

GREENER SOLUTIONS 2013

PANEL 2: SYSTEMS APPROACH TO GREENER DESIGN

MICHEL DEDEO
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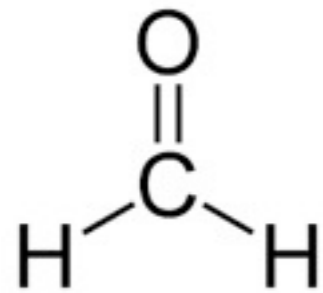


Create a water repellent finish for denim or a permanent press finish for cotton pants without toxic chemical crosslinkers.
[formaldehyde, di-isocyanates]



THE CHALLENGE

HEALTH IMPACTS



FORMALDEHYDE

SEVERE HEALTH ISSUES

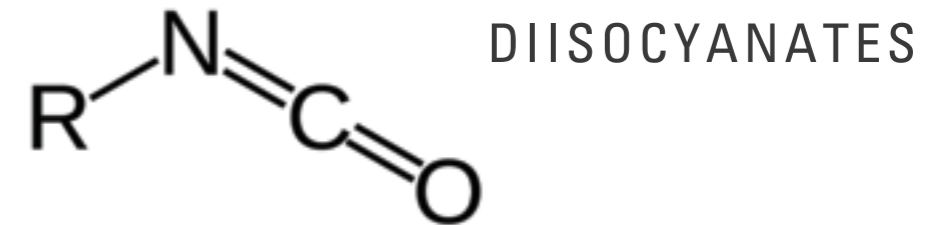
- NERVOUS SYSTEM DAMAGE
- ENDOCRINE DISRUPTION
- NASAL CANCER
- NASOPHARYNGEAL CANCER
- LEUKEMIA
- SKIN SENSITIZER
- RESPIRATORY SENSITIZER

HEALTH IMPACTS



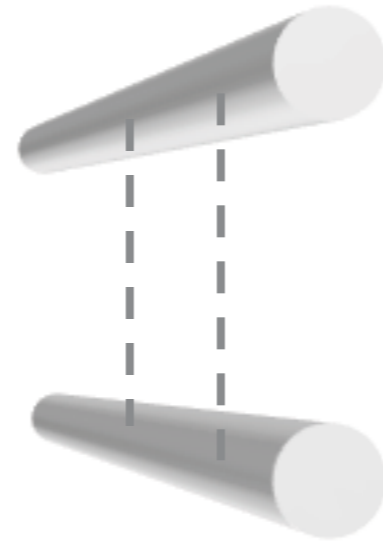
SEVERE HEALTH ISSUES

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



SEVERE HEALTH ISSUES

- SKIN, EYE, AND RESPIRATORY IRRITANT
- RESPIRATORY SENSITIZER
- ASTHMAGEN
- POSSIBLE CARCINOGEN



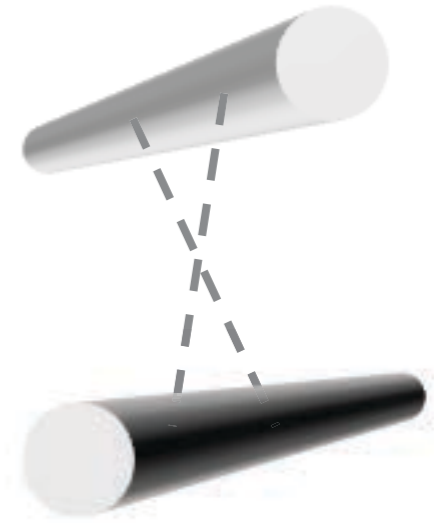
DRY COTTON FIBERS
LOOSELY BONDED

water
→



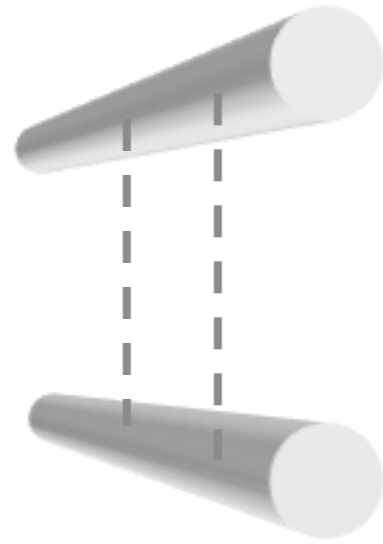
WATER BREAKS
BONDS, FIBERS MOVE

drying
→



BONDS RE-FORM
WHEN FABRIC DRIES
WRINKLES!

WHAT IS CROSSLINKING?



DRY COTTON FIBERS
LOOSELY BONDED

water
→

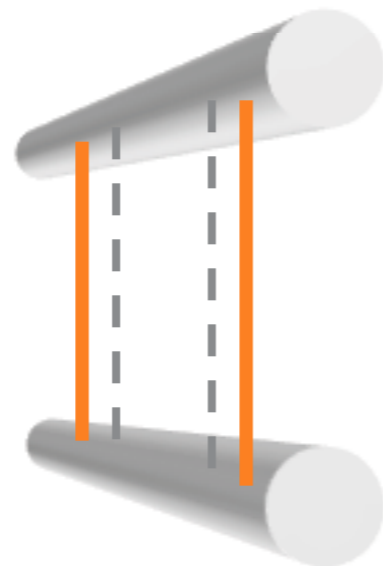


WATER BREAKS
BONDS, FIBERS MOVE

drying
→

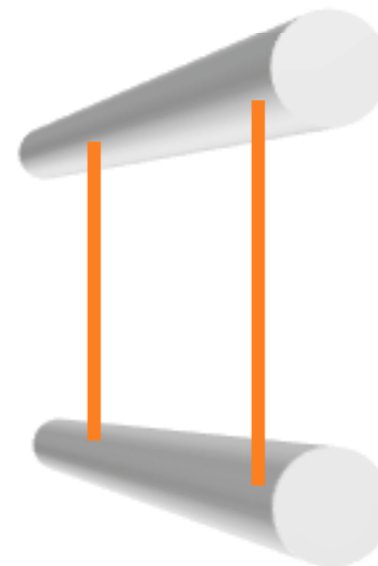


BONDS RE-FORM
WHEN FABRIC DRIES
WRINKLES!



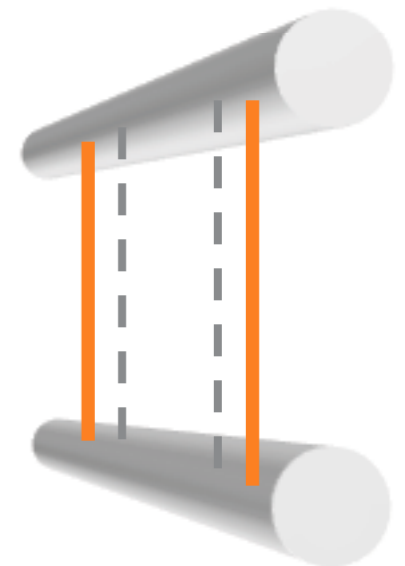
CROSSLINKED COTTON
FIBERS

water
→



WATER CANNOT
BREAK CROSSLINKERS

drying
→



NO WRINKLES!

WHAT IS CROSSLINKING?



Biomimicry is learning from and then emulating natural forms, processes, and ecosystems to create more sustainable designs.

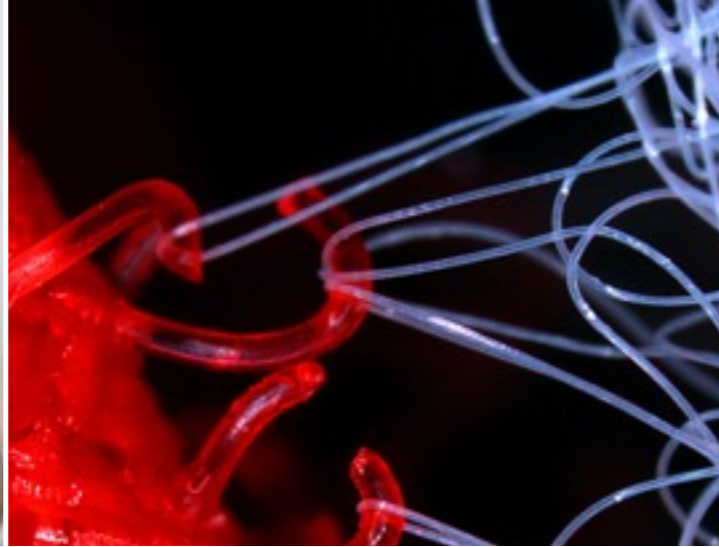


PBT modelers
ChemSpider
PubMed
SciFinder

STRUCTURAL



burr



velcro



king fisher

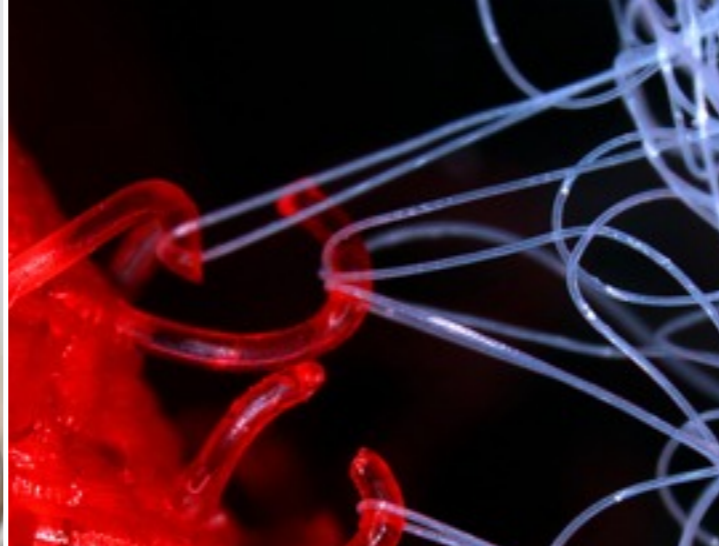


bullet train

STRUCTURAL



burr



velcro

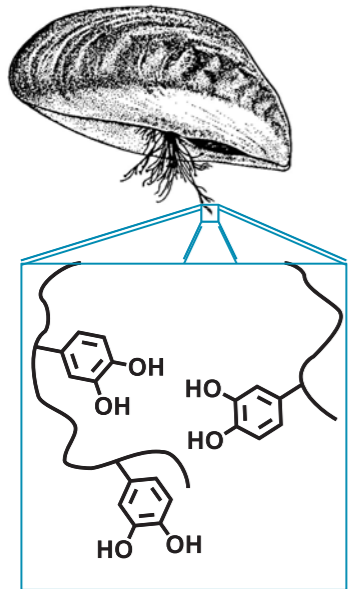


king fisher

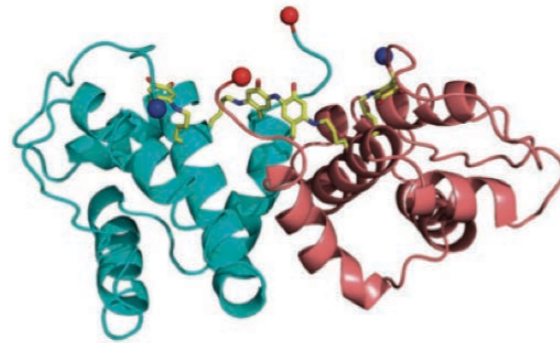


bullet train

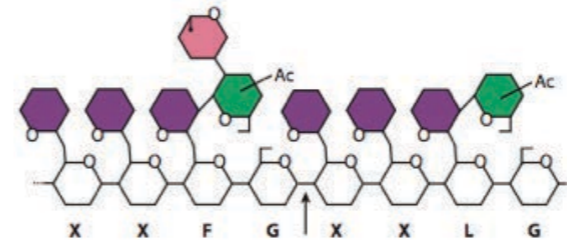
CHEMICAL



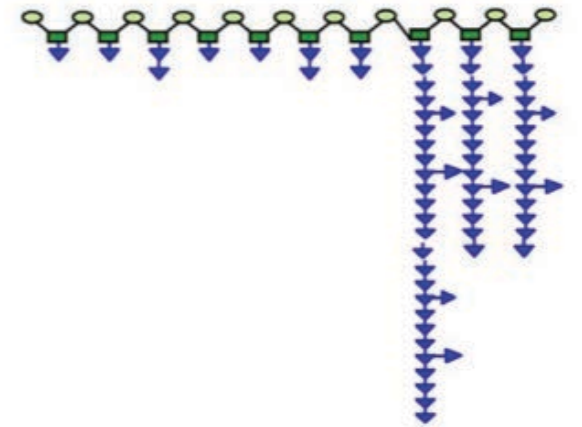
sea mussel



malaysian tree frog

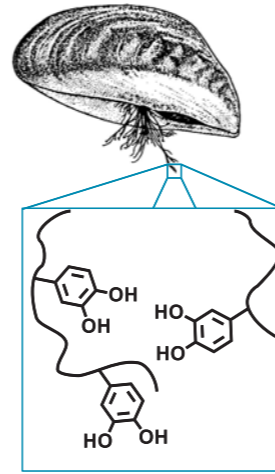


woody plant tissue



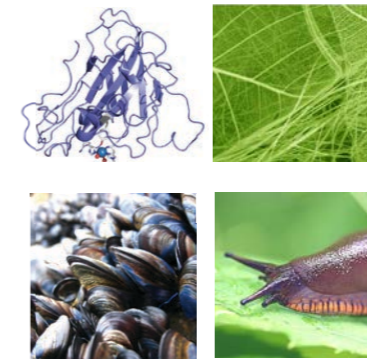
flax stem

BIOMIMICRY



INFORMED DECISIONS

- Priority **1** be **less hazardous** than the existing solution
- Priority **2** have **performance and durability** comparable to existing treatments
- Priority **3** minimize changes to the application process, cost, and consumer experience



POTENTIAL SOLUTIONS

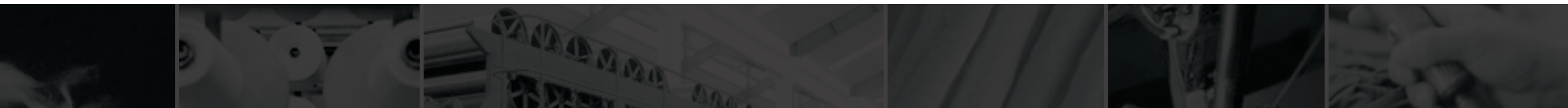
GROUP I HUMAN					GROUP II + II* HUMAN								E TOX		FATE		PHYS		
C	M	R	D	E	AT	ST sgl	rep	N sgl	rep	SnS	SnR	IrS	IrE	AA	CA	P	B	Rx	F
Red	Grey	Grey	Red	Grey	Green	Green	Green	Green	Green	Green	Blue	Green	Green	Orange	Blue/White	Orange	Orange	Green	Green
Grey	Orange/White	Grey	Grey	Red/White	Green	Orange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

HEALTH FRAMEWORK

White	White	White	White	White	White
White	Green	Yellow	Yellow	Red	Yellow
White	Yellow	Green	Green	Red	Red
White	Green	Green	Green	Yellow	Red
White	Green	Green	Green	Yellow	Red
White	Yellow	Green	Green	Red	Red
White	Red	Red	Green	Grey	Green
White	Yellow	Red	Yellow	Red	Yellow
White	Green	Red	Grey	Red	Green

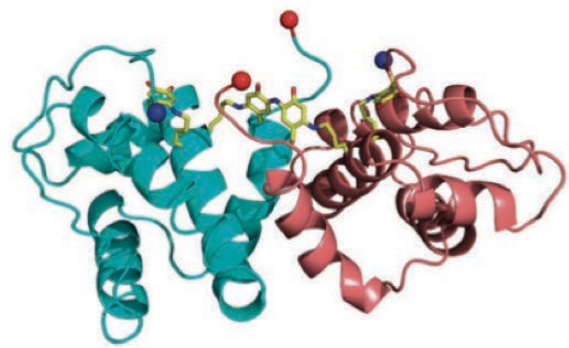
TECHNICAL FRAMEWORK

BLUE TEAM

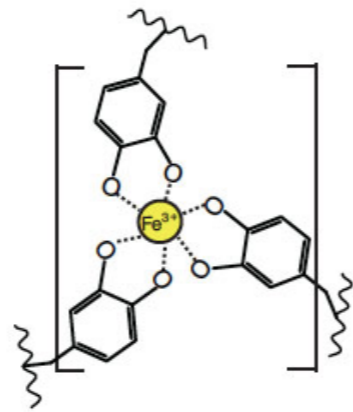




CROSSLINKED PROTEINS

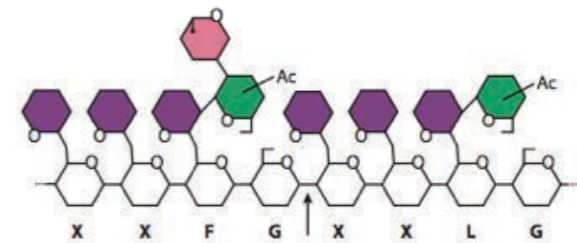


TREE FROG
Ranasmurfin protein
coordination complex

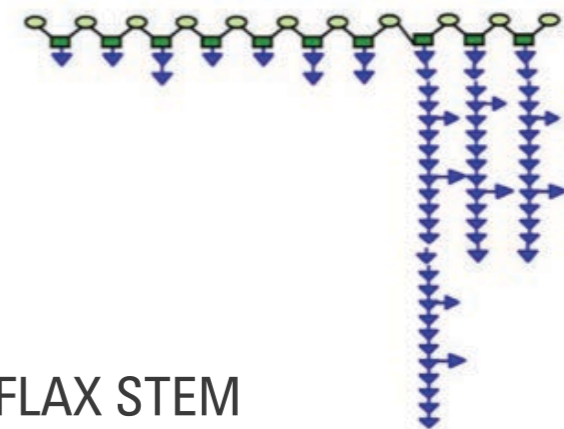


SEA MUSSEL
Catechol-iron complex

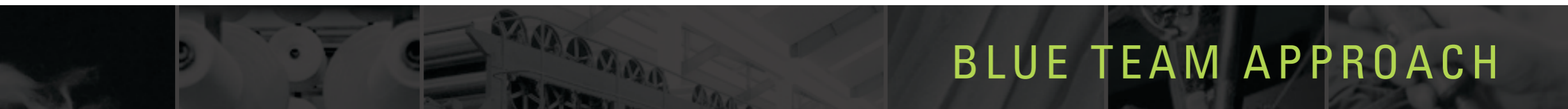
CROSSLINKED POLYSACCHARIDES

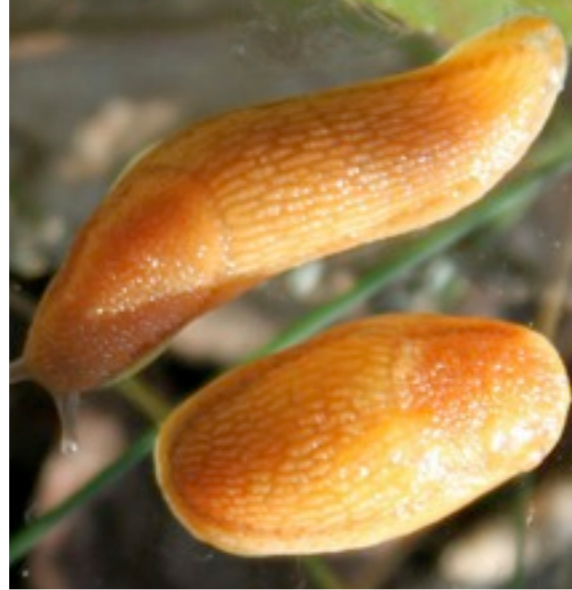


WOODY PLANTS
Xyloglucan hemicellulose

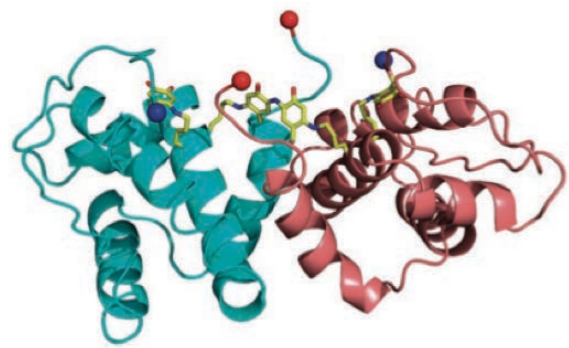


FLAX STEM
Crosslinking pectic galactans

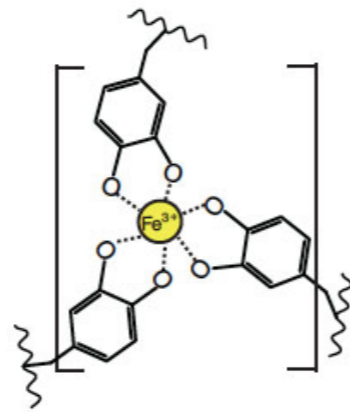




CROSSLINKED PROTEINS

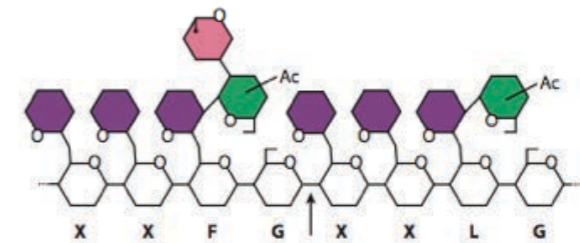


TREE FROG
Ranasmurfin protein
coordination complex

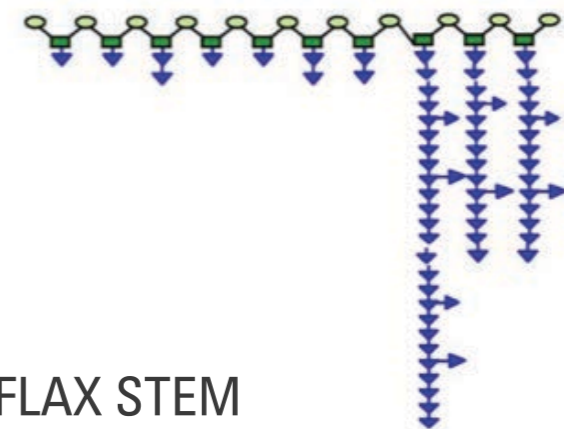


SEA MUSSEL
Catechol-iron complex

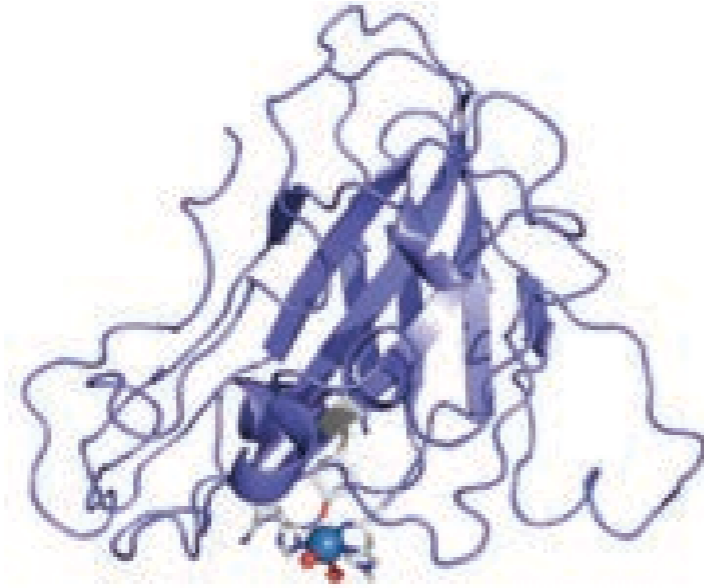
CROSSLINKED POLYSACCHARIDES



WOODY PLANTS
Xyloglucan hemicellulose



FLAX STEM
Crosslinking pectic galactans



PMO ENZYME



CELLULOSE ENZYMES



SEA MUSSEL



POTASSIUM
PERMANGANATE



PMO ENZYME



CELLULOSE ENZYMES

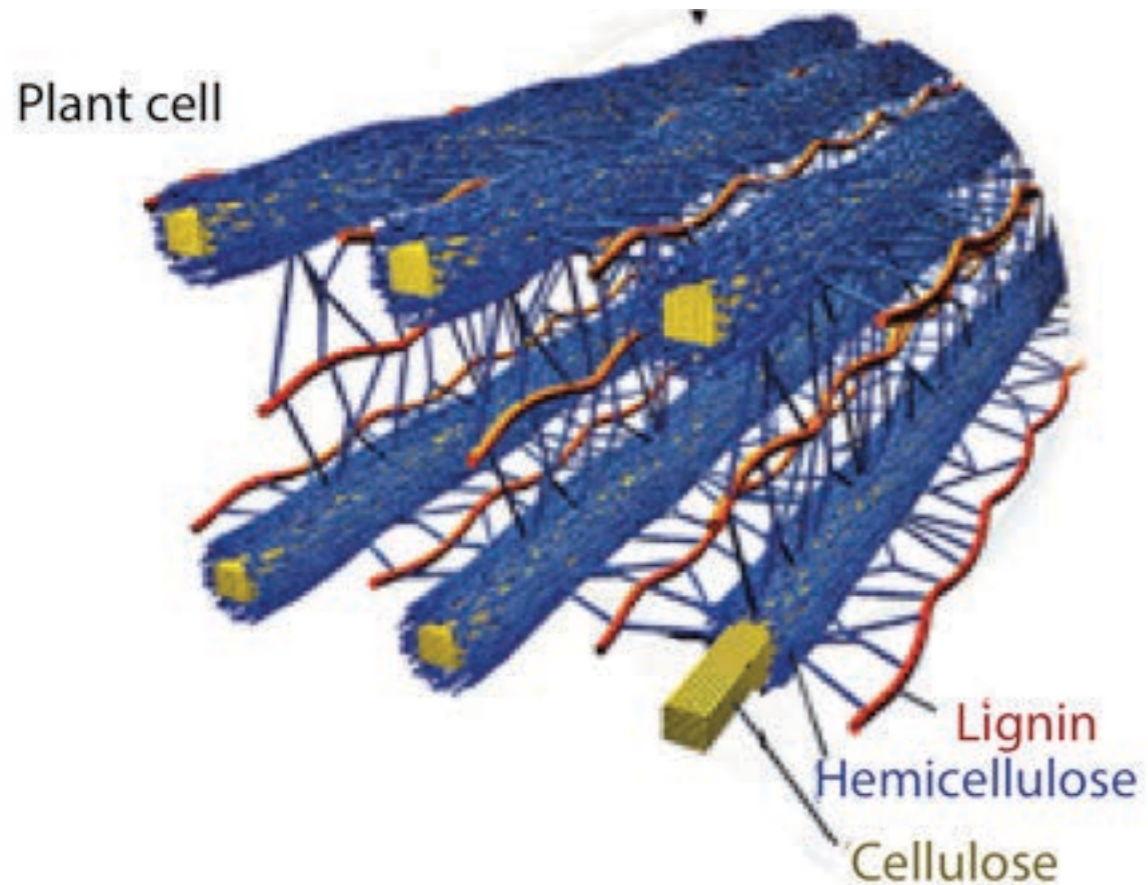


SEA MUSSEL



POTASSIUM
PERMANGANATE

LIGNIN + HEMICELLULOSE PROVIDE CROSSLINKING STRUCTURES IN PLANTS

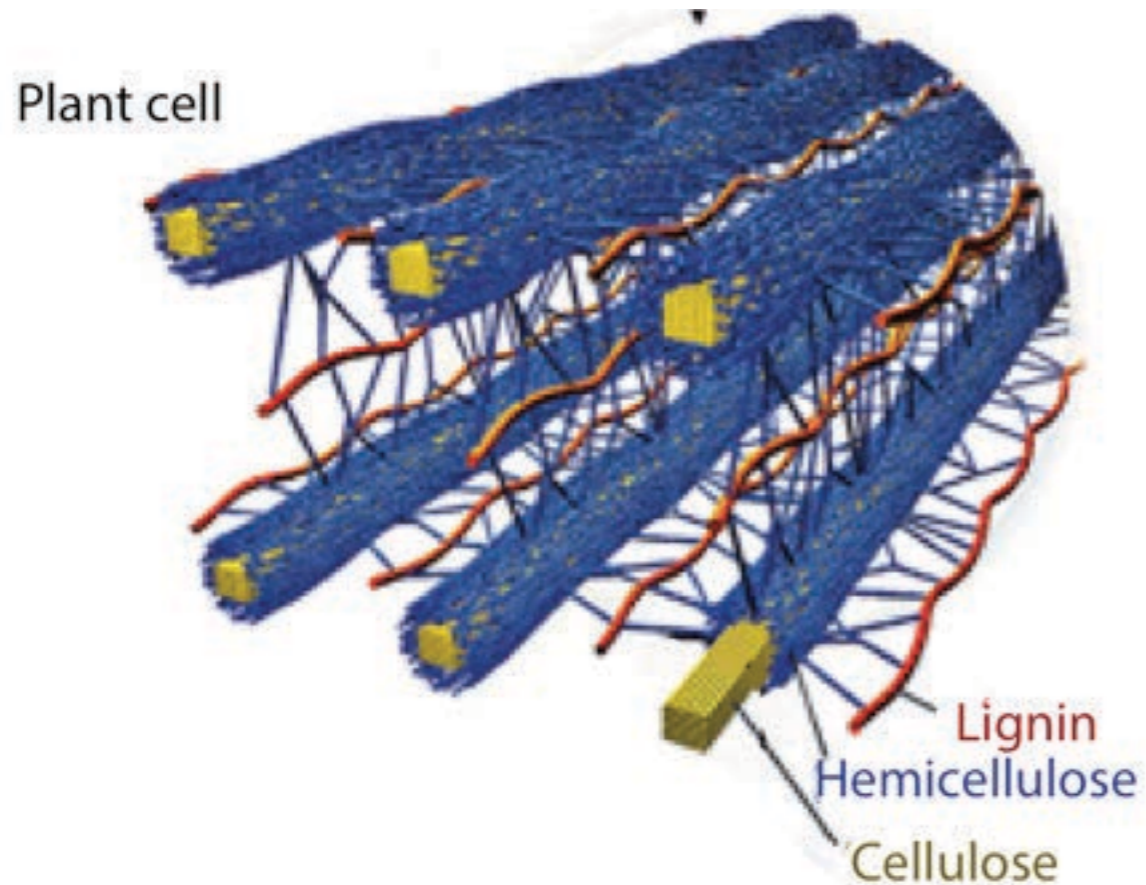


PLANT CROSSLINKING

Cellulose activation and polymerization are mediated by enzymes

Crosslinking confers mechanical strength, water repellency, and pathogen resistance

LIGNIN + HEMICELLULOSE PROVIDE CROSSLINKING STRUCTURES IN PLANTS



BENEFITS

Enzymes already used in textile industry

Enzyme processes are less harsh than current technology

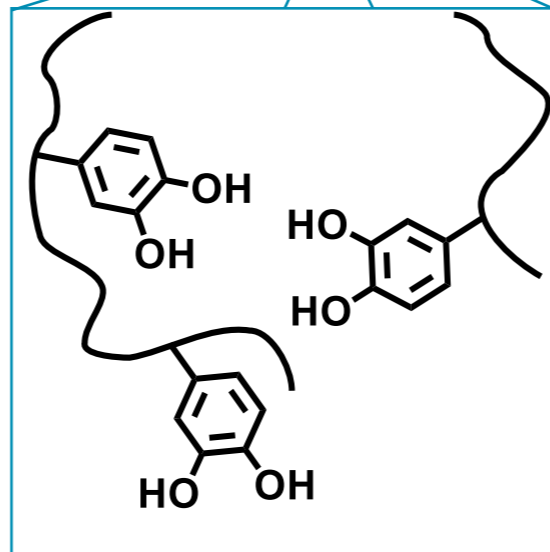
CHALLENGES

Could disrupt the fabric color and strength

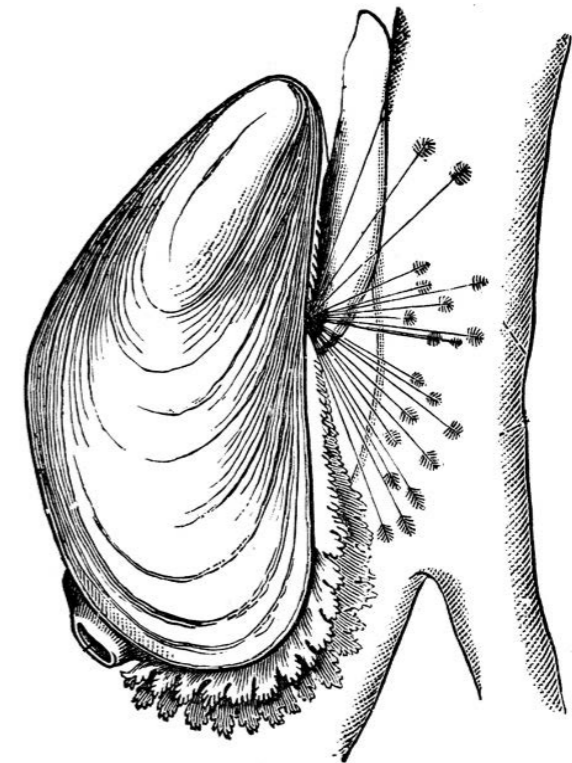
Processing times may be too long

SEA MUSSELS MAKE AMAZING GLUE

GLUE STICKS TO ROCK



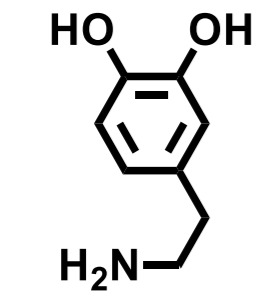
GLUE STICKS TO WOOD



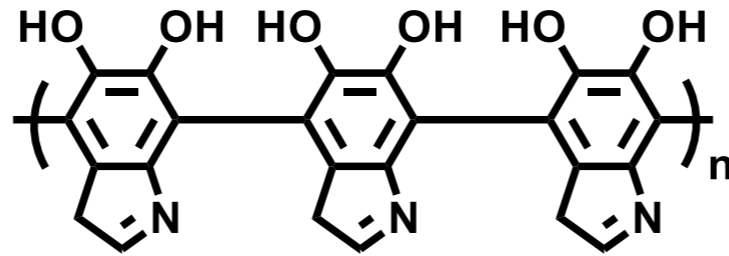
Chemicals in byssal threads allow mussels to anchor to almost any surface, even when wet.

Lee, 2006

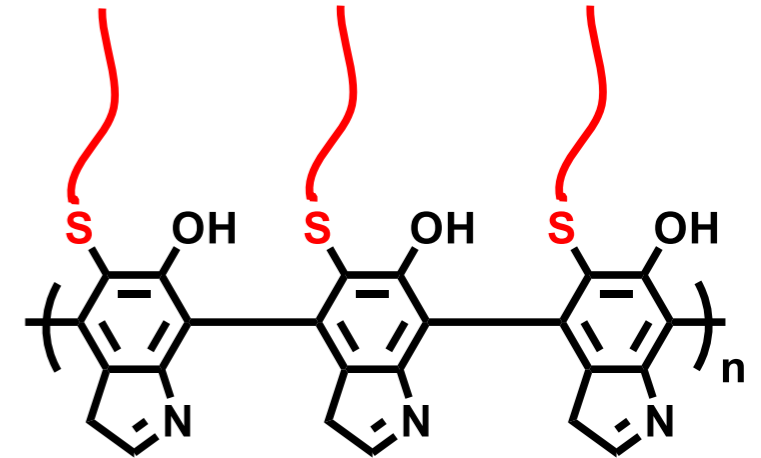
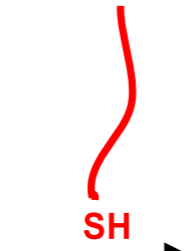
ADAPTING SEA MUSSEL GLUE TO FABRIC



DOPAMINE

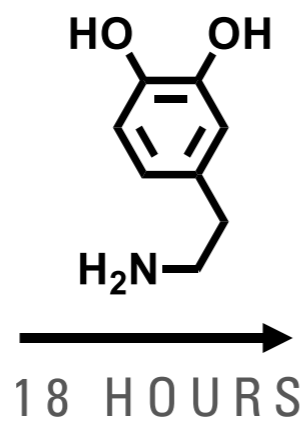
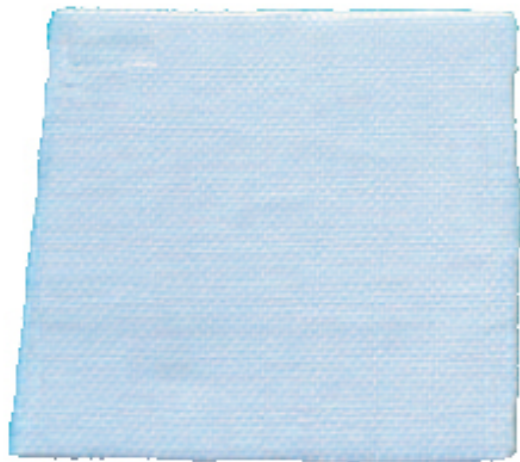


POLYDOPAMINE

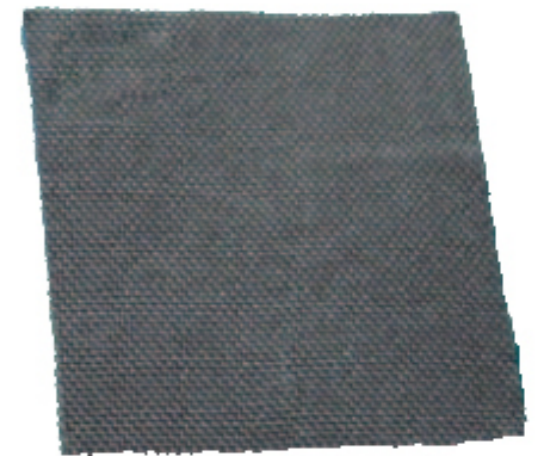


POLYDOPAMINE +
WATER REPELLENT

POLYESTER
FABRIC



30 WASHES
→



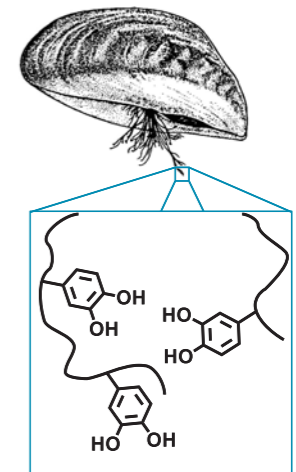
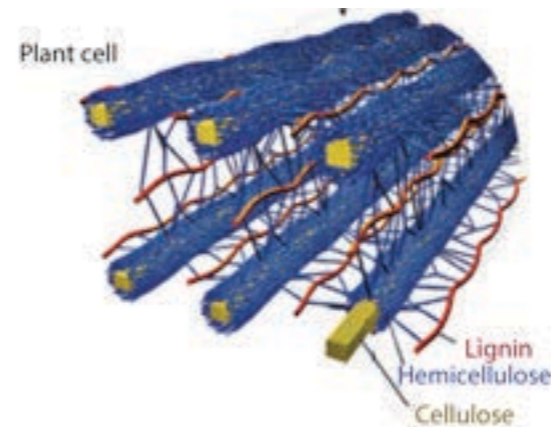
Lee 2007, Xu 2013

RECOMMENDATIONS FOR PARTNERS

There are promising solutions based on biomimicry.

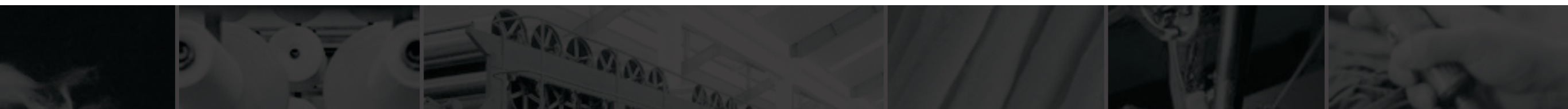
Any new solution will require additional investment.

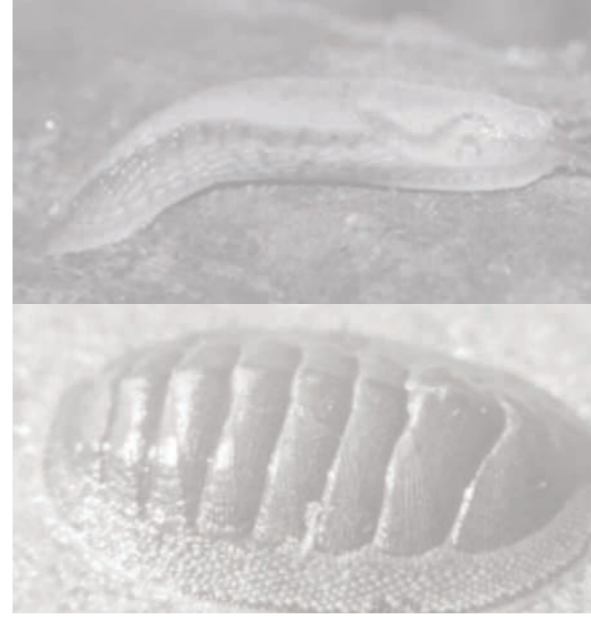
Frameworks developed for this application can be used to specify and evaluate future solutions.



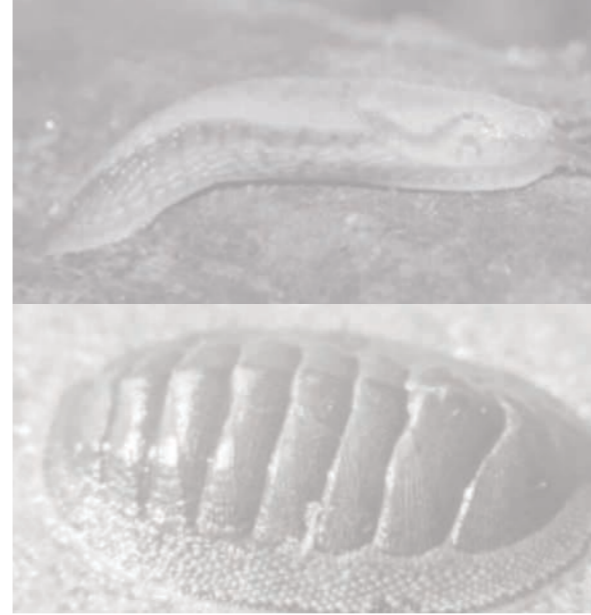
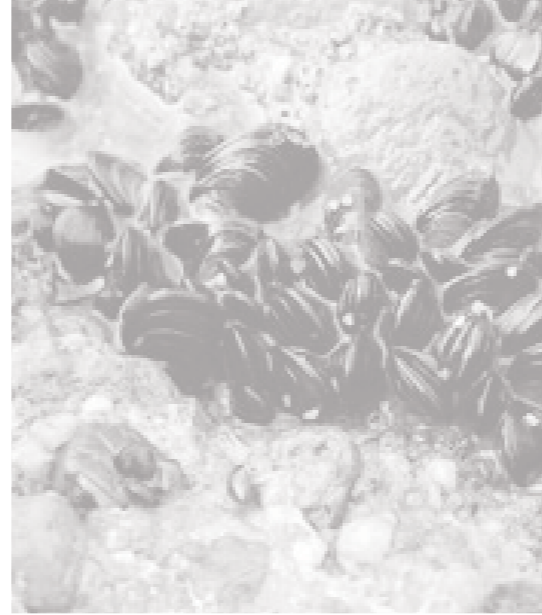
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	Green	Green	Green	Red	Yellow
	Green	Green	Yellow	Yellow	Red
	Green	Green	Green	Red	Red
	Yellow	Red	Green	Green	Red
	Yellow	Grey	Grey	Green	Yellow
	Yellow	Red	Grey	Grey	Red
	Green	Red	Grey	Grey	Green

GREEN TEAM

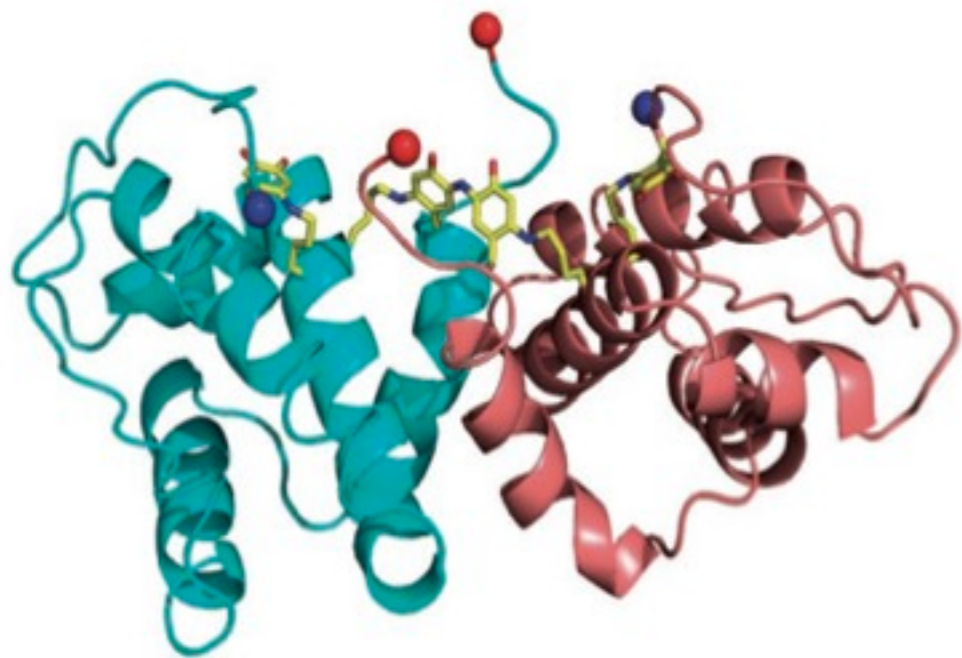




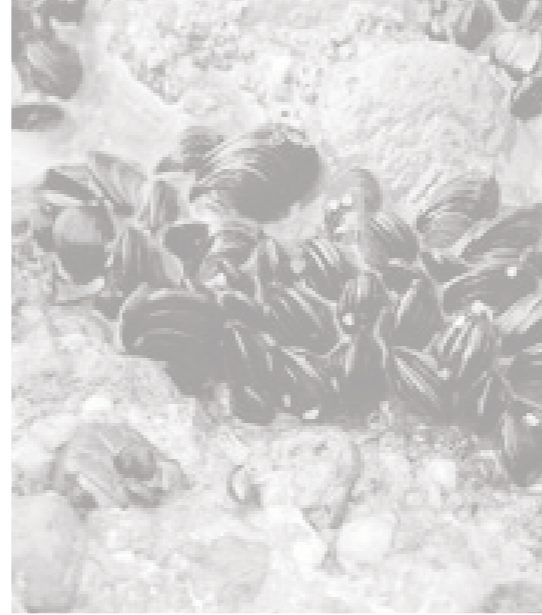
GREEN TEAM APPROACH



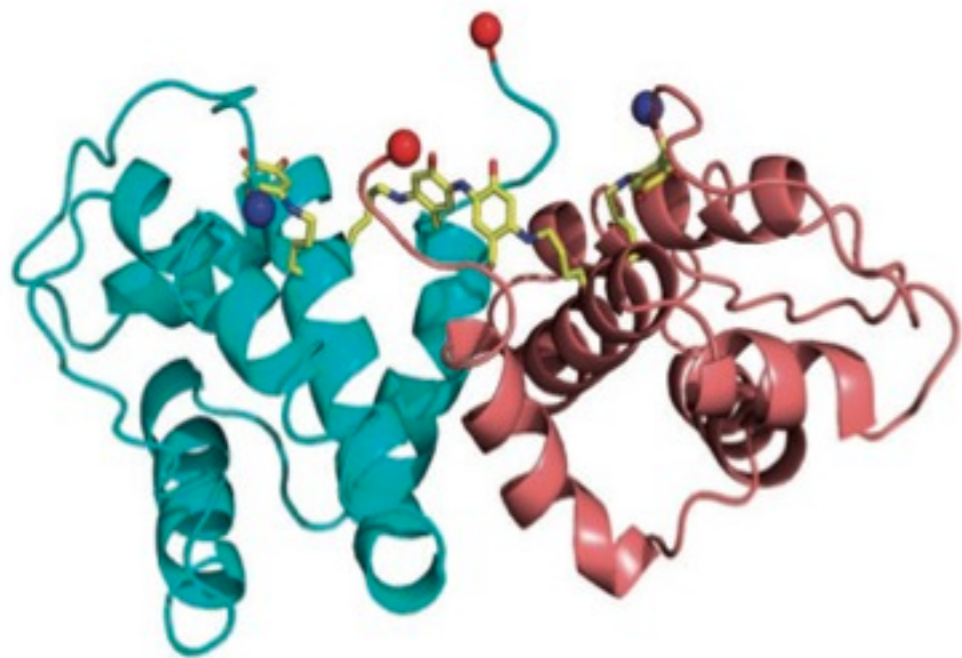
RANASMURFIN



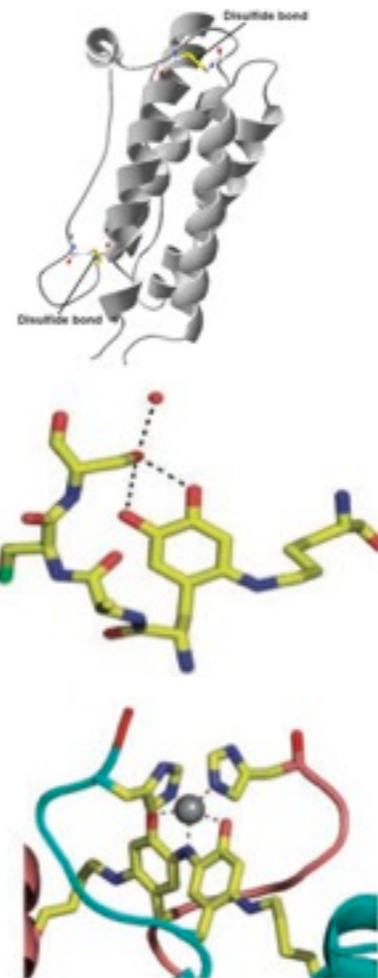
Oke, et al. 2008.



RANASMURFIN



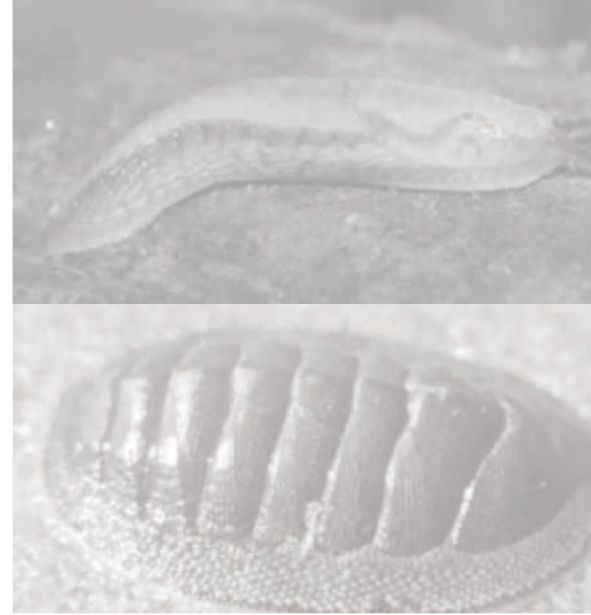
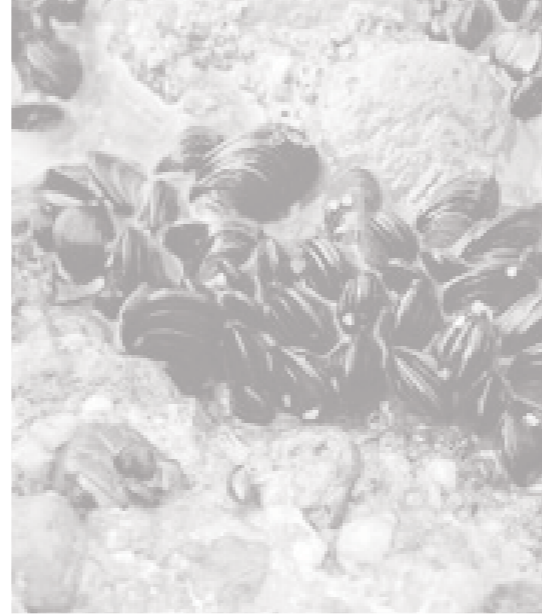
Oke, et al. 2008.



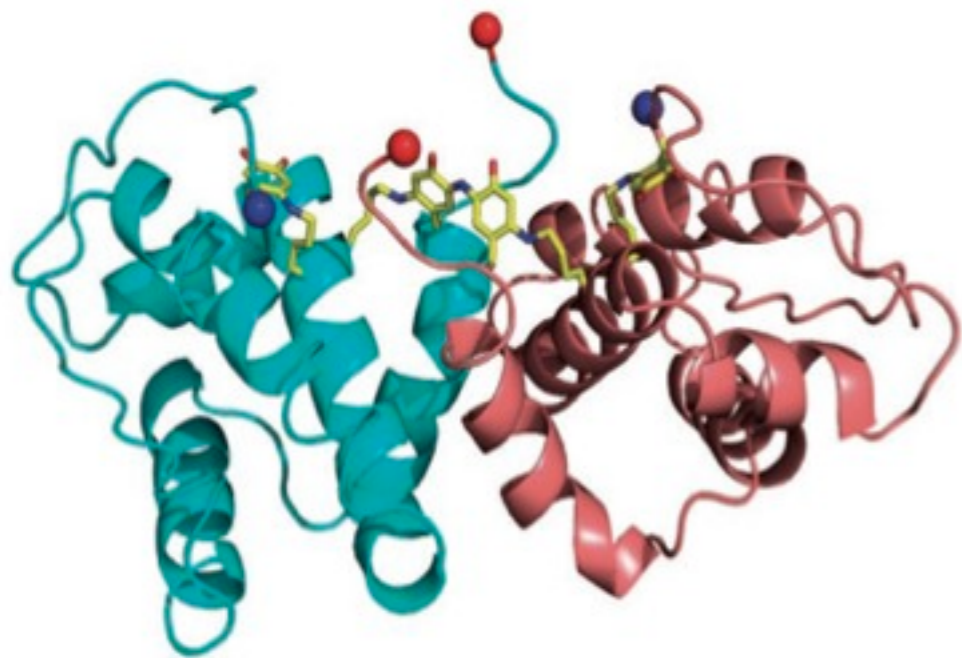
COVALENT INTERACTIONS
DISULFIDE BONDS

NON-COVALENT INTERACTIONS
HYDROGEN BONDS

ANCILLARY METALS
COORDINATION COMPLEXES

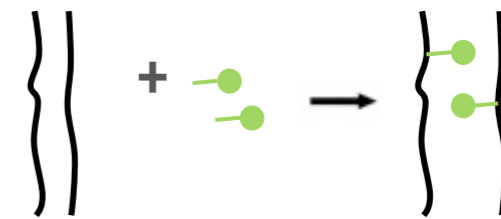


RANASMURFIN



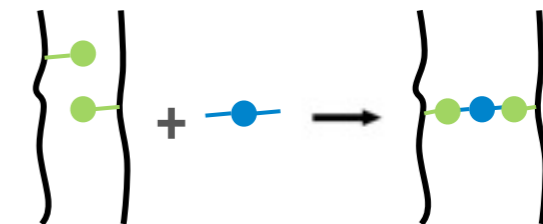
Oke, et al. 2008.

[1] BIND TO CELLULOSE

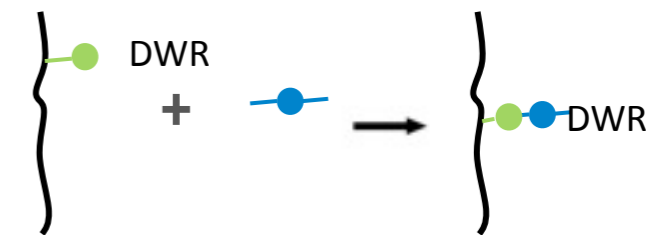


[2] PERFORM CROSSLINK

WRINKLE RESISTANCE

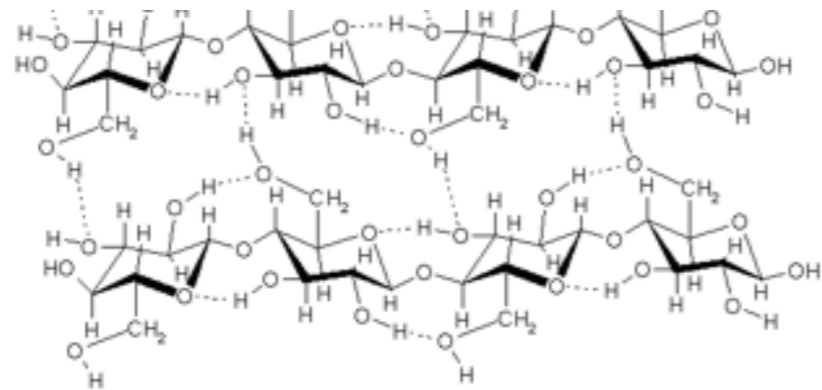


WATER REPELLENCY

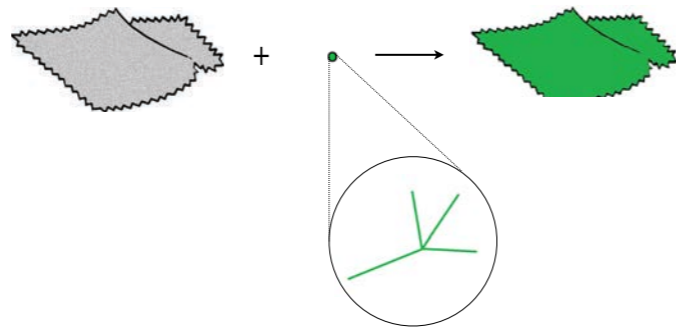


TWO-PART SOLUTION

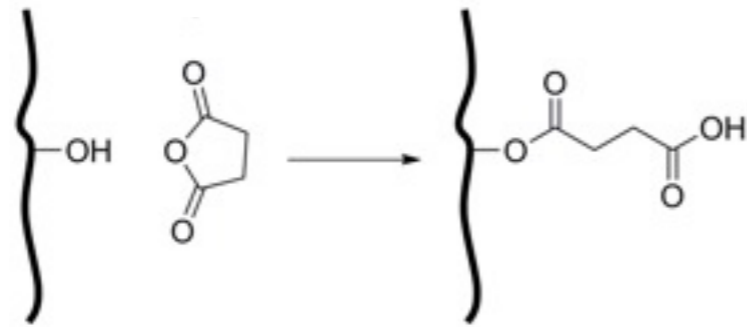
STRUCTURAL
[new weave]



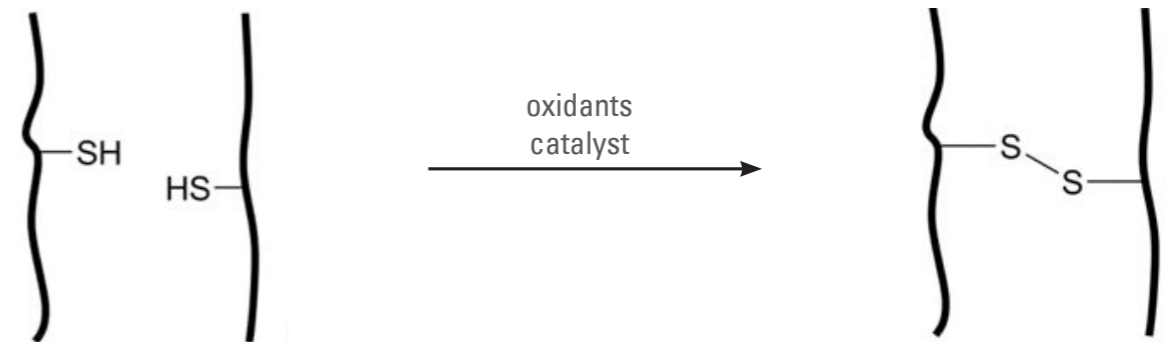
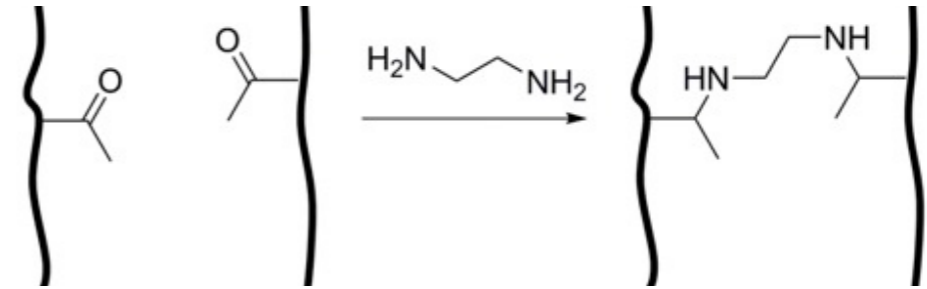
NON-COVALENT
[new coating]



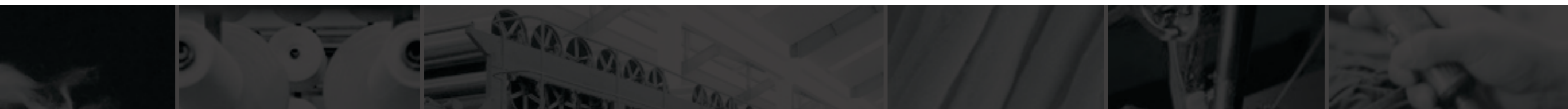
COVALENT



New Chemical Space for Crosslinking



EVALUATION FRAMEWORKS



POTENTIAL SOLUTIONS

REJECTED SOLUTIONS

	PMO ENZYME	POLY-DOPAMINE	SILANE & ALDEHYDES	PEG CATECHOL	CELLULOSE BINDING MOLECULE
CROSSLINKING ABILITY	WITH CELLULOSE	Green	Yellow	Yellow	Red
	WITH ITSELF (DURABLE PRESS)	Yellow	Green	Yellow	Red
	WITH DWR COMPOUNDS	Green	Green	Green	Red
DURABILITY	WASH STABILITY	Green	Green	Yellow	Red
	FABRIC STRENGTH	Green	Green	Green	Grey
	STABILITY: FOOD, SUN, LIQUIDS	Green	Green	Yellow	Red
APPLICATION, COST, CONSUMER	CONTROLLABLY CURED	Yellow	Green	Green	Red
	TIME OF CURING	Red	Red	Green	Grey
	CHEMICAL STABILITY	Yellow	Grey	Grey	Green
	AVAILABILITY OF RAW MATERIALS	Red	Grey	Grey	Grey
	COST OF RAW MATERIALS	Yellow	Red	Yellow	Red
	COLOR CHANGE OF FABRIC	Green	Red	Grey	Grey

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										

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										

STRATEGY
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										

**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										

**STRATEGY
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										

SYSTEMS HAZARD COMPARISON

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										

STRATEGY 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										

SYSTEMS HAZARD COMPARISON

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										
Red	Grey	Grey	Red	Grey	Green	Grey	Grey	Grey	Grey	Green	Blue	Green	Grey	Orange	Blue	Orange	Orange	Green	Green

	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	Grey	Grey	Red	Grey	Green	Grey	Grey	Grey	Grey	Green	Blue	Green	Grey	Orange	Blue/White	Orange	Orange	Green	Green
CATALYST	Grey	Grey	Grey	Red	Grey	Green	Orange	Orange	Grey	Orange	Blue	Blue	Green	Grey	Grey	Grey	Green	Grey	Orange	Green
OXIDANT	Grey	Orange/White	Orange	Grey	Orange/White	Green	Orange	Blue	Grey	Grey	Orange	Red	Orange	Orange	Orange	Orange/White	Red	Blue/White	Green	Orange
OXIDANT	Grey	Grey	Grey	Grey	Grey	Green	Orange	Grey	Blue	Grey	Green	Green	Green	Grey	Grey	Grey	Green	Green	Orange	Green
SOLVENT	Grey	Grey	Grey	Grey	Grey	Grey	Grey	Orange/White	Grey	Grey	Grey	Grey	Grey	Grey	Grey	Grey	Blue	Blue	Grey	Grey
SOLVENT	Orange/White	Grey	Grey	Red	Grey	Green	Blue	Blue	Grey	Orange	Blue	Blue	Red	Red	Grey	Grey	Green	Green	Orange	Green

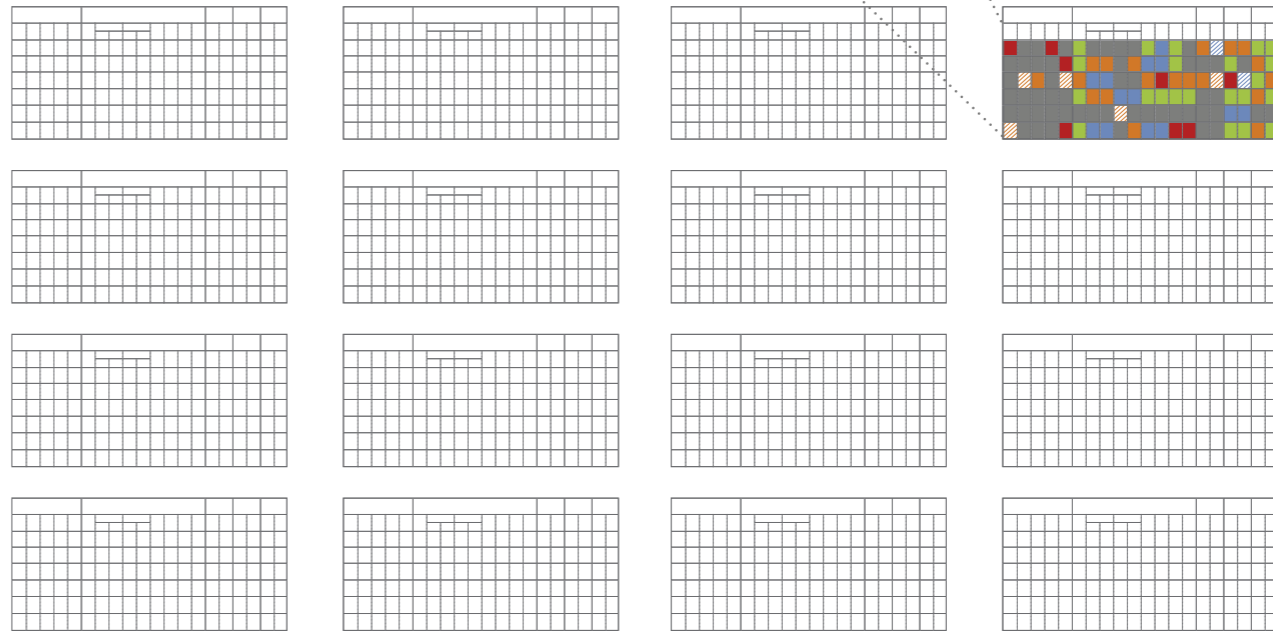
SYSTEMS HAZARD COMPARISON

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										
Red	Grey	Grey	Red	Grey	Green	Grey	Grey	Grey	Grey	Green	Blue	Green	Grey	Orange	Blue	Orange	Orange	Green	Green

	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	Grey	Grey	Red	Grey	Green	Grey	Grey	Grey	Grey	Green	Blue	Green	Grey	Orange	Blue/White	Orange	Orange	Green	Green
CATALYST	Grey	Grey	Grey	Red	Grey	Green	Orange	Orange	Grey	Orange	Blue	Blue	Green	Grey	Grey	Grey	Green	Grey	Orange	Green
OXIDANT	Grey	Orange/White	Orange	Grey	Orange/White	Green	Orange	Blue	Grey	Grey	Orange	Red	Orange	Orange	Orange	Orange/White	Red	Blue/White	Green	Orange
OXIDANT	Grey	Grey	Grey	Grey	Grey	Green	Orange	Blue	Blue	Green	Green	Green	Green	Grey	Grey	Grey	Green	Green	Orange	Green
SOLVENT	Grey	Grey	Grey	Grey	Grey	Grey	Grey	Orange/White	Grey	Grey	Grey	Grey	Grey	Grey	Grey	Grey	Blue	Blue	Grey	Grey
SOLVENT	Orange/White	Grey	Grey	Red	Grey	Green	Blue	Blue	Grey	Orange	Blue	Blue	Red	Red	Grey	Grey	Green	Green	Orange	Green

SYSTEMS HAZARD COMPARISON

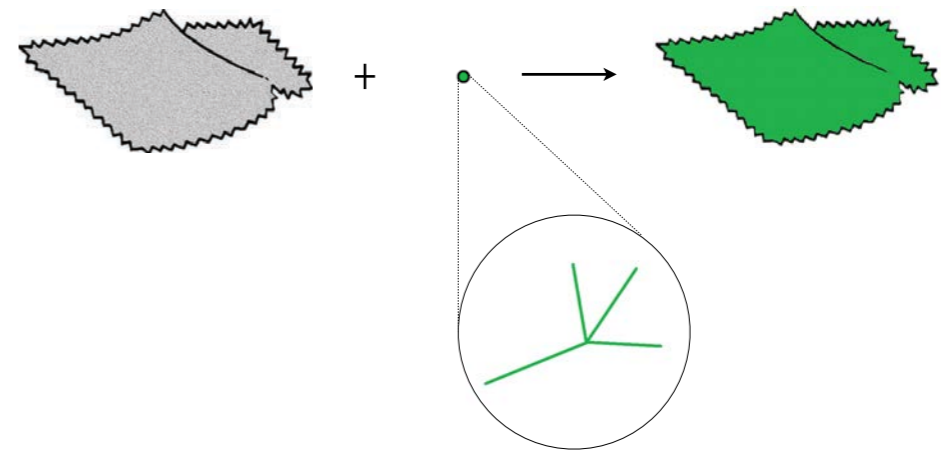
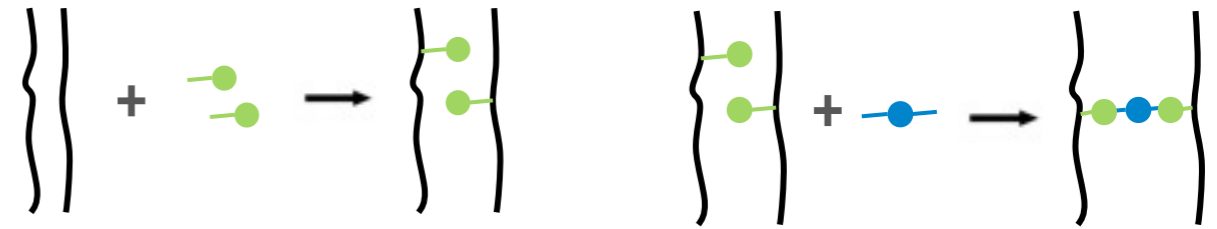


RECOMMENDATIONS FOR PARTNERS

Biomimetic crosslinking is a two-part challenge

Harnessing non-covalent and structural interactions opens up new chemical space

Technical and health frameworks developed specifically for this application can be used to evaluate future solutions



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										
Red	Grey	Grey	Red	Grey	Green	Orange	Grey	Orange	Blue	Green	Grey	Grey	Orange	Blue/White	Orange	Green	Orange	Green	Orange
Grey	Orange/White	Grey	Orange/White	Grey	Blue	Grey	Orange	Red	Orange	Orange	Orange/White	Red	Blue/White	Green	Orange	Green	Orange	Green	Orange
Grey	Grey	Grey	Grey	Grey	Green	Orange	Blue	Green	Green	Grey	Grey	Grey	Grey	Grey	Grey	Blue	Grey	Grey	Grey
Orange/White	Grey	Grey	Red	Green	Blue	Grey	Orange/White	Grey	Blue	Red	Red	Grey	Grey	Green	Green	Orange	Green	Orange	Green

WHAT WE LEARNED

What constitutes a good research question?

Different for academia versus corporate world (LS&Co.)

Academics publish in peer-reviewed journals, companies protect proprietary information

Negotiating potential conflicts of interest between public and private research

Use of different tools/skill sets that may not be used in a purely academic project

Clear expectations from client

Consistent communication between all stakeholders

THANK YOU!

Meg Schwarzman and Marty Mulvihill

Amanda Cattermole, LS&Co.

Mark Dorfman and Julie Sammons, Biomimicry Institute

Claudia Polsky, California Department of Justice

Berkeley Center for Green Chemistry

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Sara Tischhauser, Katherine Tsen