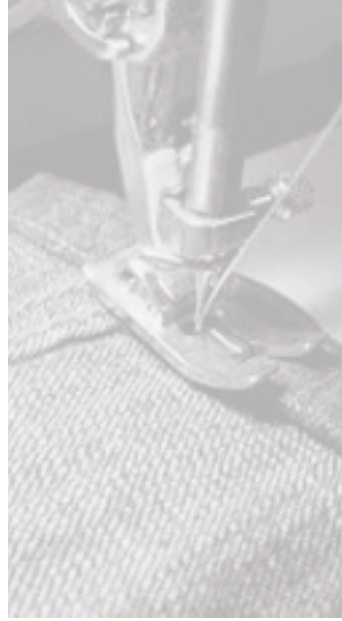
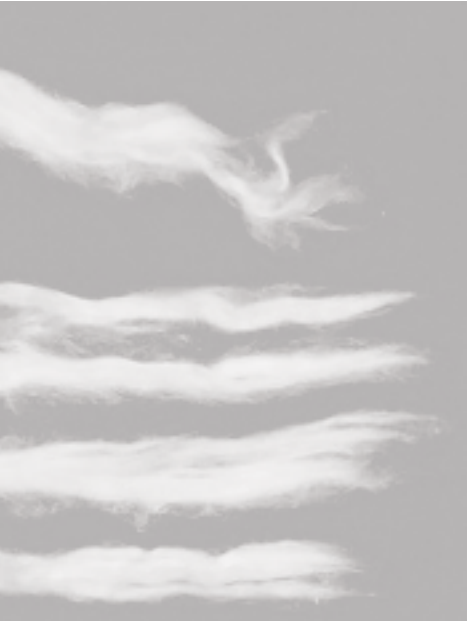
POLY THIOLATION

	GRP I	II + II*	E TOX	FATE	PHYS
POLYMER					
THIOLATING AGENT					
CATALYST					
REDUCTANT					
THIOLATED POLYMER					

POLY COATING

	GRP I	II + II*	E TOX	FATE	PHYS
MONOMER					
CATALYST					
STRENGTHENER					
FIBER					
SOLVENT					
FUNCTIONALIZER					

CONCLUSIONS



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TECHNICAL
FEASIBILITY

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CONCLUSIONS

TEXTILE CROSSLINKING CAN BE CONSIDERED IN TWO PARTS: LINKAGE WITH CELLULOSE AND CROSSLINKING.

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TEXTILE CROSSLINKING CAN BE CONSIDERED IN TWO PARTS: LINKAGE WITH CELLULOSE AND CROSSLINKING.

TECHNICAL AND HEALTH EVALUATION FRAMEWORKS CAN BE APPLIED TO CURRENTLY PROPOSED AND FUTURE SOLUTIONS.

CONTEXT

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TECHNICAL
FEASIBILITY

TECHNICAL
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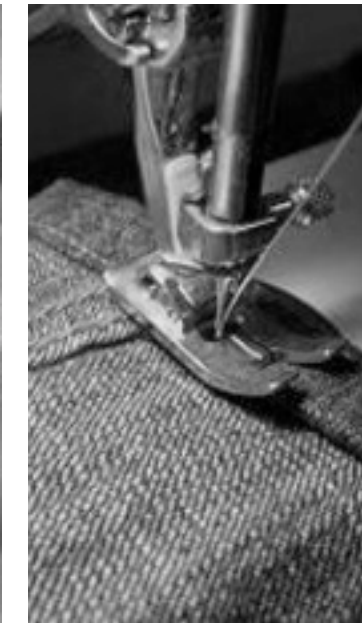
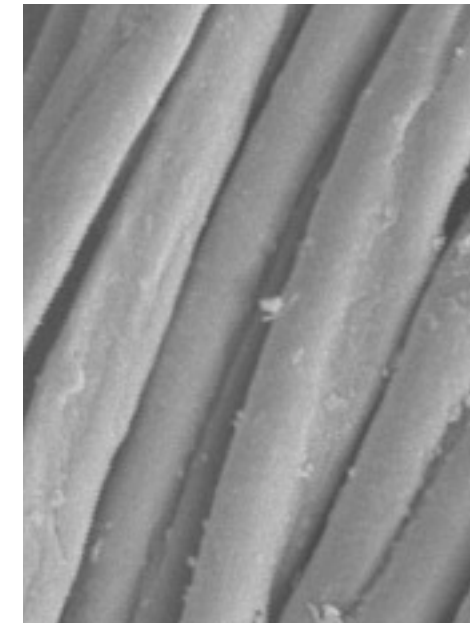
CONCLUSIONS

CONCLUSIONS

TEXTILE CROSSLINKING CAN BE CONSIDERED IN TWO PARTS: LINKAGE WITH CELLULOSE AND CROSSLINKING.

TECHNICAL AND HEALTH EVALUATION FRAMEWORKS CAN BE APPLIED TO CURRENTLY PROPOSED AND FUTURE SOLUTIONS.

CONCLUSIONS FROM FRAMEWORKS ARE COMPLEX AND NUANCED, AND THERE IS OFTEN A TRADEOFF BETWEEN PERFORMANCE AND HEALTH CONSIDERATIONS



THANK YOU