Newsprint Research

- This is a summary of research conducted at the Smithsonian Center for Materials Research and Education (SCMRE) during the summer of 2003.
- This work was conducted by two interns, Evan Quasney and Kathy Hufford, under the supervision of David Erhardt and Charles Tumosa.
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Newsprint

permanence and degradation: newsprint over the last 100 years

new research presented by:

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massachussetts institute of technology

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university of michigan

13 August 2003
10:00 am
scmre theater

Smithsonian Center
for Materials Research and Education

Permanence and Degradation: Newsprint Over the Last 100 Years

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University of Michigan

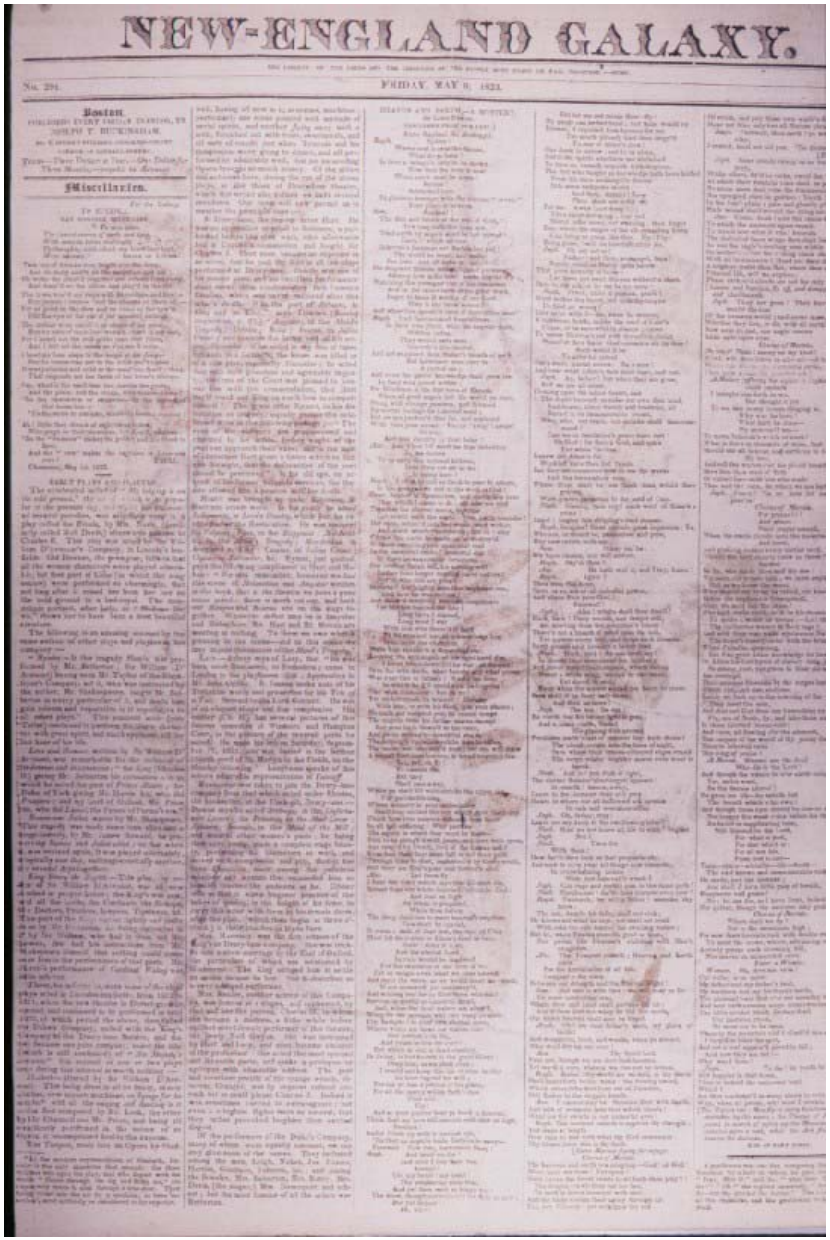
Charles Tumosa, Ph.D.
W. David Erhardt, Ph. D.

Introduction

- Printed material on paper dominates written communication
- Paper records have finite life … how finite?
- Mechanical concepts addressed and discussed
- Chemical concepts linked to mechanical properties
- Scope of research newsprint-specific

Wood-based Newspapers Tested

06/01/2003	Washington Post
11/17/2001	Washington Post
11/27/2000	Washington Post
08/03/1999	Washington Post
12/02/1998	Washington Post
11/02/1997	Washington Post
07/10/1997	Washington Post
01/26/1997	Washington Post
05/07/1995	Washington Post
11/14/1993	Washington Post
02/08/1983	Washington Post
10/20/1983	Washington Post
07/07/1985	Washington Post
09/11/1985	Washington Post
12/14/1988	Washington Post
12/15/1988	Washington Post
10/25/1999	Washington Post
07/01/1975	Vineland Times Journal
12/11/1960	New York Times
09/13/1950	Christian Science Monitor
12/02/1934	Topeka Daily Capital
04/11/1915	Detroit Free Press
10/07/1905	Detroit Free Press
01/03/1890	The World
05/07/1875	New York Semi-Weekly Times


NEW-ENGLAND GALAXY.

Definitions

Strain = Δ length / length

- extensibility of paper
- change in length

$$\varepsilon = \Delta L / L$$

Stress = Force / Area

- 'strength' of the paper
- randomized based on sizing or technology

$$\sigma = F / A$$

Stress-Strain Curve

- Graph of stress versus strain
- Basis for finding plastic and elastic regions

Tensile (Young's) Modulus

- Numeric value of the flexibility / stiffness of the paper

$$E = \sigma / \varepsilon$$

Definitions

Isotropic:

- Specimen behaves the same in all directions

Orthotropic:

- Specimen behaves differently in mutually perpendicular directions

Breaking Strain:

- Percent elongation at which a specimen fails

Breaking Stress:

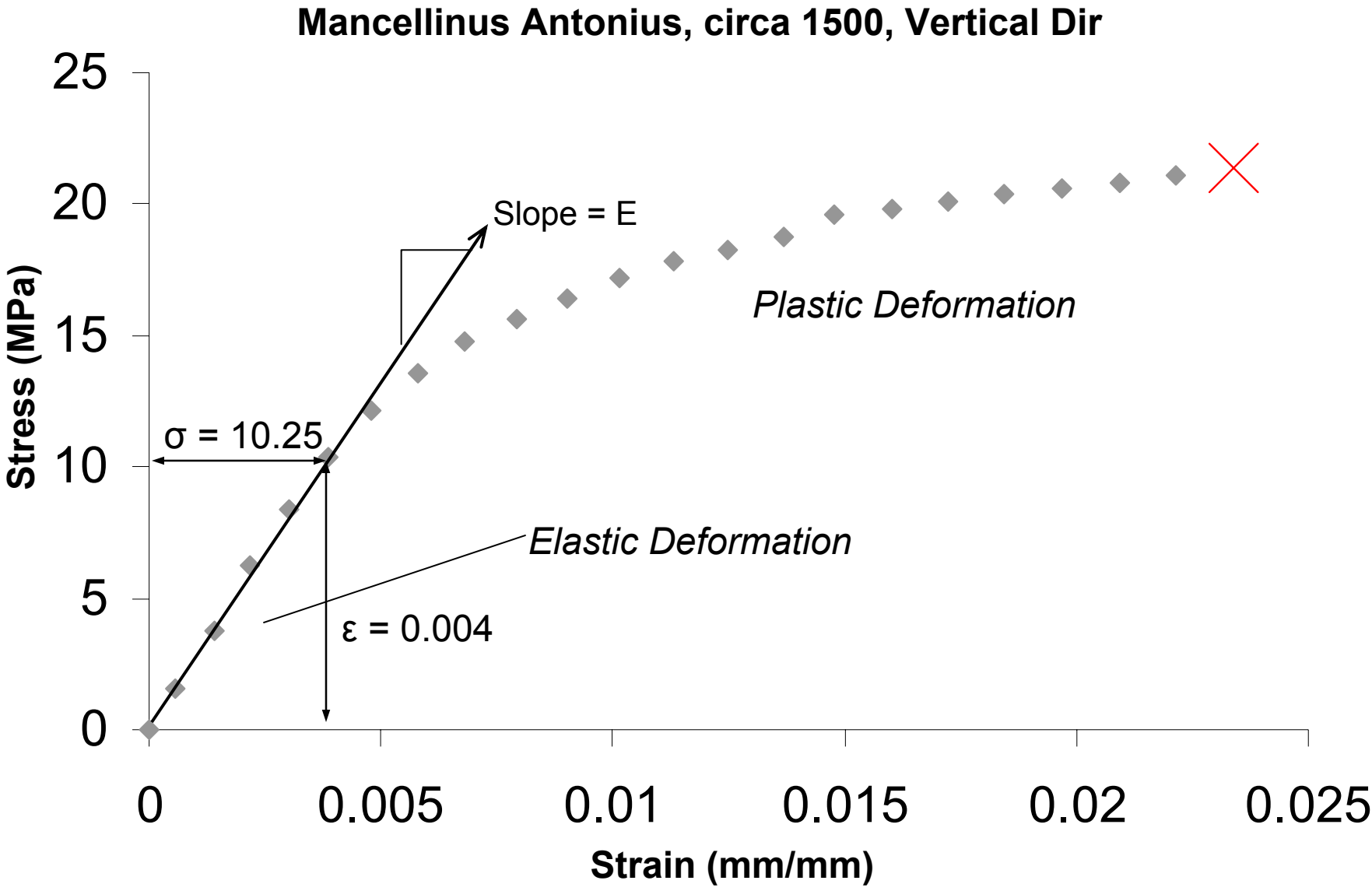
- Pressure at the breaking strain; tensile strength of specimen

Region Deformation:

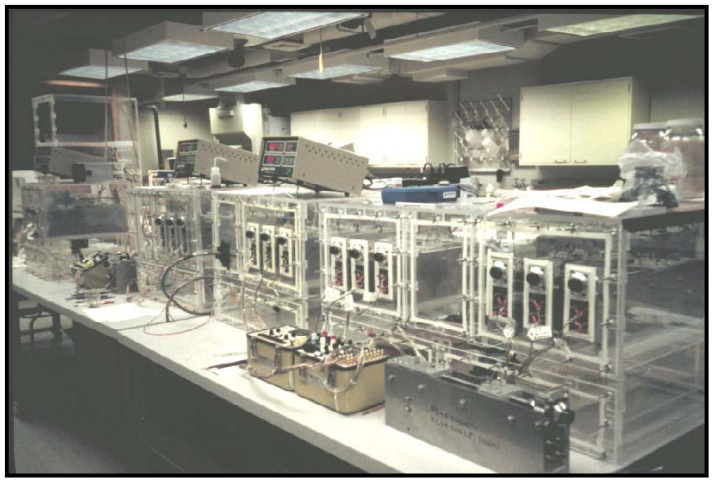
Elastic – Flexible Modulation of Specimen

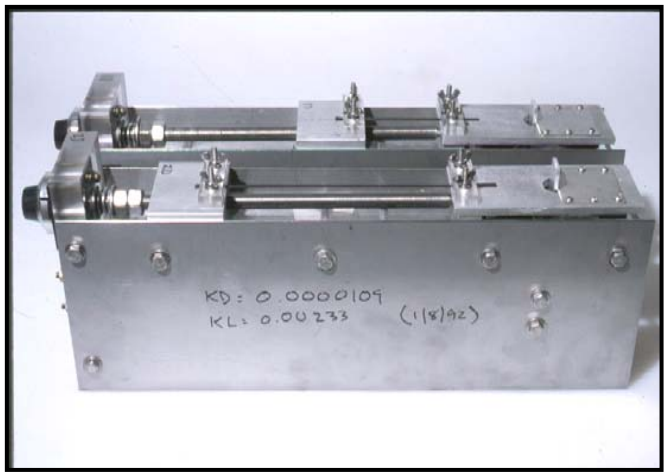
Plastic – Permanent Irreparable Damage to Specimen

General Stress-Strain Curve



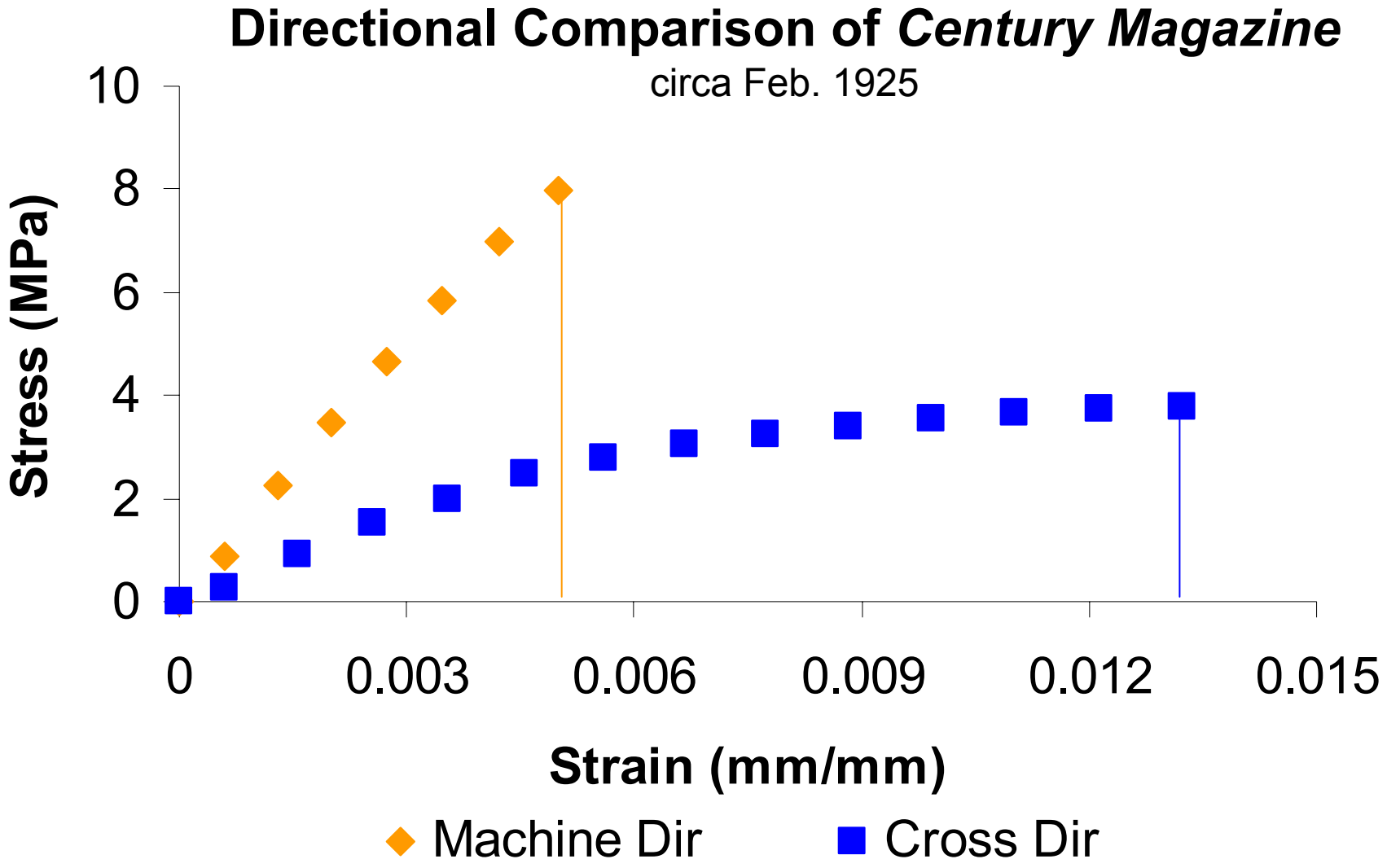
Method



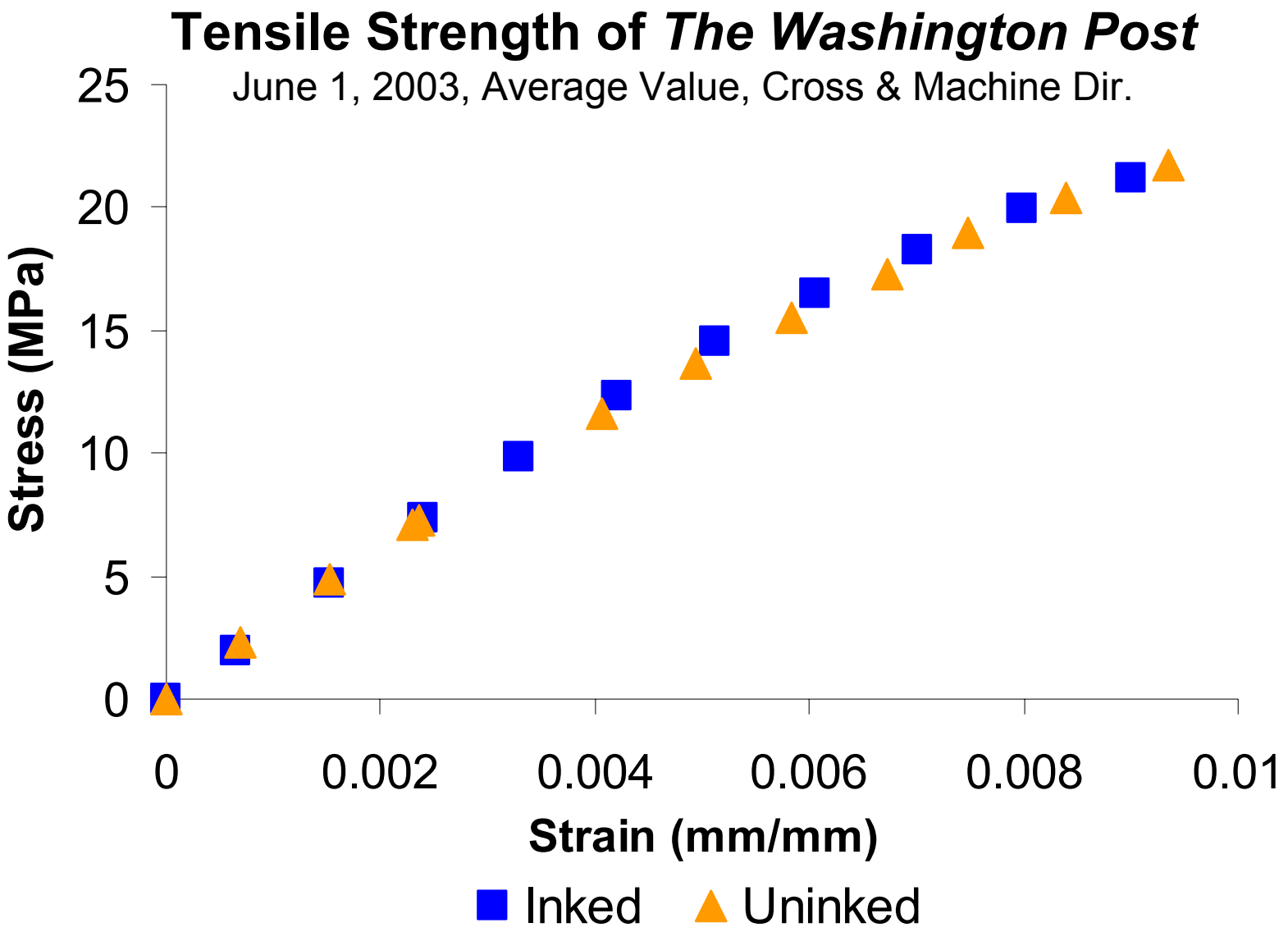


- Tests performed on screw-driven tensile tester in environmental chambers
- Incremental length change standard: 30-seconds, 1/200 (0.005) inches
- Tests performed between 42 – 52% RH and 22.5 – 24.2 deg. C
- 4 distinctly different sub-variations of each specimen examined

Machine v. Cross Direction



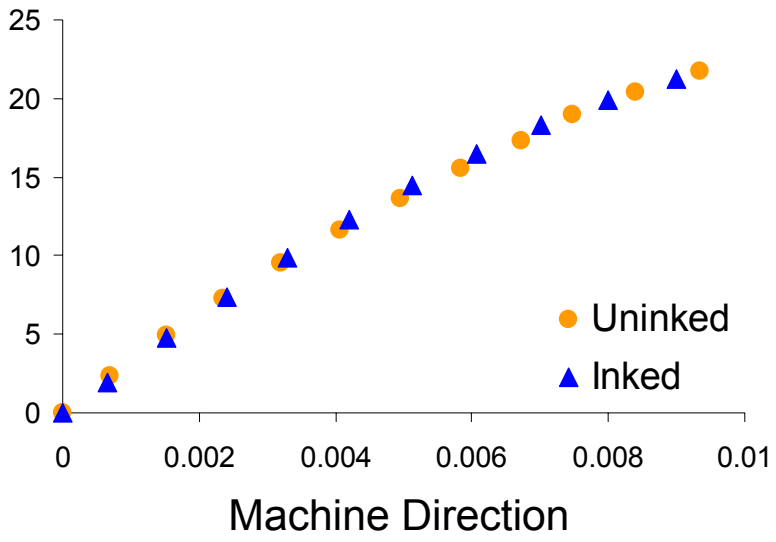
Initial Application

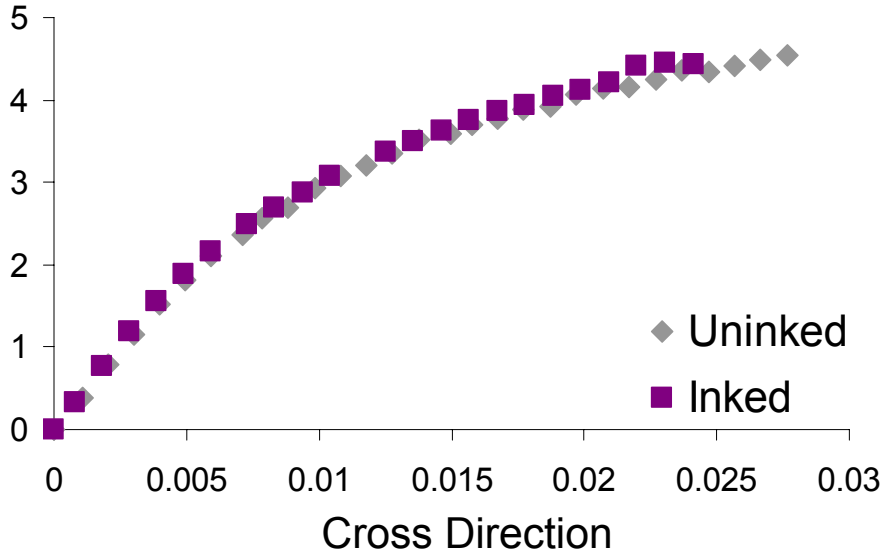


Initial Application

Individual Axial Comparison of Inked v. Uninked Paper

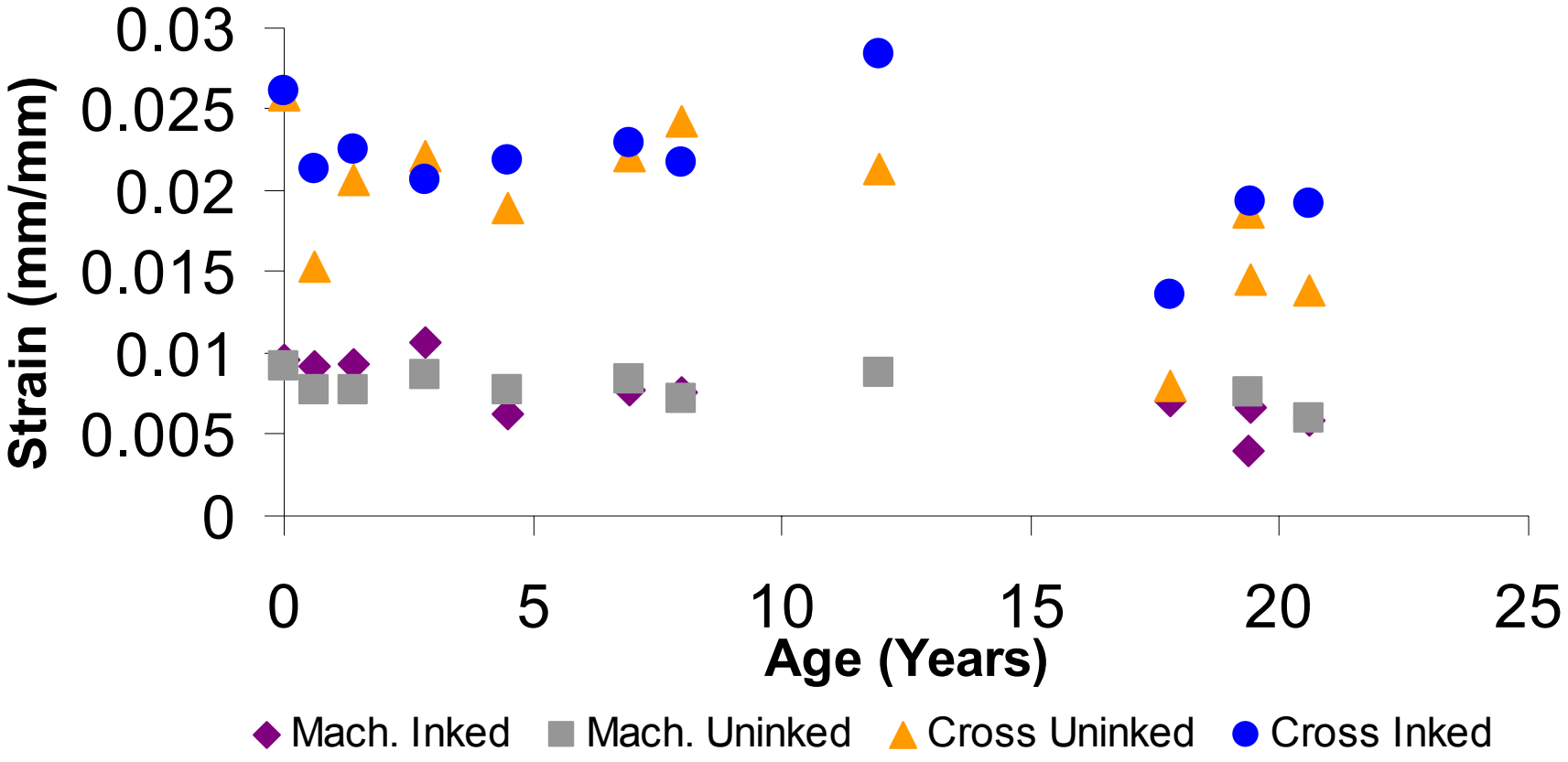
The Washington Post, June 1, 2003





- Orthotropic behavior present in specimens
- Very little difference between inked and uninked strains

20 Year Study in Lab Environment



- No great change, but a slight decreasing trend is exhibited
- Degradation small enough that overall damage is minimal
- Specimens could last 100-150 years

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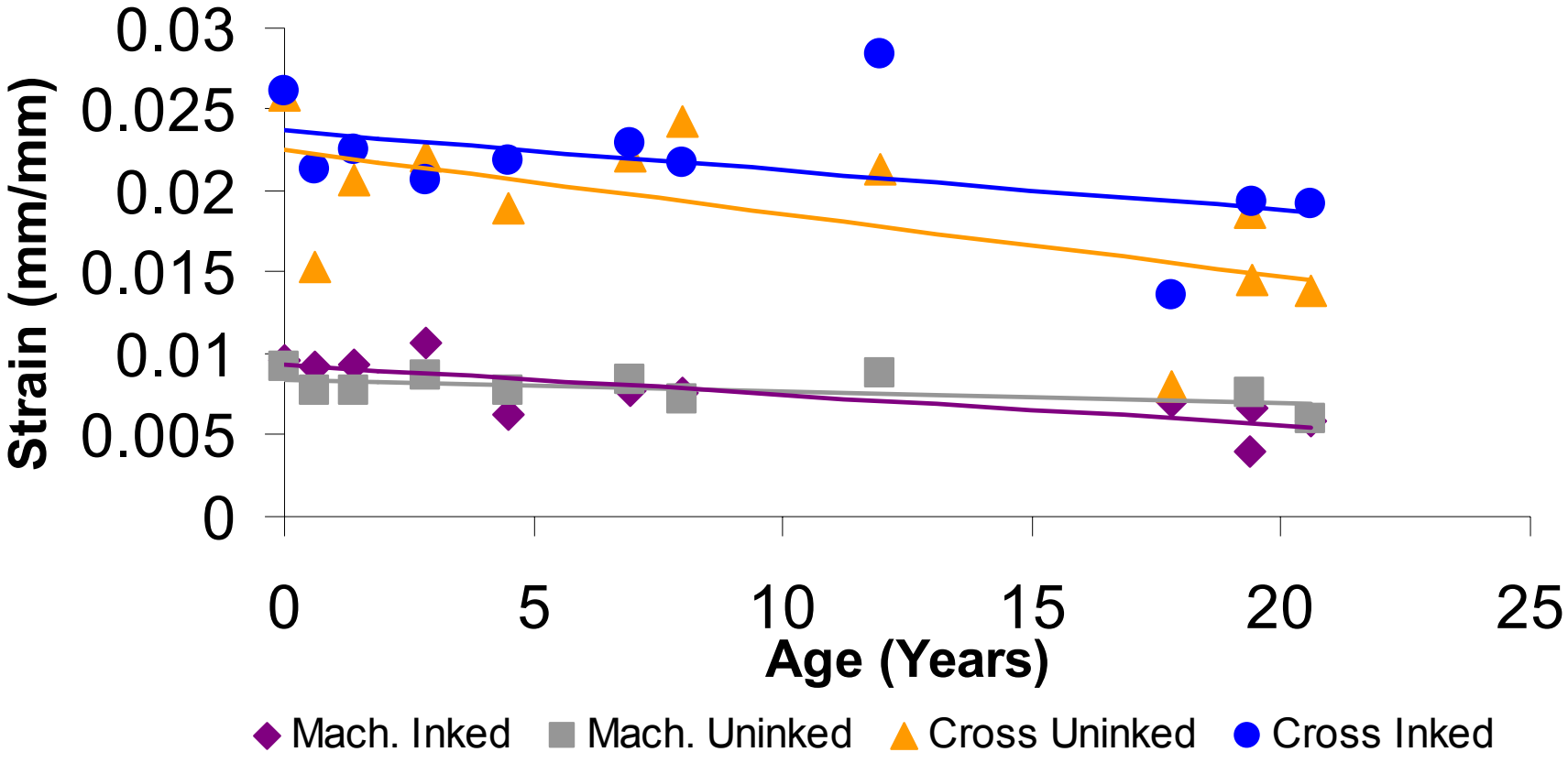

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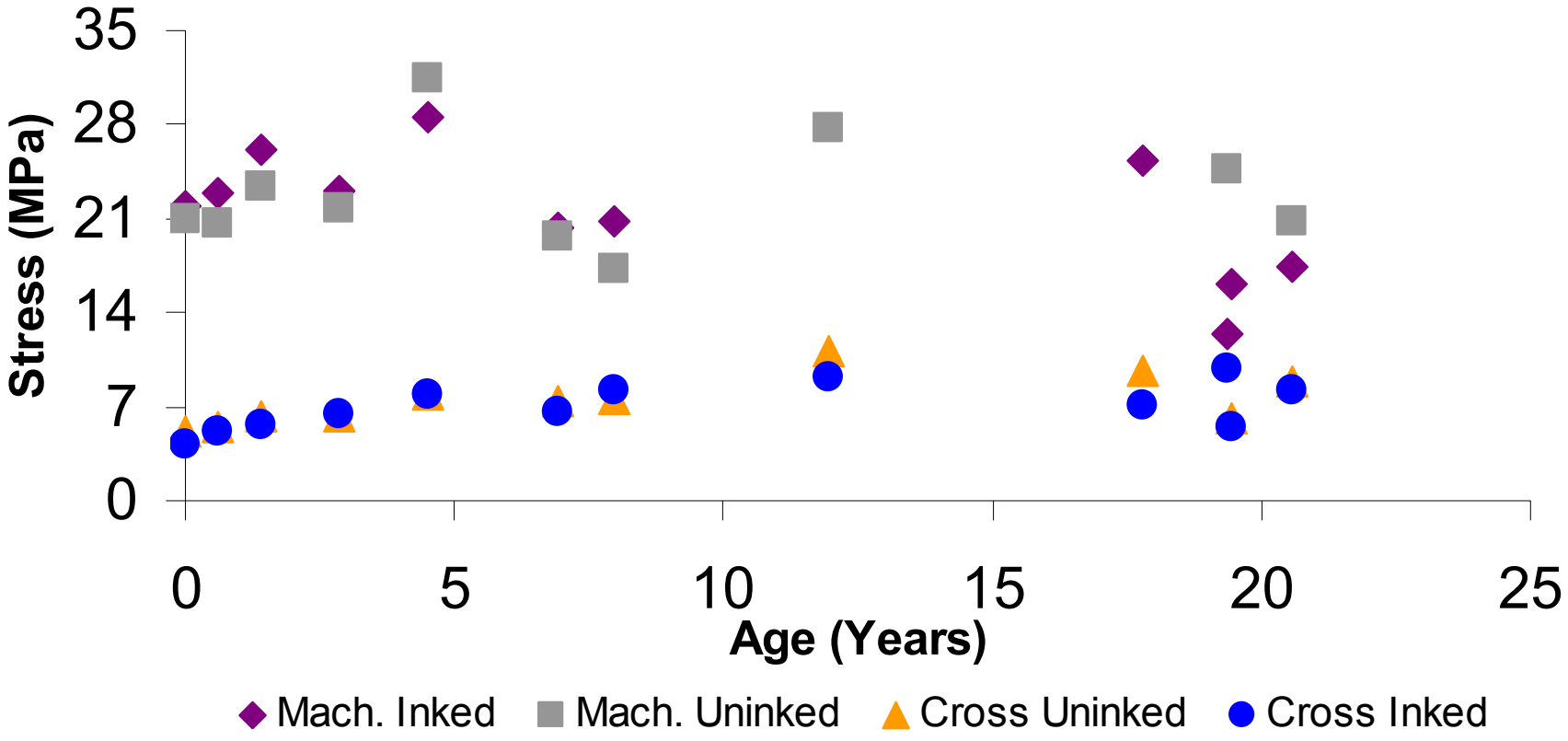
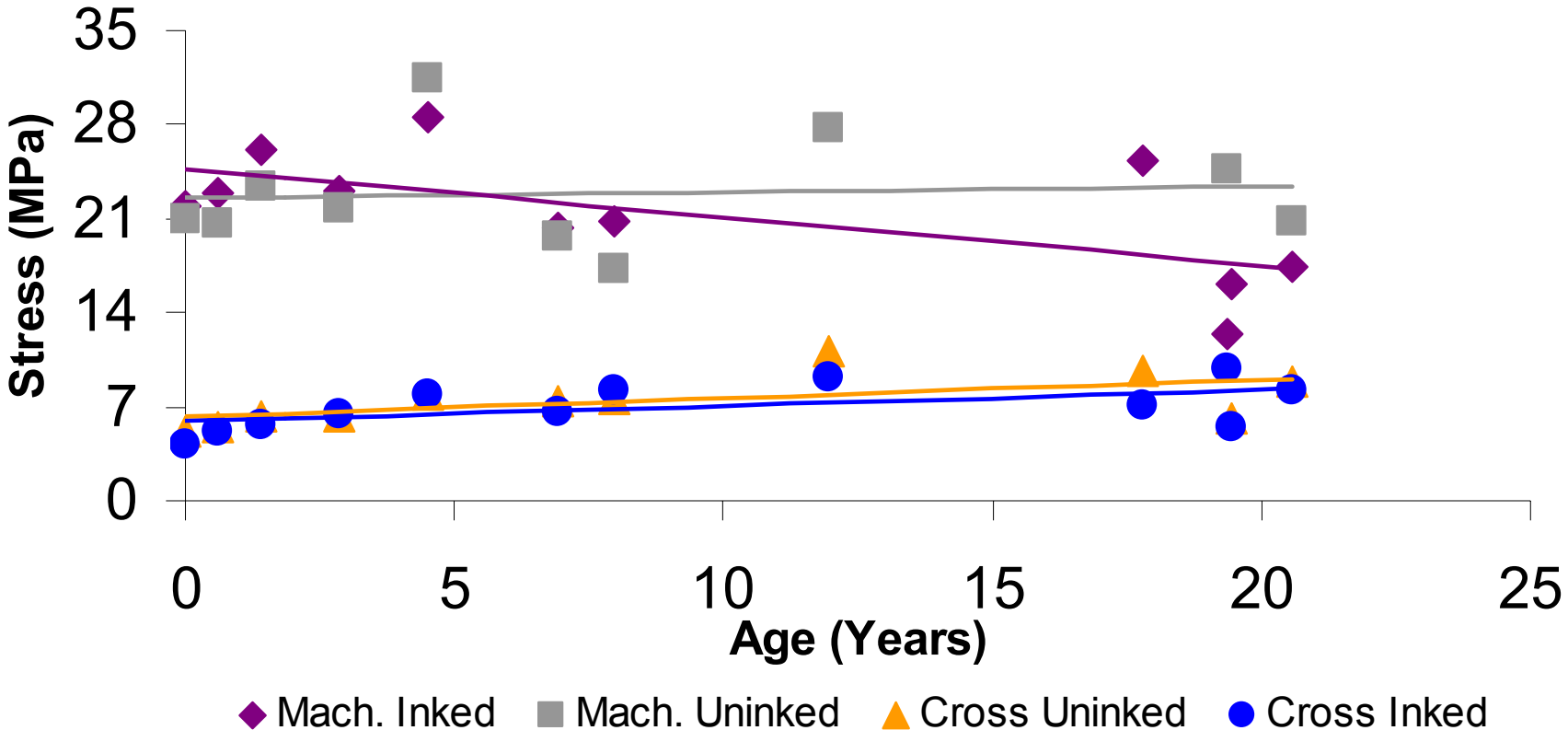


- No distinguishable change in strength of specimens
- Specimens will last a long time under Standard Laboratory Conditions

20 Year Study in Lab Environment



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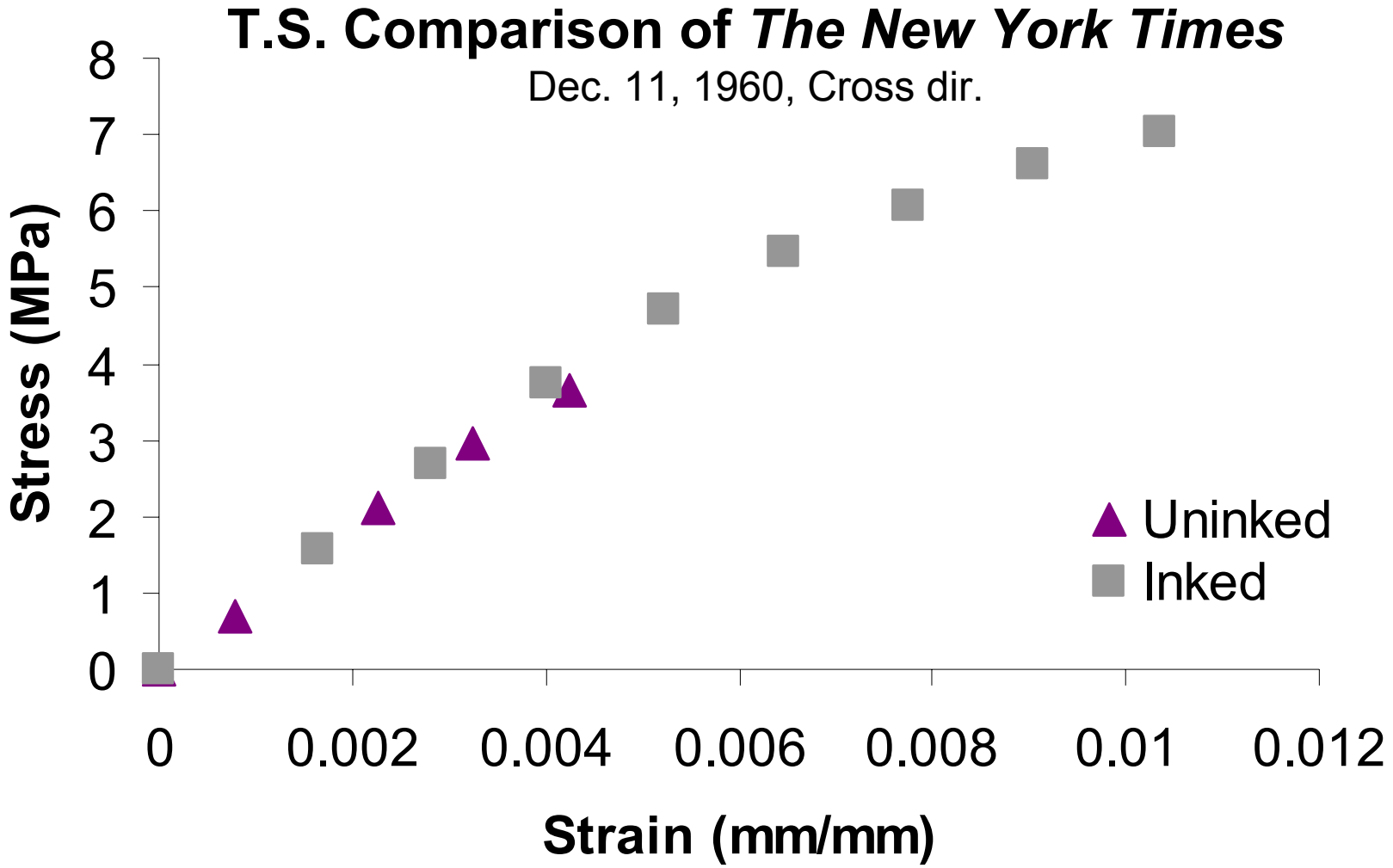
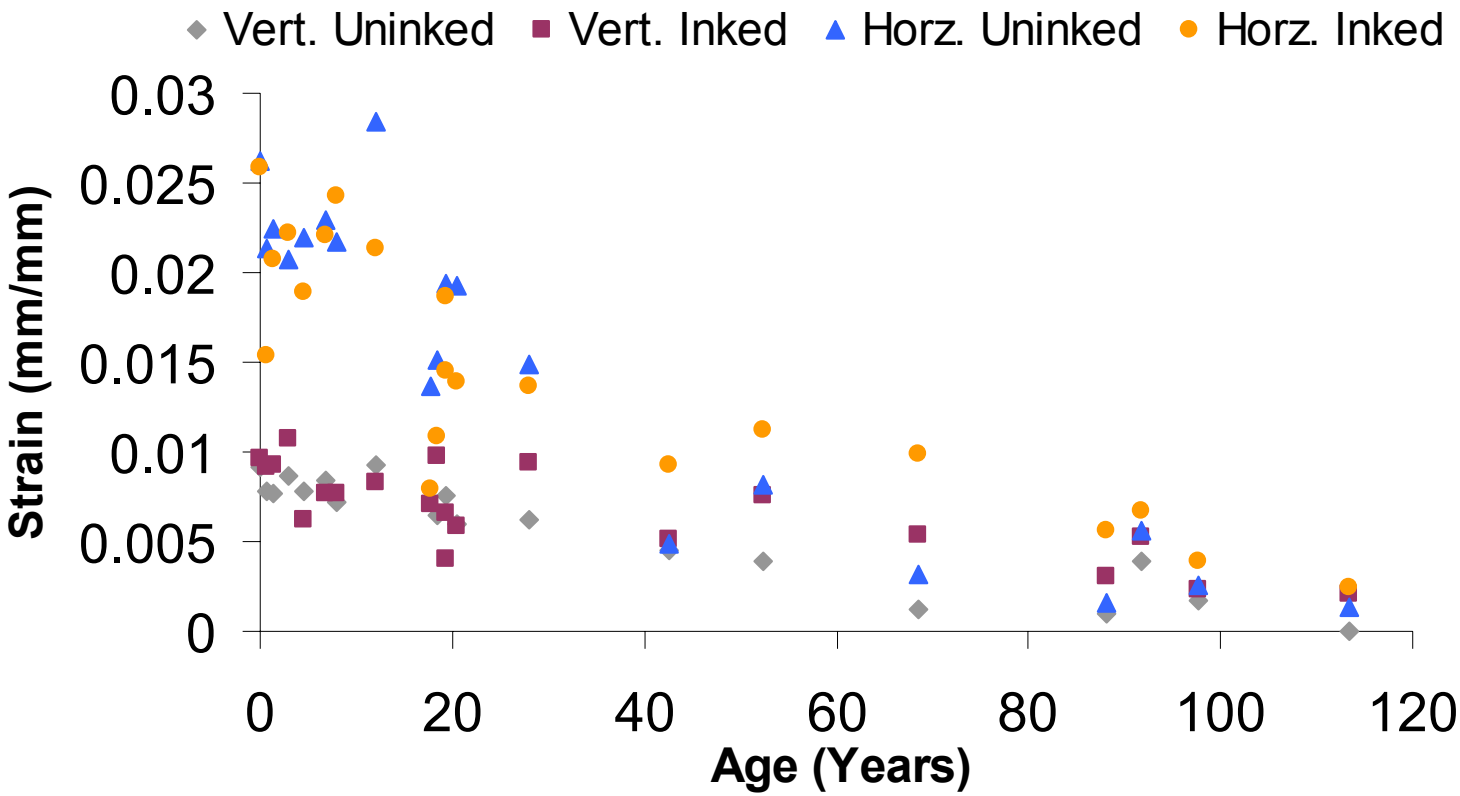
Inked v. Uninked Paper



120 Year Variable Test

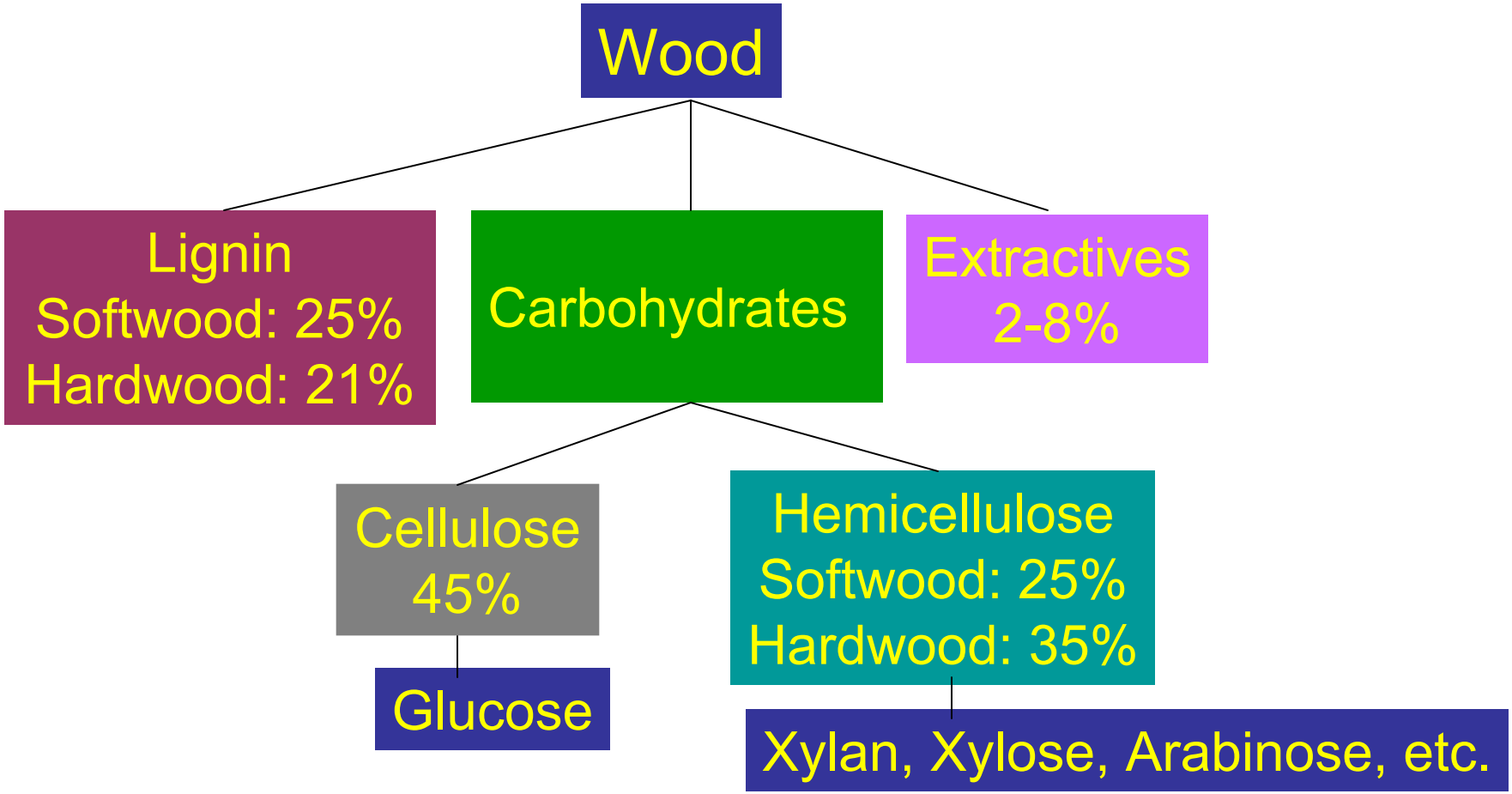


- Loss of elastic region occurs when breaking strains drops below 0.005
- Acute fragility not present until samples are 80 years old
- Total specimen disintegration only occurs after ALL breaking strains are less than 0.003

Scientific Significance

- Newsprint can last 100 years if given nominal attention
- Archival facilities can provide up to an additional 50 – 100 years of viable storage
- Flexibility and elasticity data will help build an accurate model to predict degradation

Chemical Composition of Wood



Cellulose:

Glucose — Glucose — Glucose — Glucose — Glucose —

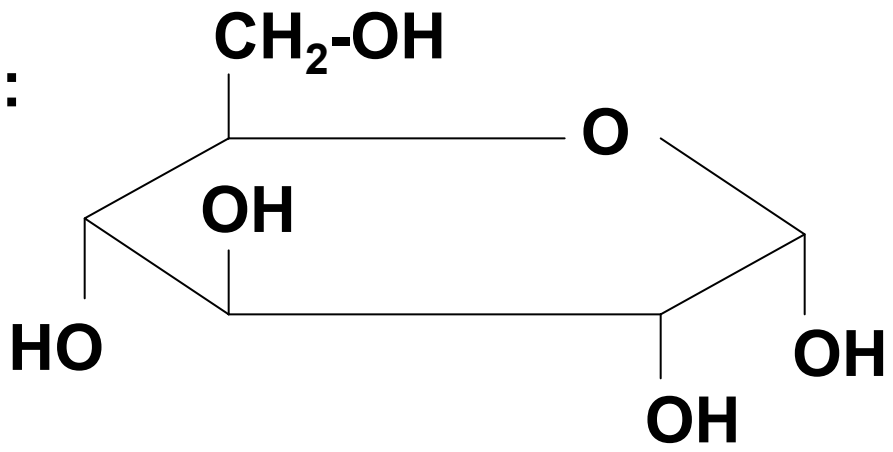
Glucose Trimer:

Glucose — Glucose — Glucose

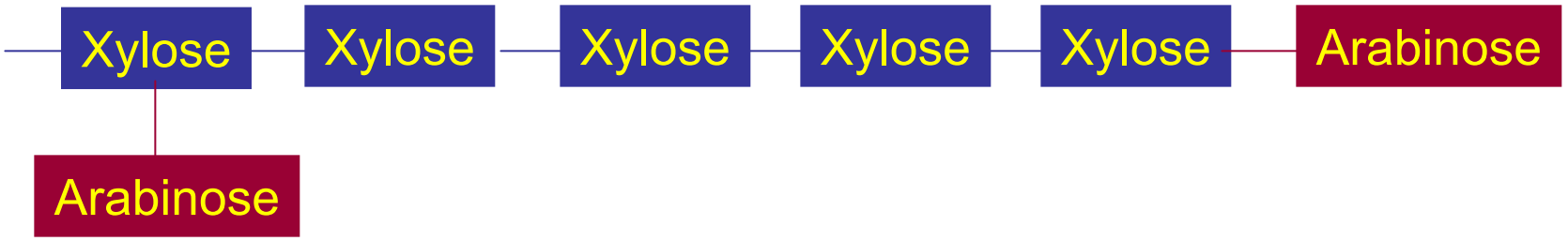
Glucose Dimer:

Glucose — Glucose

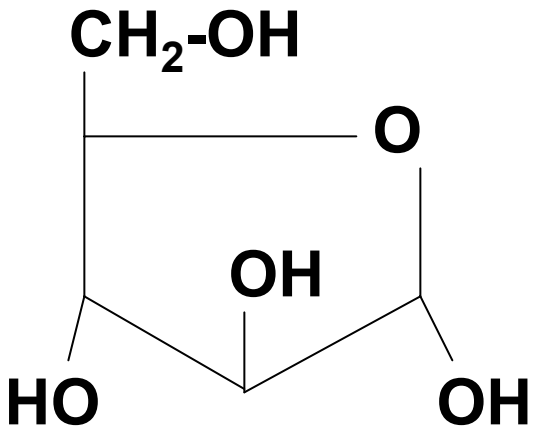
Glucose:



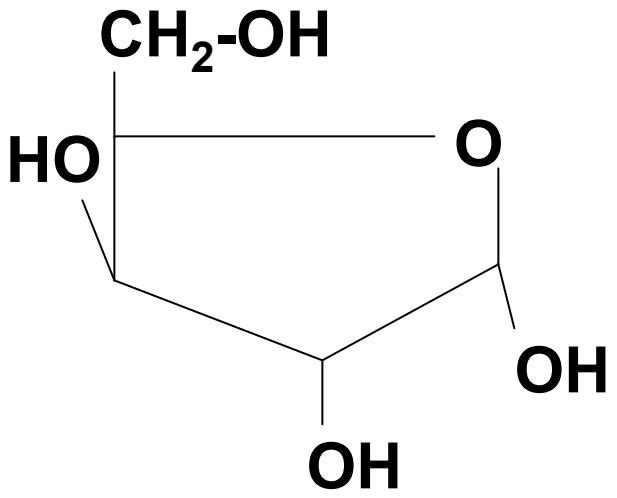
Xylan:



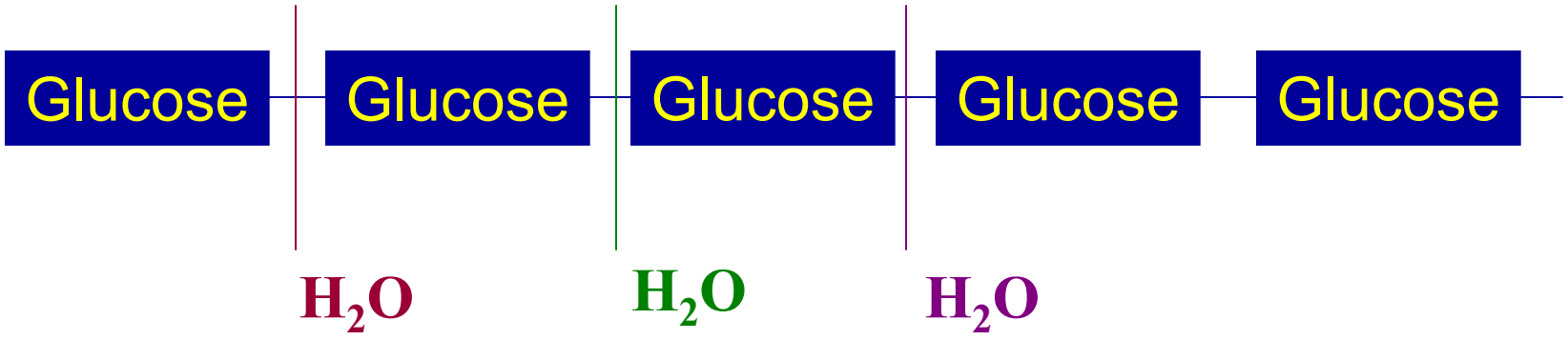
Xylose:

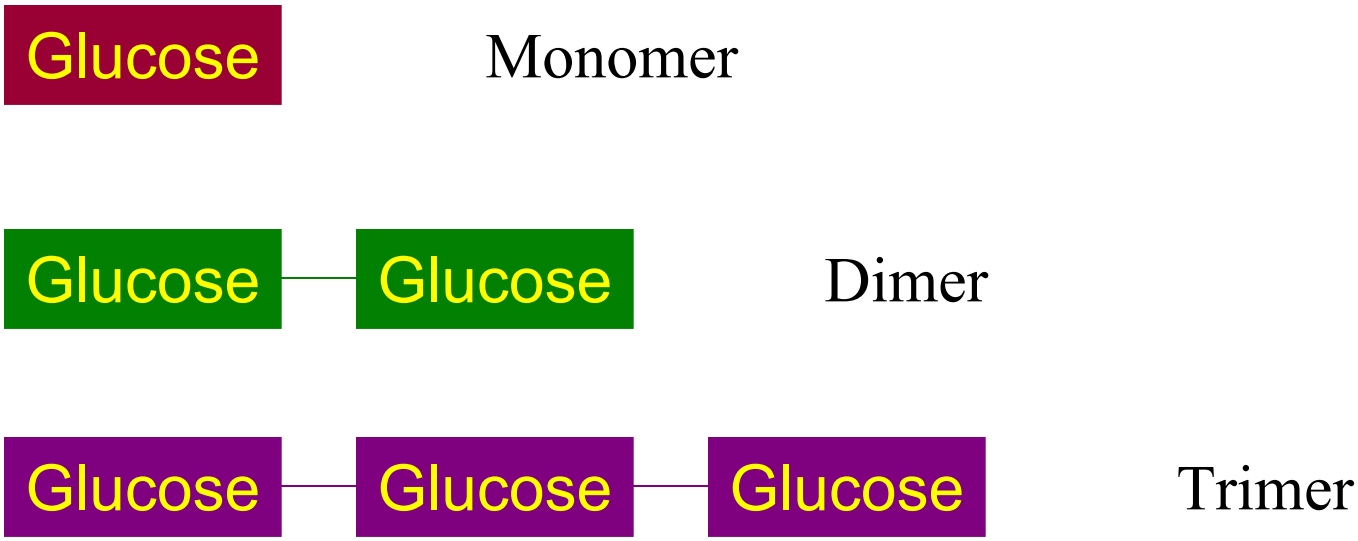


Arabinose:



Hydrolysis of Cellulose

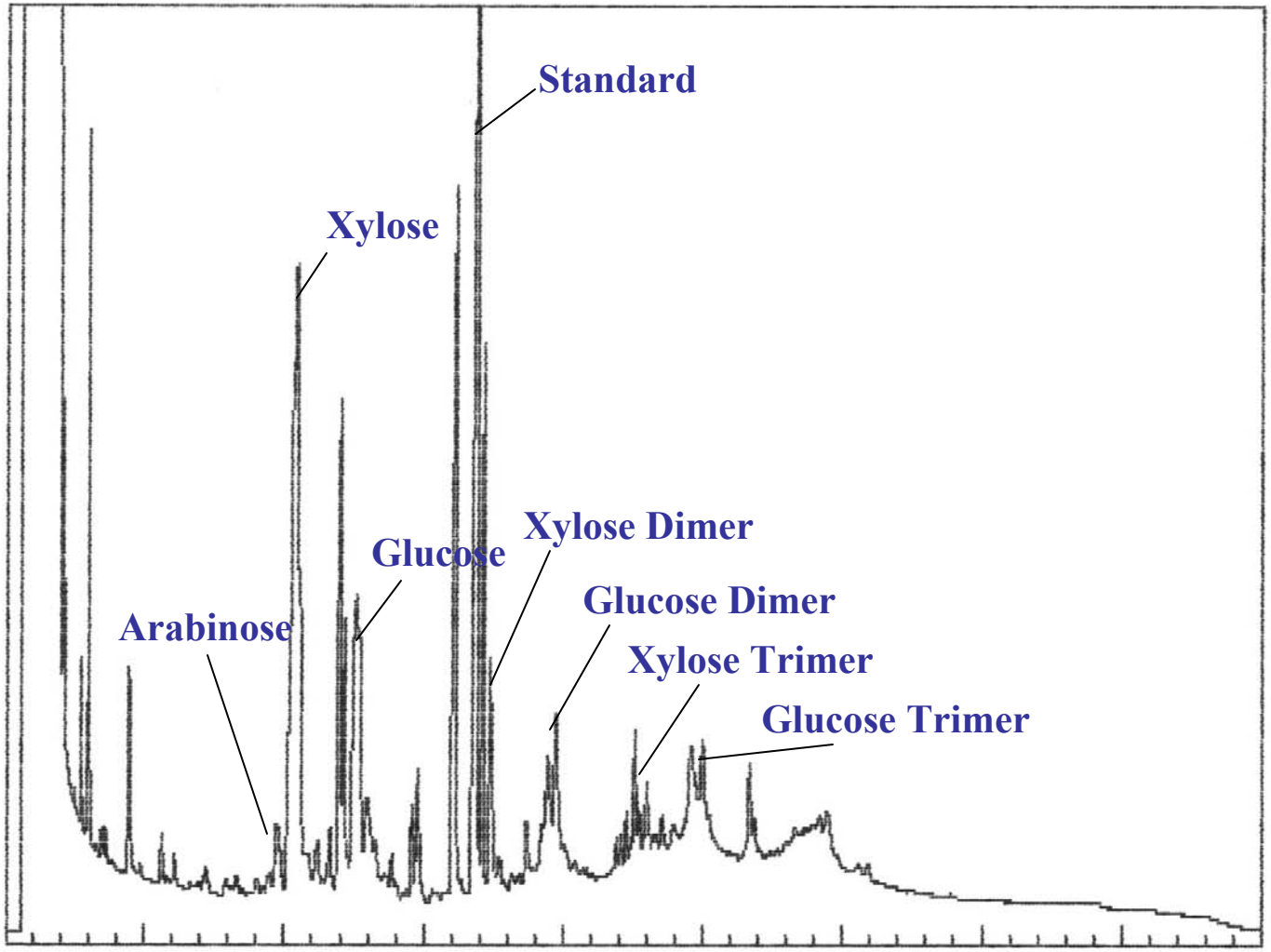




Method

- Samples prepared, extracted in water, filtered, and evaporated under vacuum
- Derivatized with STOX (commercial reagent containing internal standard), HMDS, and trifluoroacetic acid
- Supernatant analyzed by gas chromatography
- Sugars identified by comparison of retention times against internal standards

Plot of data file: C:detfree3.PTS
Date: 07-30-2003 Time: 09:48:30
Sample Name: DetroitFreePre1905
Start Time= 0.01Stop Time = 45.01Min. Scale= 0Max. Scale= 999999



Approximate Retention Times of Sugar Peaks

Standard: 16.70

Glucose: 12.57

Xylose: 10.43

Arabinose: 10.20

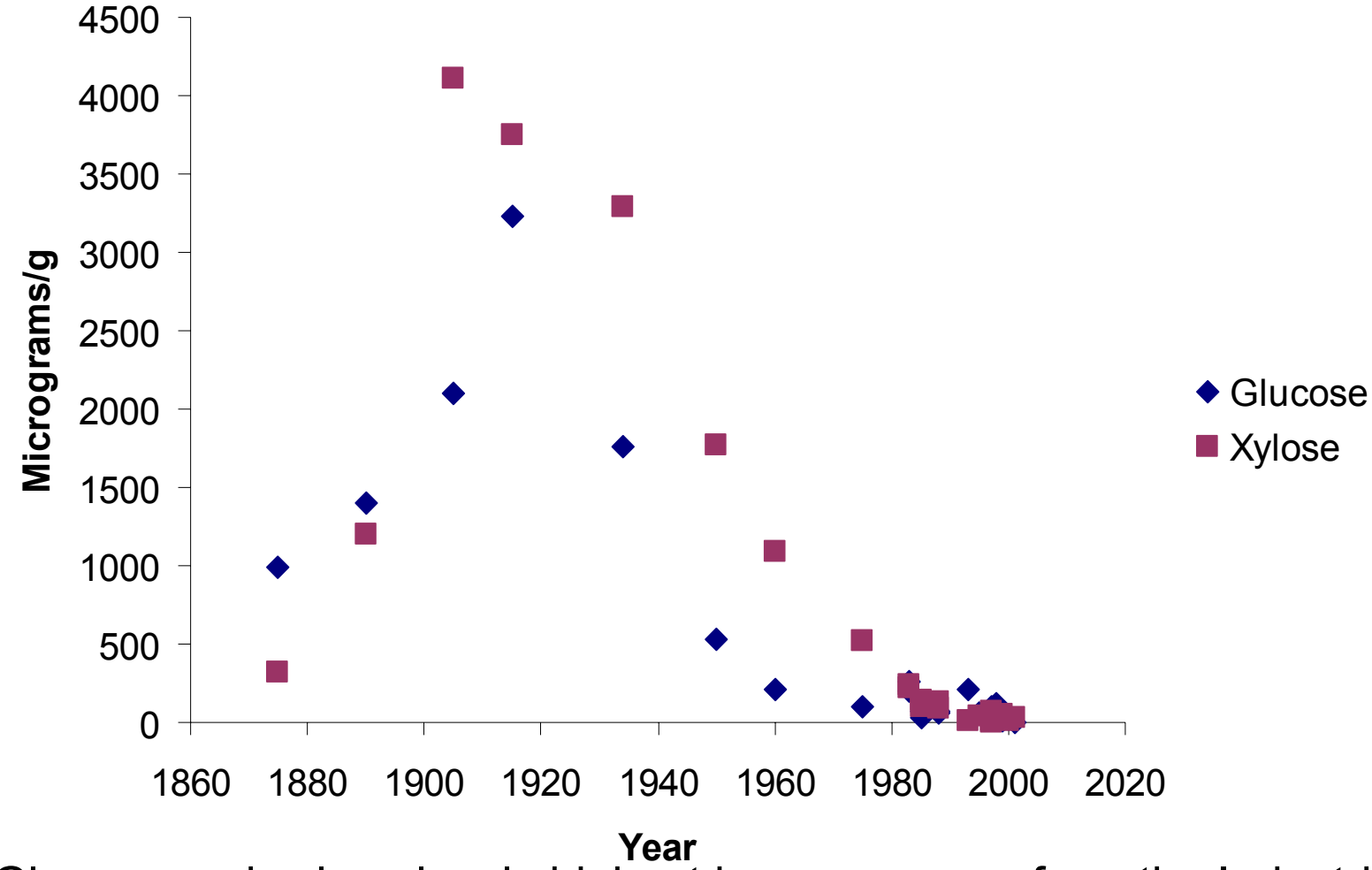
Glucose Dimer: 19.45

Glucose Trimer: 24.55

Xylose Dimer: 17.45

Xylose Trimer: 22.55

Sugar Content in Wood-based Newspapers



- Glucose and xylose levels highest in newspapers from the Industrial Revolution
- Of interest are the spikes around World War I and the relative stability of the past 20 years

History of Papermaking Technology

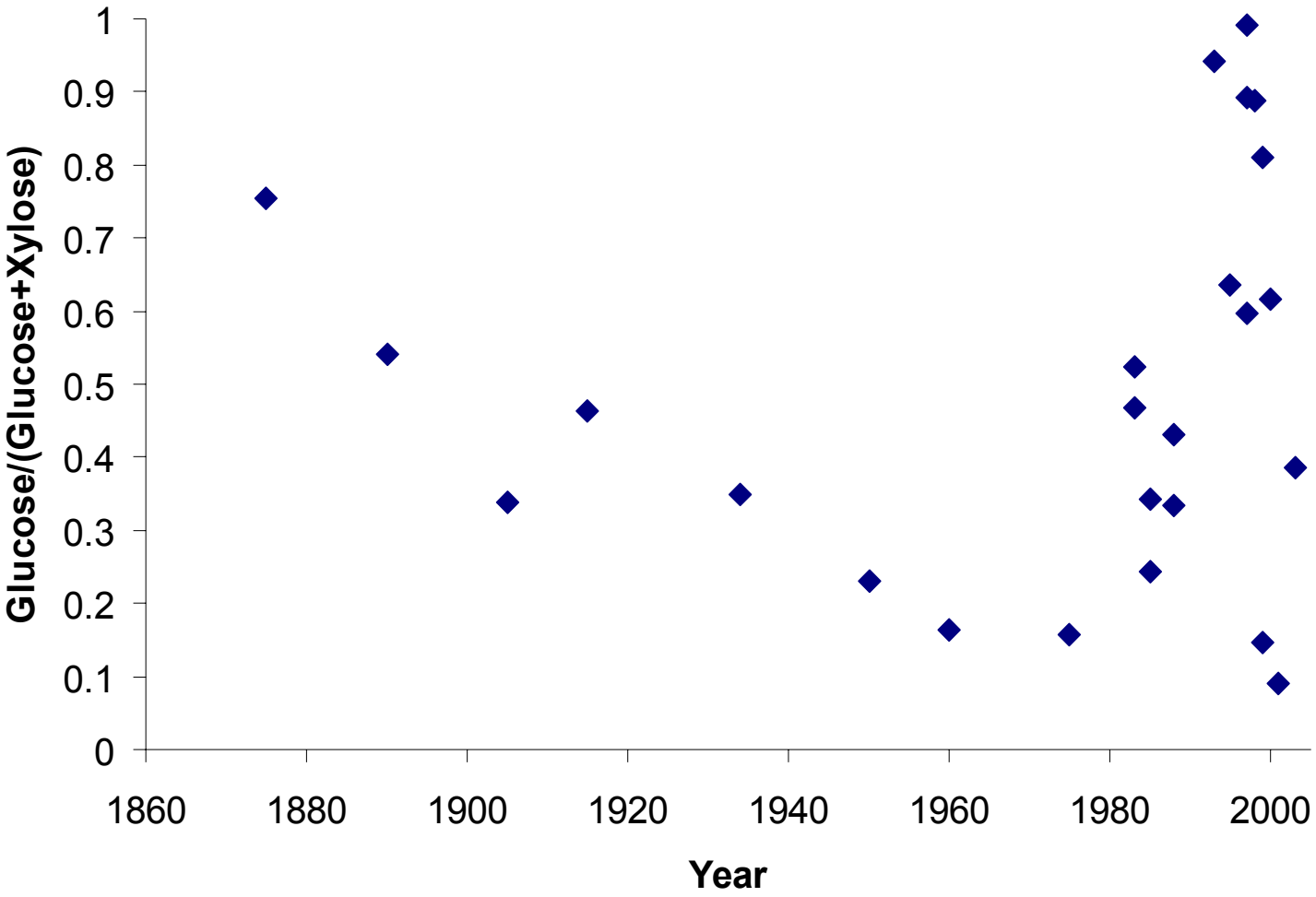
- The Industrial Revolution (1875-1950) brought commercial use of wood-pulp paper and mass production processes

- Commercial use of the acid sulfite process (1880s) and Kraft process with bleaching (1930s) caused a transition from mechanical to chemical processing

- Glucose and xylose levels peak in the World War I era

- After World War I, new technology and processing techniques were invented

Glucose Fraction in Wood-based Newspapers



- Pre-1980 glucose ratio shows a different mechanism than post-1980
- Kinetics study?
- Changes in data from 1980 to present are particularly interesting

History of Papermaking Technology

- The USA Today Effect: Launching of the USA Today in 1982 and the use of color in newspapers

- The environmental movement and recycling of newspapers

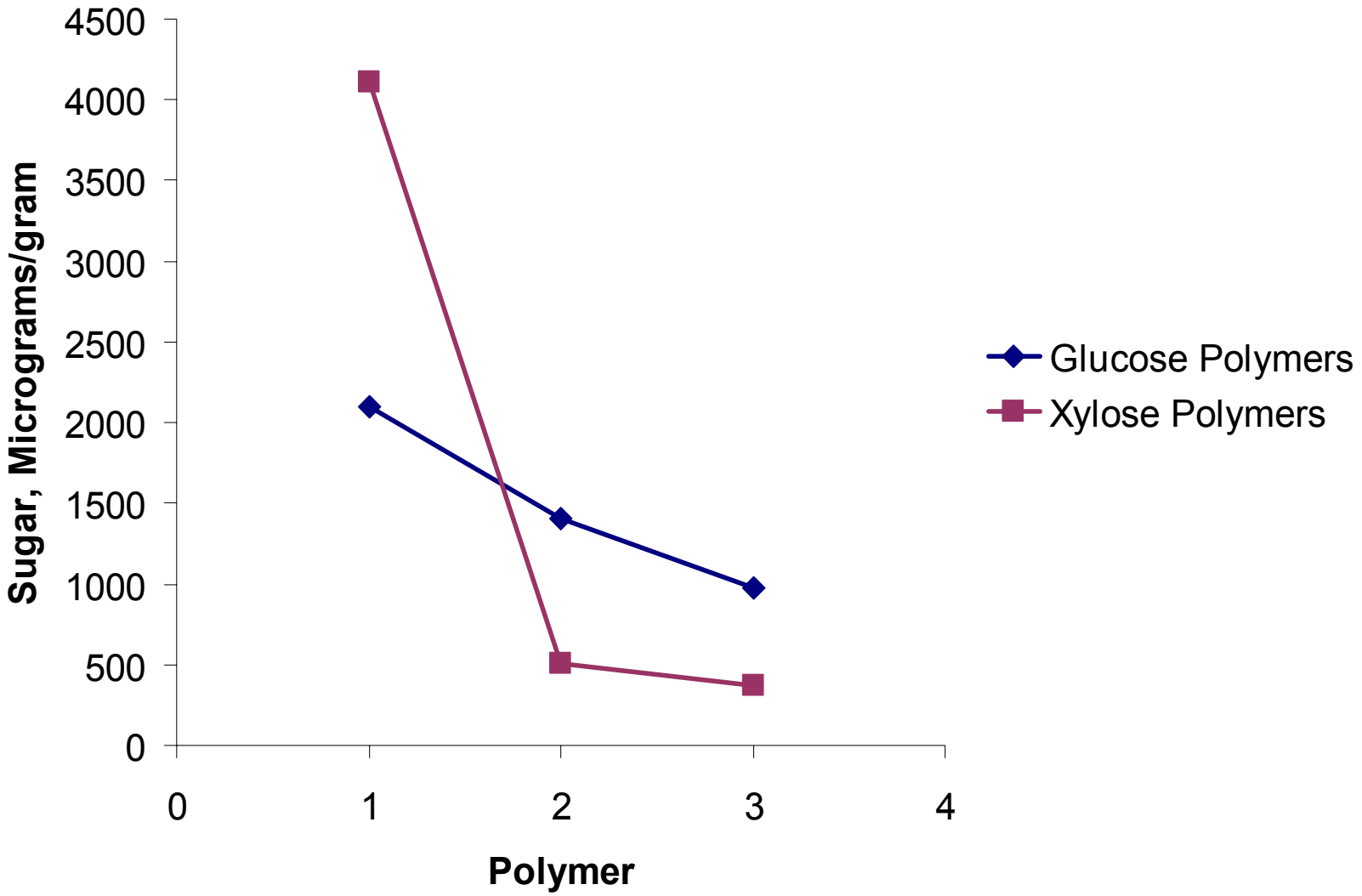
- Advanced machinery requires thinner material

- Multitude of processes for newspaper manufacturers to choose from: refiner, chemical, thermo, chemothermo, isothermo, etc.

- Further research

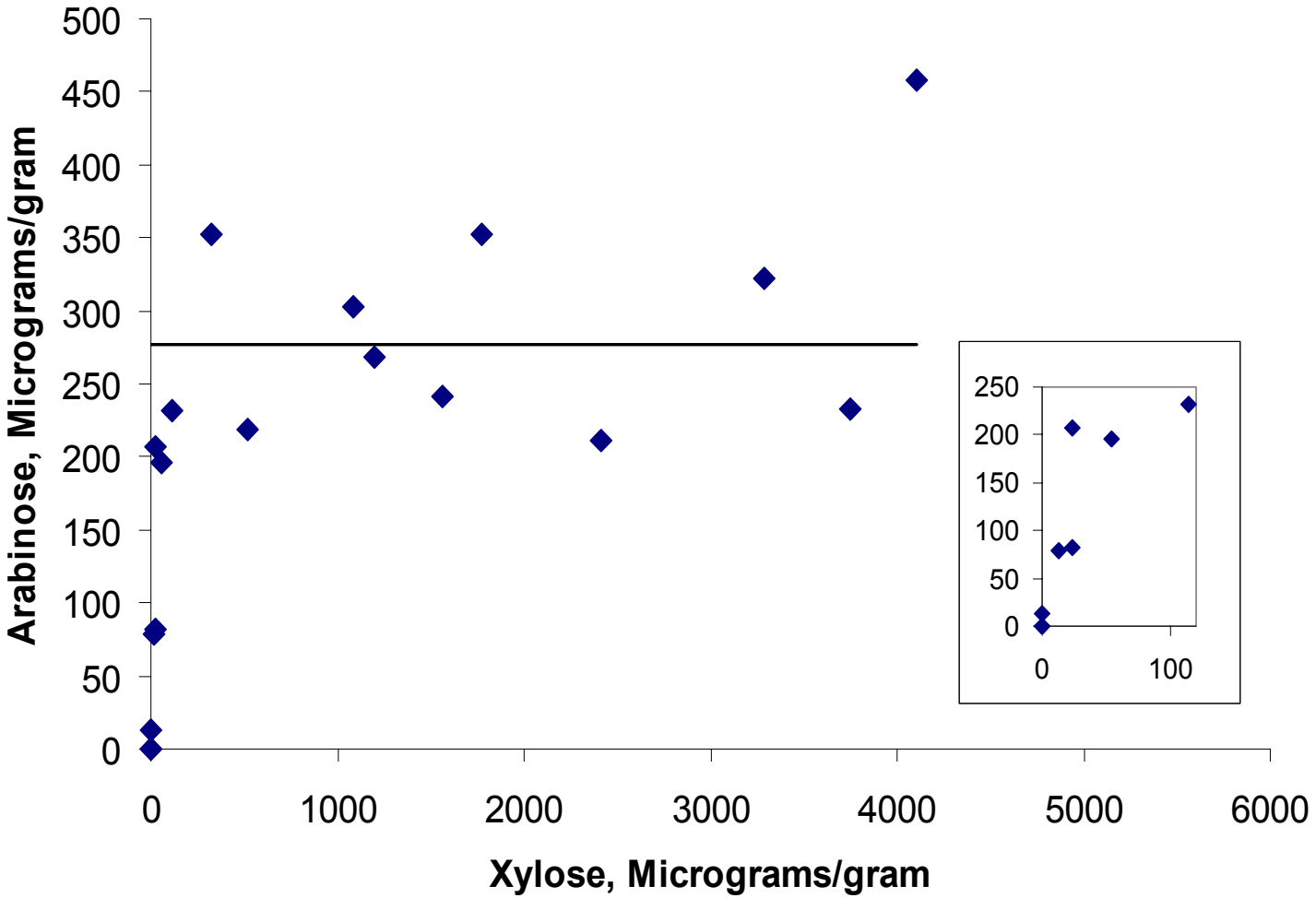
Sugar Polymers

Detroit Free Press, 1905



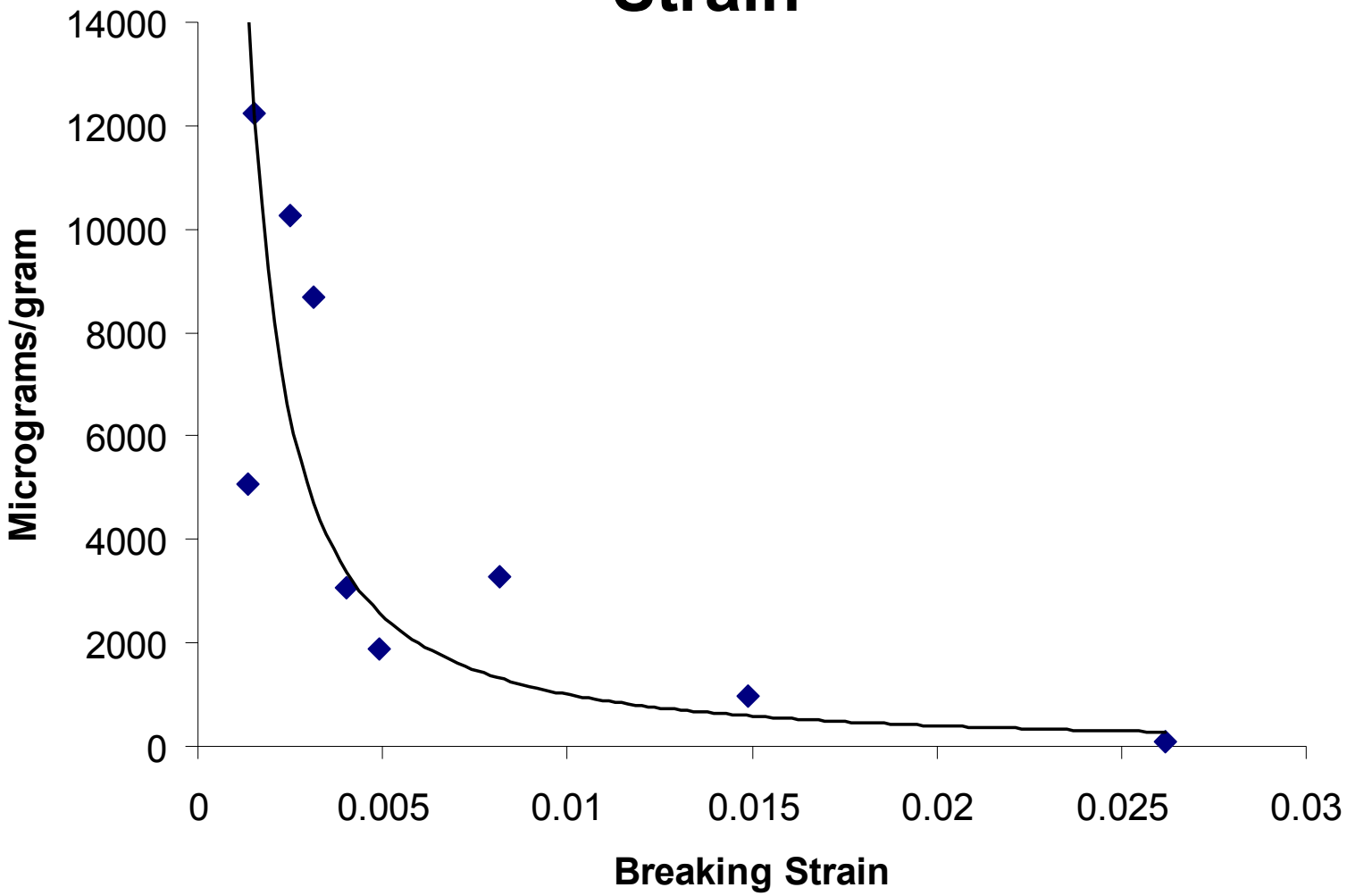
- Xylose is more hydrolytic and more likely to hydrolyze to monomer than is glucose

Arabinose and Xylose in Wood-based Newspapers



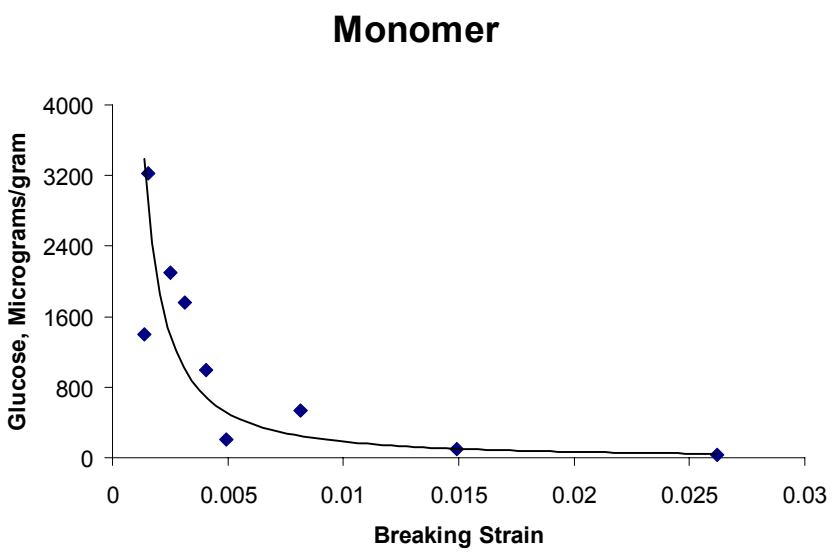
- Initial, sharp increase in arabinose, and then nearly constant value
- Arabinose molecules must be located at the end of the molecule or on branches, and are hydrolyzed first

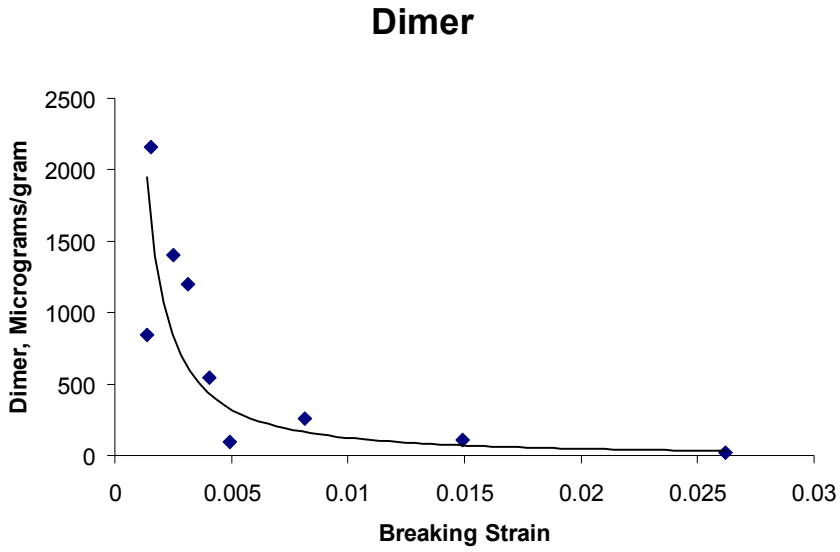
Total Measured Sugar Content vs. Breaking Strain

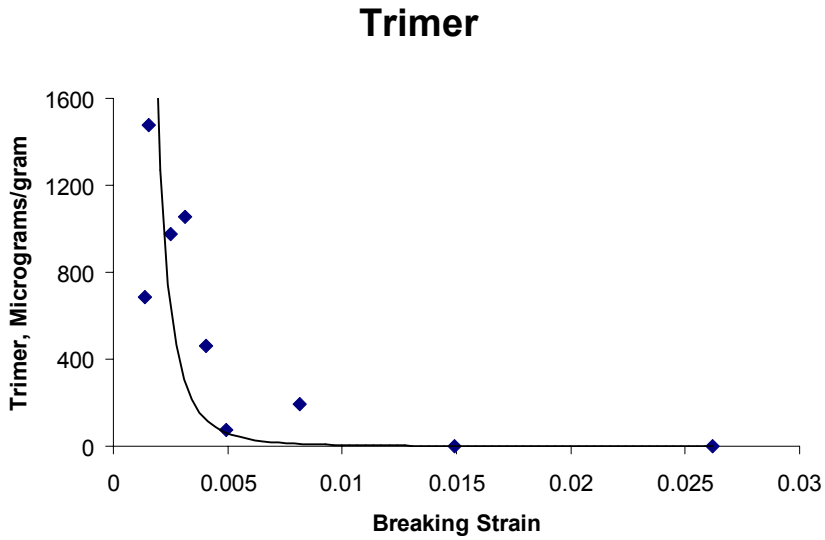


- Similar trends appear across other sugar data
- Illustrates the presence of a surface phenomenon

Glucose Polymers vs. Breaking Strain







Hydrolysis Mechanism Conclusions

- Issue of dueling factors of technology and time in the process of degradation
- Xylan hydrolysis vs. cellulose hydrolysis
- Order of degradation, illustration of mechanistic details of hydrolysis
- Surface phenomenon
- Ideas for further research in kinetics and the history of papermaking technology

Summary

- Mechanical and physical properties of specimens directly related to hydrolysis of cellulose and hemicellulose
- Hydrolysis of cellulose and hemicellulose affects breaking strain and plasticity of specimen
- Remaining life span of specimen can be estimated via sugar content analysis and/or mechanical testing