

ANIMAL FIBER METROLOGY

Chris Lupton

**Texas AgriLife Research
The Texas A&M System
San Angelo**

**IRAQ AGRICULTURAL EXTENSION
REVITALIZATION GROUP**

San Angelo, Texas October 21, 2009



SHEEP AND GOAT INDUSTRY IN TEXAS

SPANISH EXPLORERS INTRODUCED SHEEP TO THE SOUTHWEST IN THE 1500s, AND SPANISH MISSIONS DEPENDED ON THE ANIMALS FOR FOOD AND CLOTHING. THE FIRST ANGORA GOATS, KNOWN FOR THE BEAUTY AND STRENGTH OF THEIR MOHAIR, WERE BROUGHT TO TEXAS IN 1853 BY COL. W.W. HAUPT. PIONEER OF MODERN SHEEP RANCHING IN TEXAS FROM 1857 TO 1867 WAS GEORGE WILKINS KENDALL, WHO ENCOURAGED OTHERS WITH GLOWING REPORTS OF THE INDUSTRY'S FUTURE WHILE IMPROVING HIS OWN FLOCKS. KENDALL, WAS ONE OF THE FIRST TO CROSSBREED THE COARSE-WOOLED MEXICAN CHURRO SHEEP WITH THE FINE-WOOLED MERINO VARIETY BROUGHT BY EUROPEAN SETTLERS.

THE LAND, CLIMATE, AND VEGETATION OF THE EDWARDS PLATEAU AREA ESPECIALLY SUITED THE RAISING OF SHEEP AND GOATS. AFTER 1870, WITH NEW MARKETS AND ABUNDANT LAND, THE INDUSTRY BOOMED. RANCHERS FOUGHT DISEASE, PREDATORS, DEADLY PLANTS, AND DROUTHS TO BUILD THEIR FLOCKS. TODAY TEXAS IS THE LEADING PRODUCER OF SHEEP AND GOATS IN THE NATION, AND SAN ANGELO IS THE MAJOR MARKET CENTER FOR THESE ANIMALS AND THEIR WOOL. RESEARCH FACILITIES SUCH AS THE SAN ANGELO RESEARCH AND EXTENSION CENTER, BUILT IN 1969 THROUGH THE EFFORTS OF GEN. EARL RUDDER, THEN PRESIDENT OF THE TEXAS A & M SYSTEM, WORK FOR THE INDUSTRY'S CONTINUED PROSPERITY.

(1974)

Animal fiber program

- **Develop and evaluate improved procedures for measuring value-determining characteristics of animal fibers.**
- **Collaborate in research projects that require fiber production and quality to be quantified.**

Animal fiber program

- **Project Leader: Chris Lupton**
- **Research Associate: Faron Pfeiffer**
- **Research Assistant: Sue Engdahl**
- **Student Assistants: Eddie Swinney, Gary Henson, Kendra Franke (ASU)**
- **(Graduate students, ASU and TAMU)**
- **Plus administrative, secretarial, bookkeeping, and maintenance support from the unit and CS.**

Species we work with

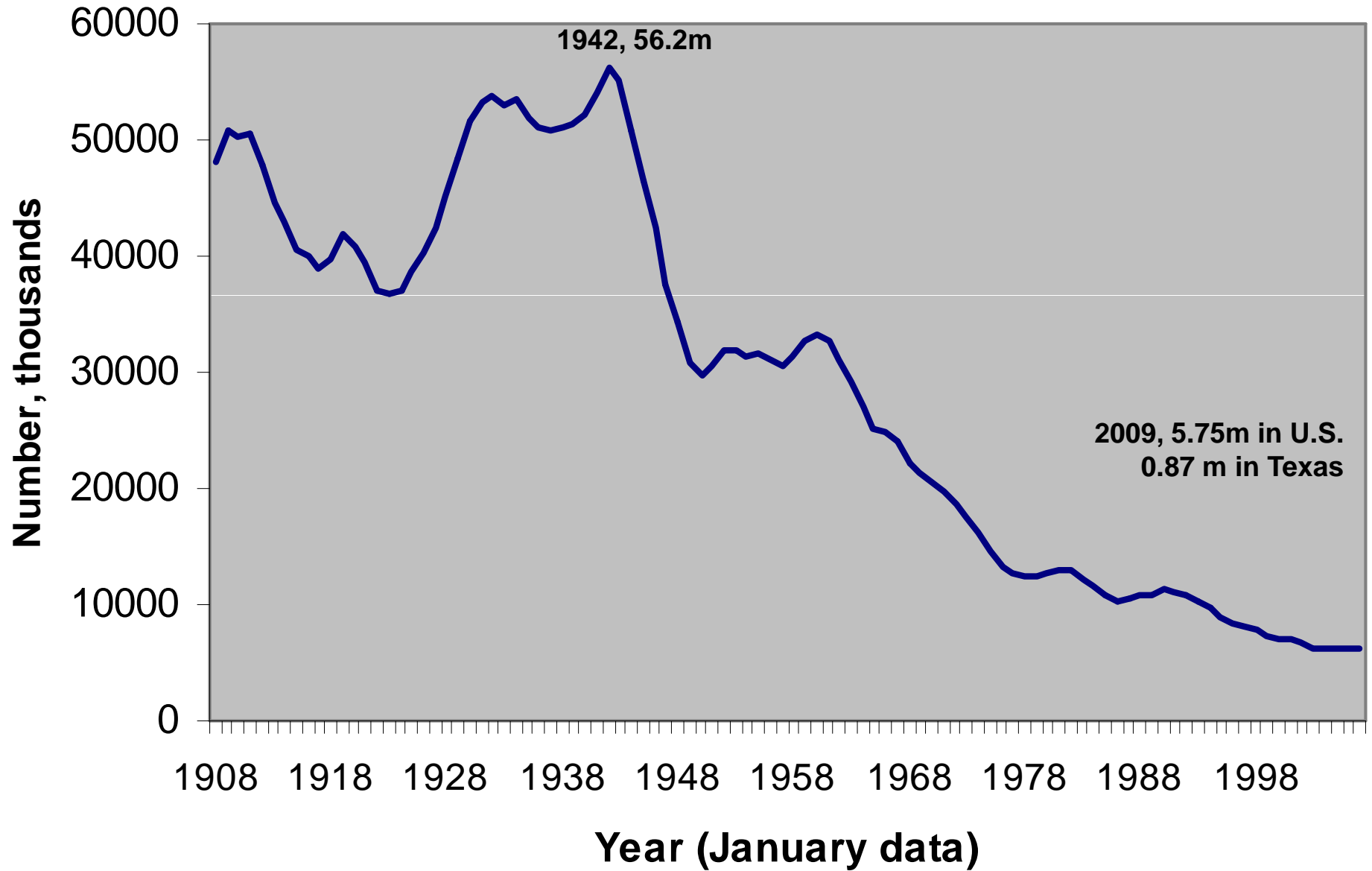


Muskox (qiviut), rabbit, dog, cattle, mice, *et al.*

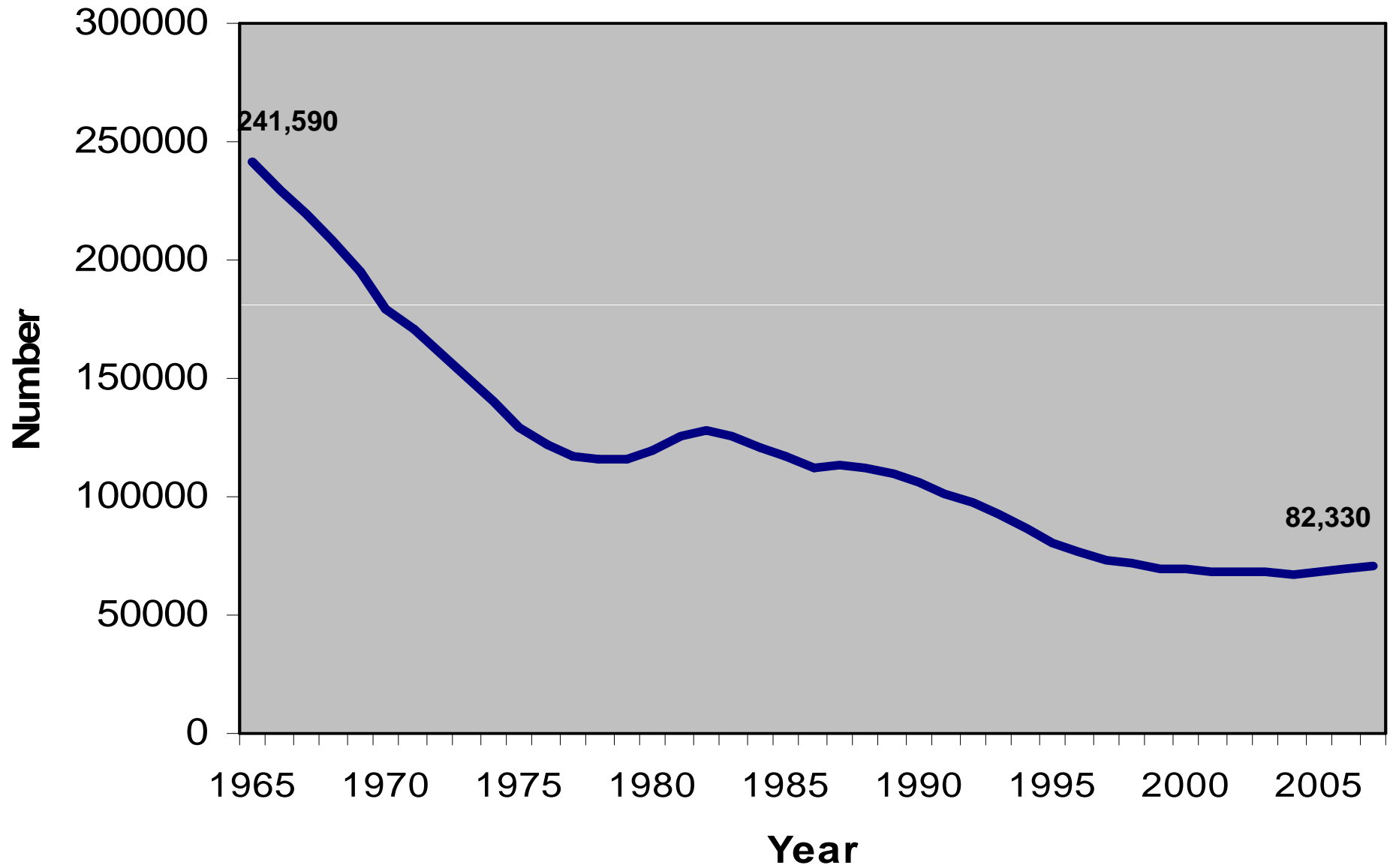
U.S. animal fiber testing labs

- One commercial and 3 academic labs.
- Our AgriLife Research lab is well equipped and staffed.
- Consequently, there are plenty of opportunities for collaboration with AgriLife Research, USDA, ARS, and other scientists in academia on projects that have high national priority.

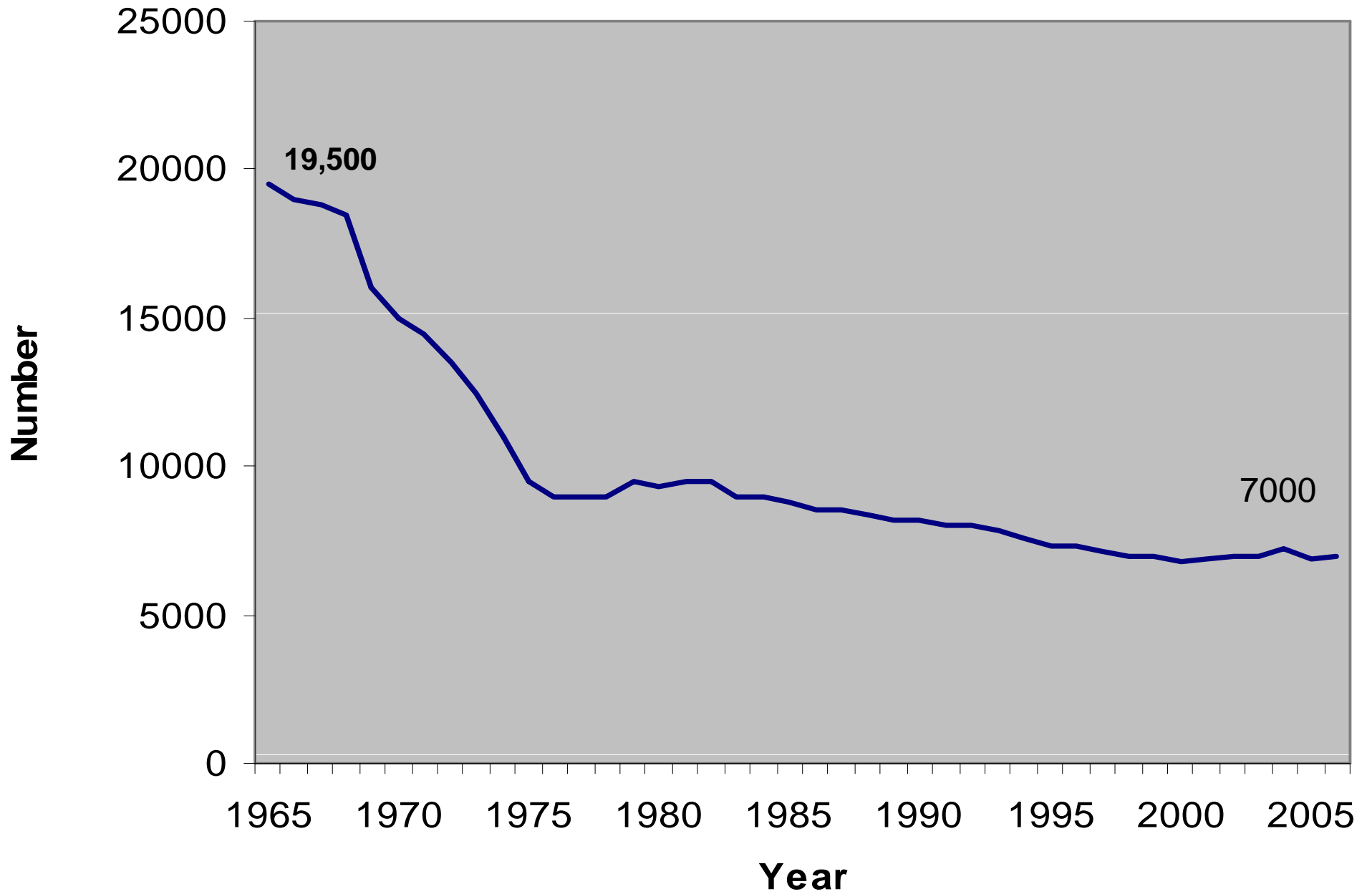
Total sheep and lambs, 1908 to 2009



Number of operations with sheep



Sheep operations in Texas

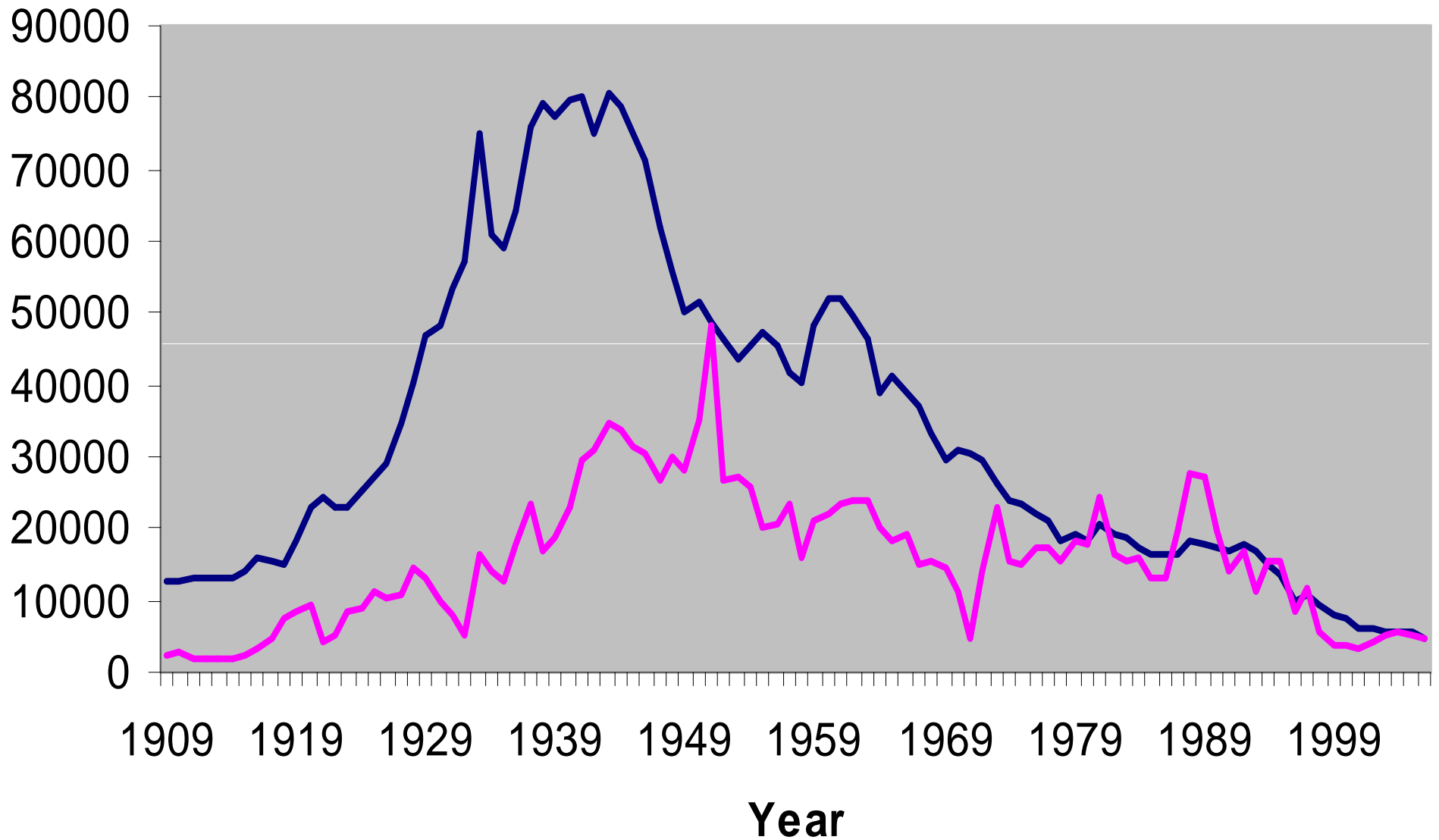


National sheep and goat operations (farms) and trends

2008 data

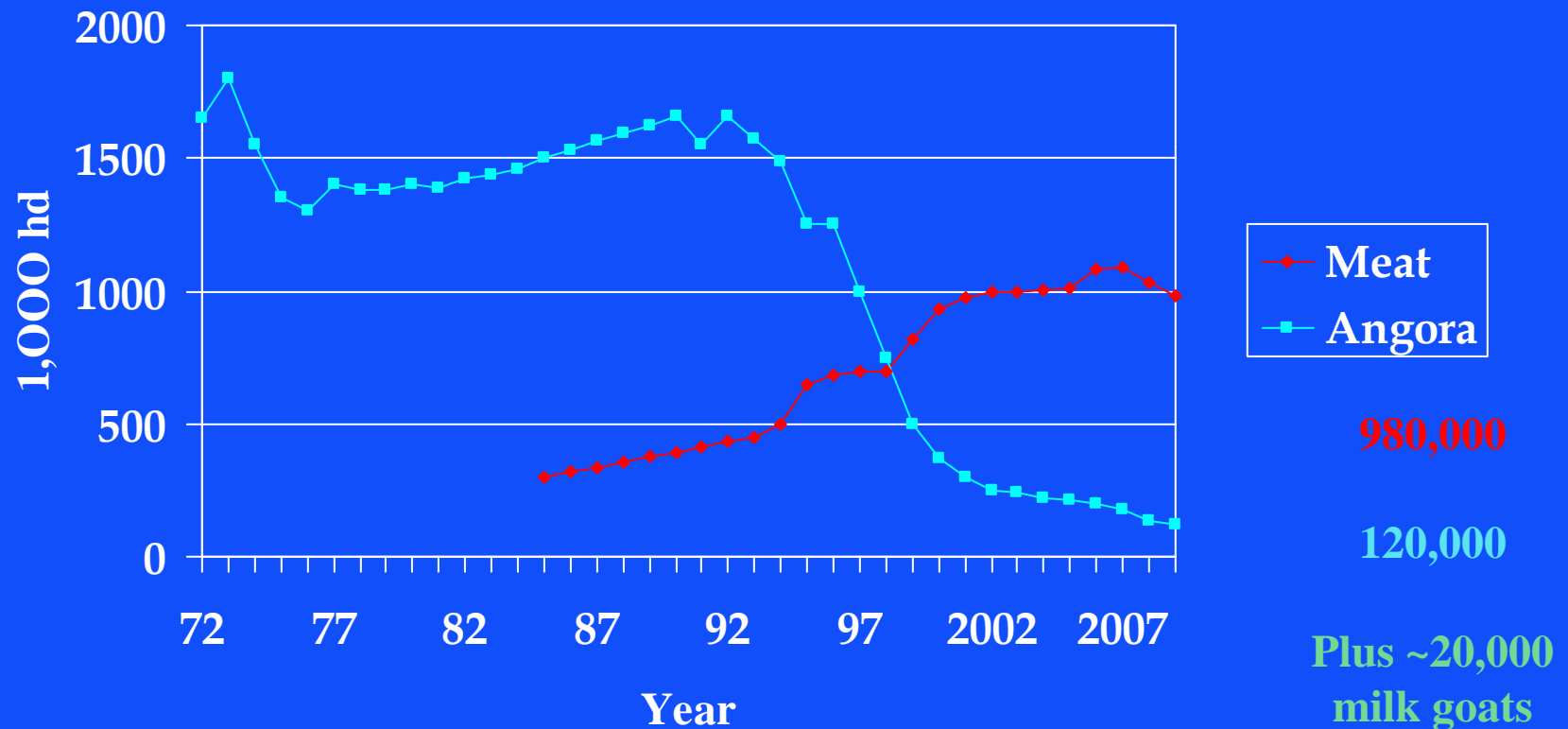
- Sheep 82,330. Down 1% compared with 2007
- Angora goats 6500. Down 10%.
- Dairy goats 29,000. Up 6%.
- Meat goats 128,800. Up 5%.

Texas wool production and value, 1909 to 2009



— Production, 1000 lb — Value of production, 1000\$

Texas goat numbers



Animal fiber metrology

“Current technology”



Sampling

- **From live animal**
- **From shorn fleece**
- **From packages (bags or bales)**

Sampling

- **Mid side, best single indicator**
- **Random (core or grid) sample from part of (e.g., saddle) or whole fleece**
- **Random (core or grab [manual or machine]) sample from packaged fiber**

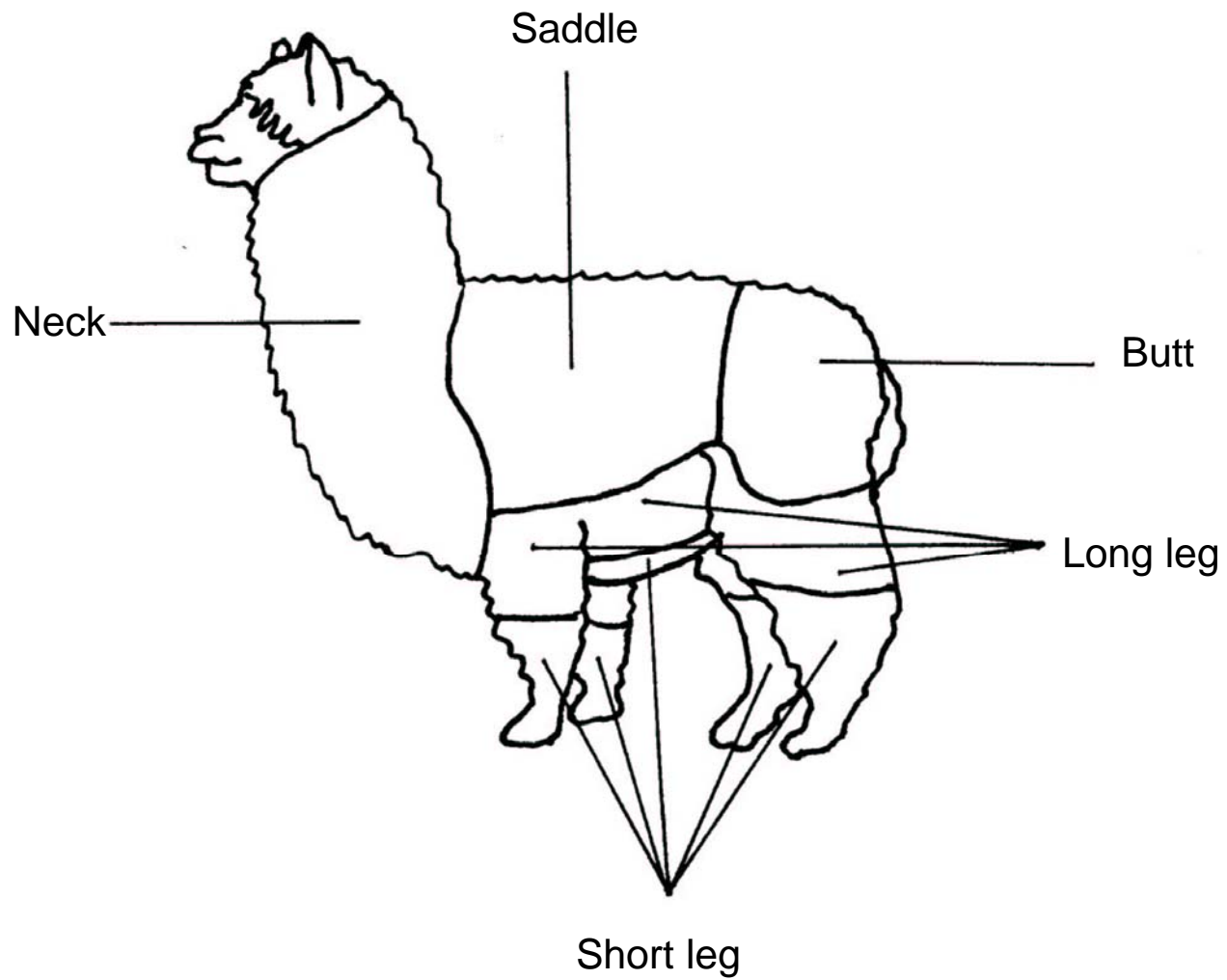
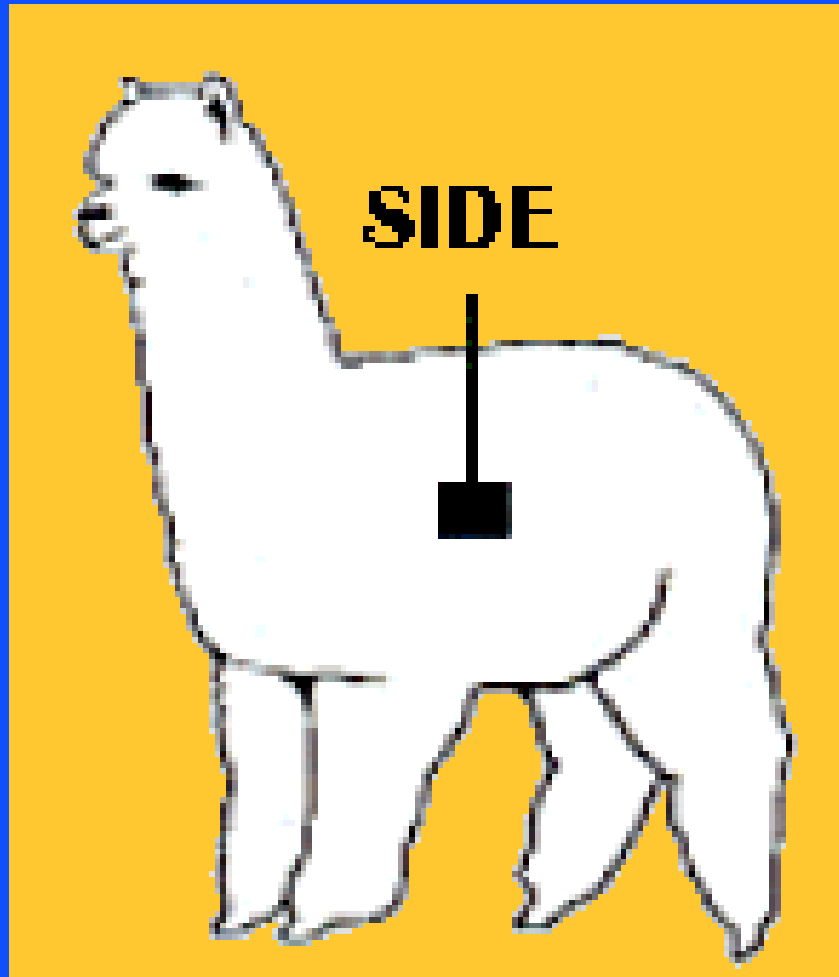
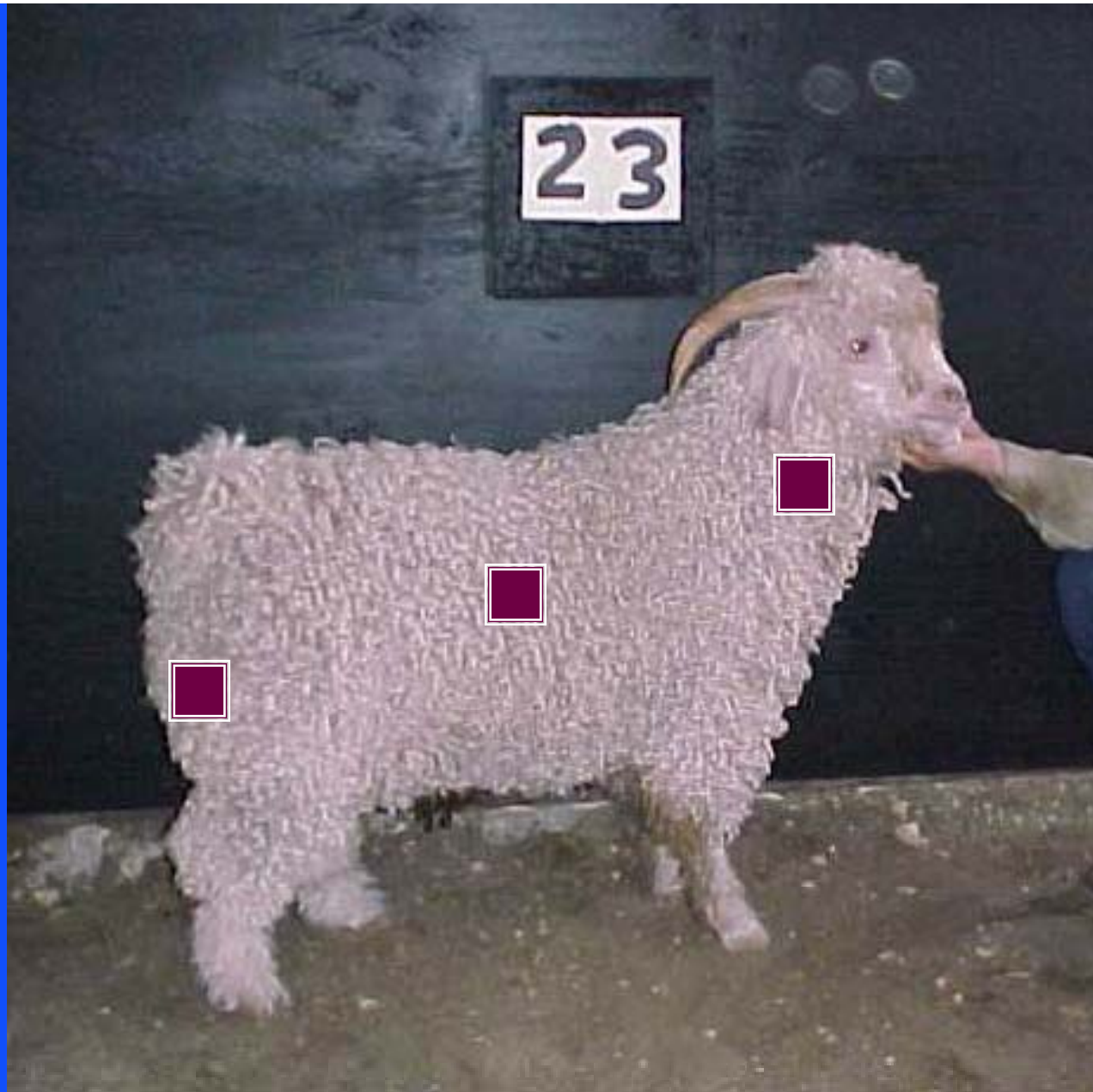


Figure 1. Five (normally) distinct fleece components

Yocom-McColl's alpaca mid-side diagram





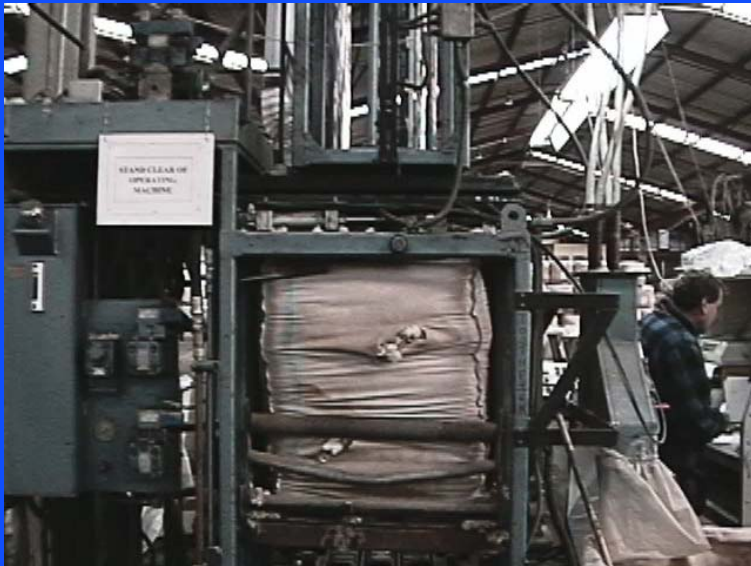
Neck, side, and britch samples for fiber diameter and medullation



Core & grab sampling bales



Core sampling bales



Fleece and fiber characteristics that are measured or calculated

- **Weight (raw and clean; whole or components), kg**
- **Clean yield, % (WB, LSY, CWFP, SDY)**
- **Vegetable matter content, % (VMB, VMP)**
- **Average staple length, SD, mm, and CV, %**
- **Average staple strength, SD, N/ktex, CV, %, POB (and % tip, middle, and base breaks).**

Fleece and fiber characteristics that are measured or calculated (contd.)

- **Average fiber diameter, SD, microns, CV, %**
- **Comfort factor, % fibers < or = to 30 microns**
- **Spinning fineness, microns**
- **Average fiber curvature, SD, deg/mm, CV, %**
- **Resistance to compression, kPa**
- **Medullated fibers (med, kemp and total medullation, ASTM), or total medullated fibers, flat fibers, and objectionable fibers, % or number / 10,000 (IWTO). Also AFD, SD, and CV of medullated fibers.**

Fleece and fiber characteristics that are measured or calculated (contd.)

- **Dark fibers (in white fleeces or vice versa), number / 10,000 or number / unit weight.**
- **Color, tristimulus values, brightness or yellowness.**
- **Luster.**
- **Fibers per unit area of skin.**

Relative commercial importance of raw specialty animal fiber traits (McGregor, 2006).

Trait	Scoured	Top/noil	Yarns	Cloth
Mean fiber diameter	****	****	****	****
Comfort factor	-	-	*	***
CV of fiber diameter	-	-	**	**
Clean yield	****	-	-	-
VM (amount and type)	***	***	**	**
Staple strength/ POB	**	*	-	-
Mean fiber length	**	****	**	**
CV of fiber length	**	**	*	*
Dark fibers	*	*	*	***

Relative commercial importance of raw specialty animal fiber traits (McGregor, 2006) contd.

Trait	Scoured	Top/noil	Yarns	Cloth
Medullated fibers	**	**	**	***
Fiber crimp	*	*	**	**
Color	*	-	-	**
Style and handle	-	-	**	**

* Some significance
 **** Highly significant

Sampling the staple

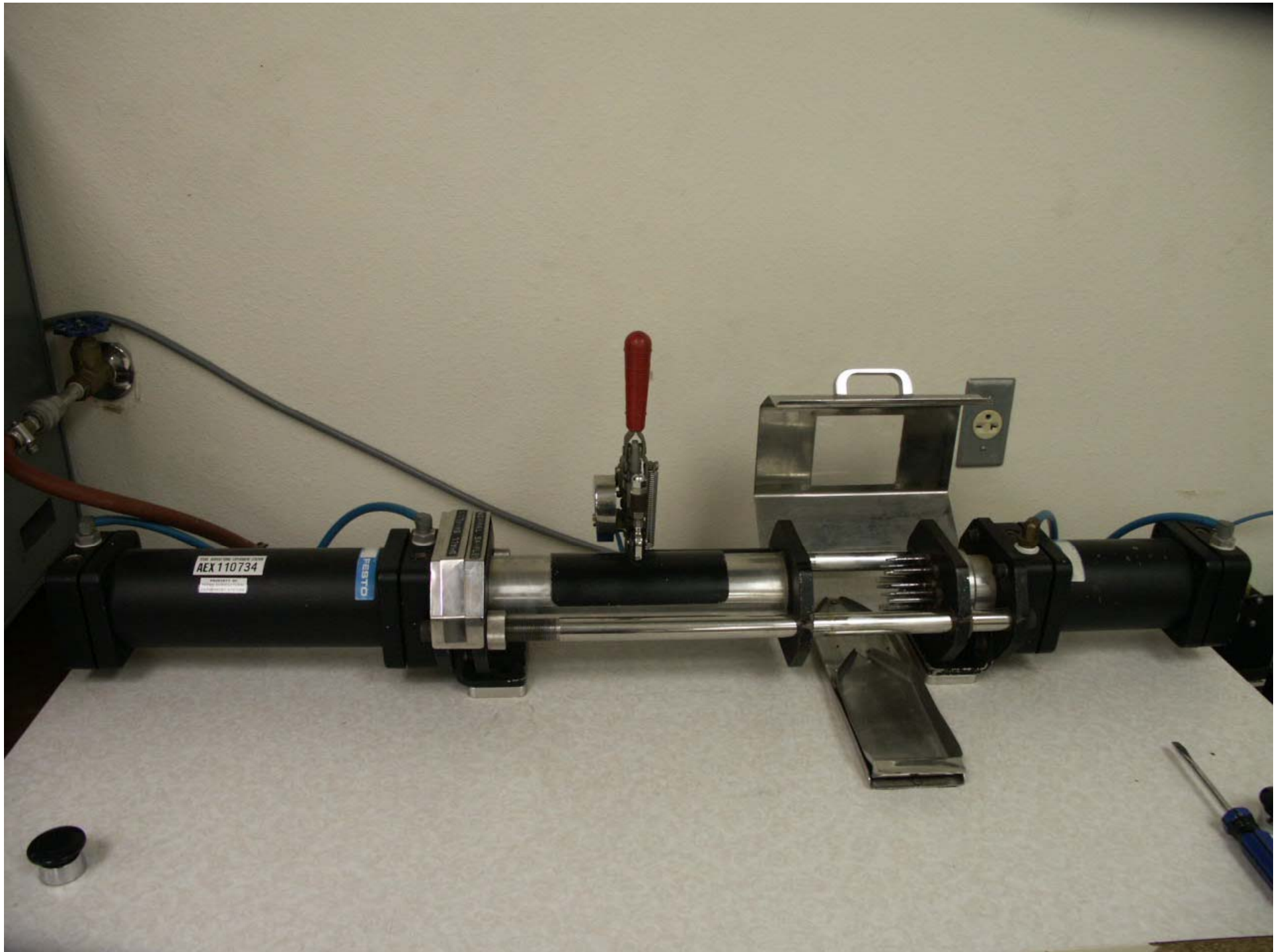
- Guillotine (2 mm) the base of staple (OFDA 100 or Laserscan).
- Guillotine elsewhere along the staple.
- Measure the whole staple (OFDA2000).
- Minicore the whole staple (2 mm).

- Measuring each type of sub-sample will give you a different result, but all are potentially useful.





Courtesy:
Yocom-McColl
Testing Labs, Inc.







Standard methodology

- **American Society for Testing and Materials (ASTM)**
- **International Wool Textile Organisation (IWTO)**

Fleece and fiber characteristics that are measured or calculated

- ✓ Weight (raw and clean; whole or components), kg
- ✓ Clean yield, %
- ✓ Vegetable matter content, %
- Average staple length, SD, mm, and CV, %
- Average staple strength, SD, N/ktex, CV, %, POB (tip, mid, base or fraction)

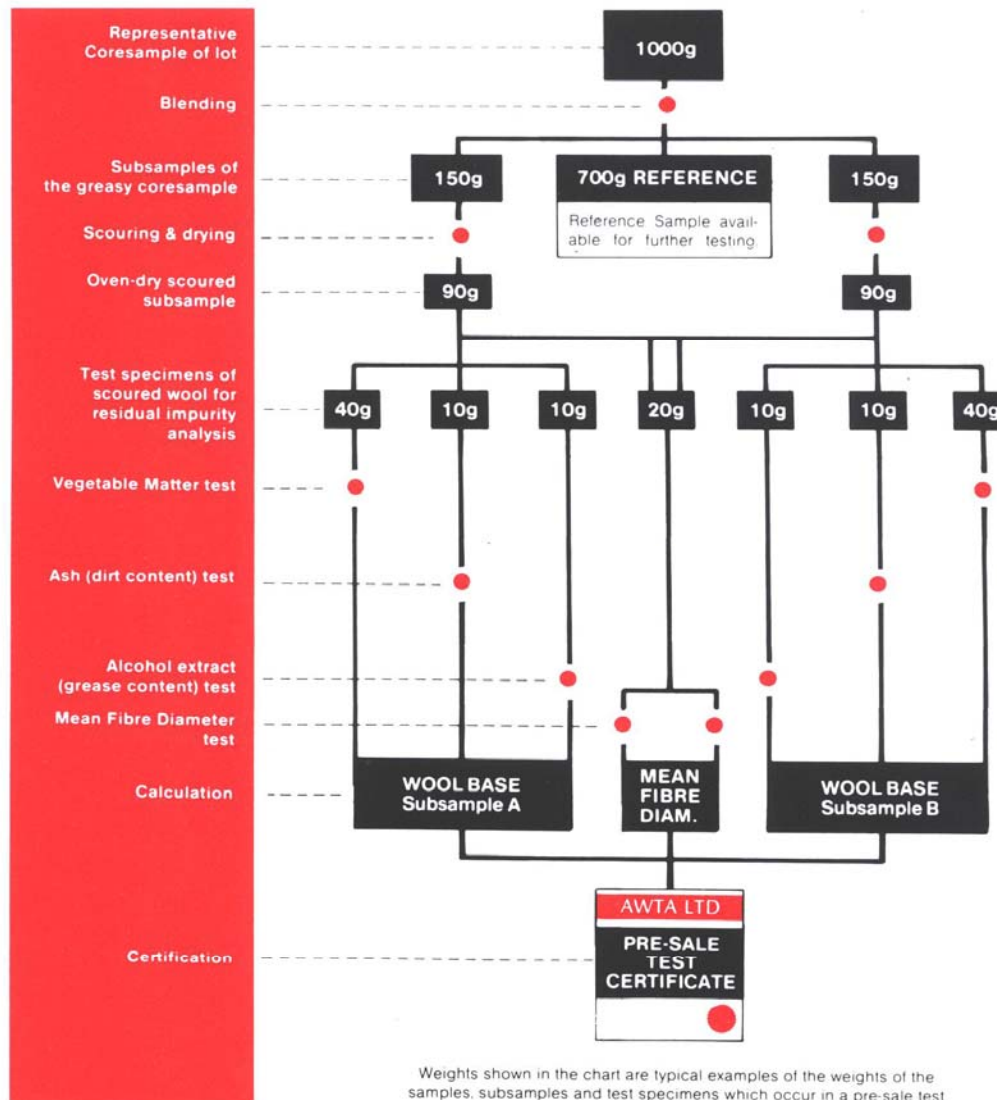
Clean fiber base

- Mass of clean, dry fiber with all impurities removed expressed as a % of the original “greasy” fiber mass.
- Usually report the fiber base after adjusting for allowed moisture (12%), residual grease (1.5%) and ash (0.5%).

Vegetable matter base

- **Mass of oven-dried scoured burrs, seeds, twigs, leaves, and grasses, free of mineral matter and alcohol-extractable matter expressed as a % of the mass of the sample.**

Presale Measurement Procedure



Weights shown in the chart are typical examples of the weights of the samples, subsamples and test specimens which occur in a pre-sale test

NIRS

- Allows us to quantify broad classes of compounds or individual compounds that contain different chemical bonds.
e.g., protein (in this case **keratin**), lipids (wool wax), cellulose and lignins (**vegetable matter**), and water.
- NIRS is also sensitive to particle size (potential for estimating AFD, SDFD, AC).

Near-infrared Reflectance Spectroscopy



NIRS Measurements

- **Non-destructive and results available in less than two minutes.**
- **Currently, only being used commercially to replace one of the gravimetric tests (residual grease).**

X-ray instrument for estimating clean yield



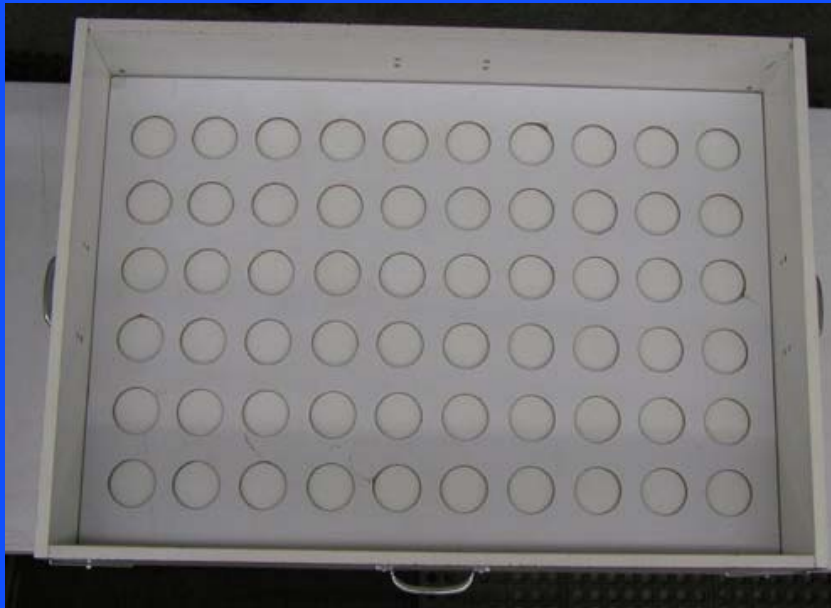
Fleece and fiber characteristics that are measured or calculated

- ✓ Weight (raw and clean; whole or components), kg
- ✓ Clean yield, %
- ✓ Vegetable matter content, %
- ✓ Average staple length, SD, mm, and CV, %
- Average staple strength, SD, N/ktex, CV, %, POB (tip, mid, base or fraction)



Length Measurement, contd.

Grid sampling



Average staple length, SD,
and CV of staple length

Length & Strength Testing



Staples in a Tray

Measuring Length



ATLAS

Fleece and fiber characteristics that are measured or calculated

- ✓ Weight (raw and clean; whole or components), kg
- ✓ Clean yield, %
- ✓ Vegetable matter content, %
- ✓ Average staple length, SD, mm, and CV, %
- ✓ Average staple strength, SD, N/ktex, CV, %, POB (tip, mid, base or fraction)

Staple Strength Measurement

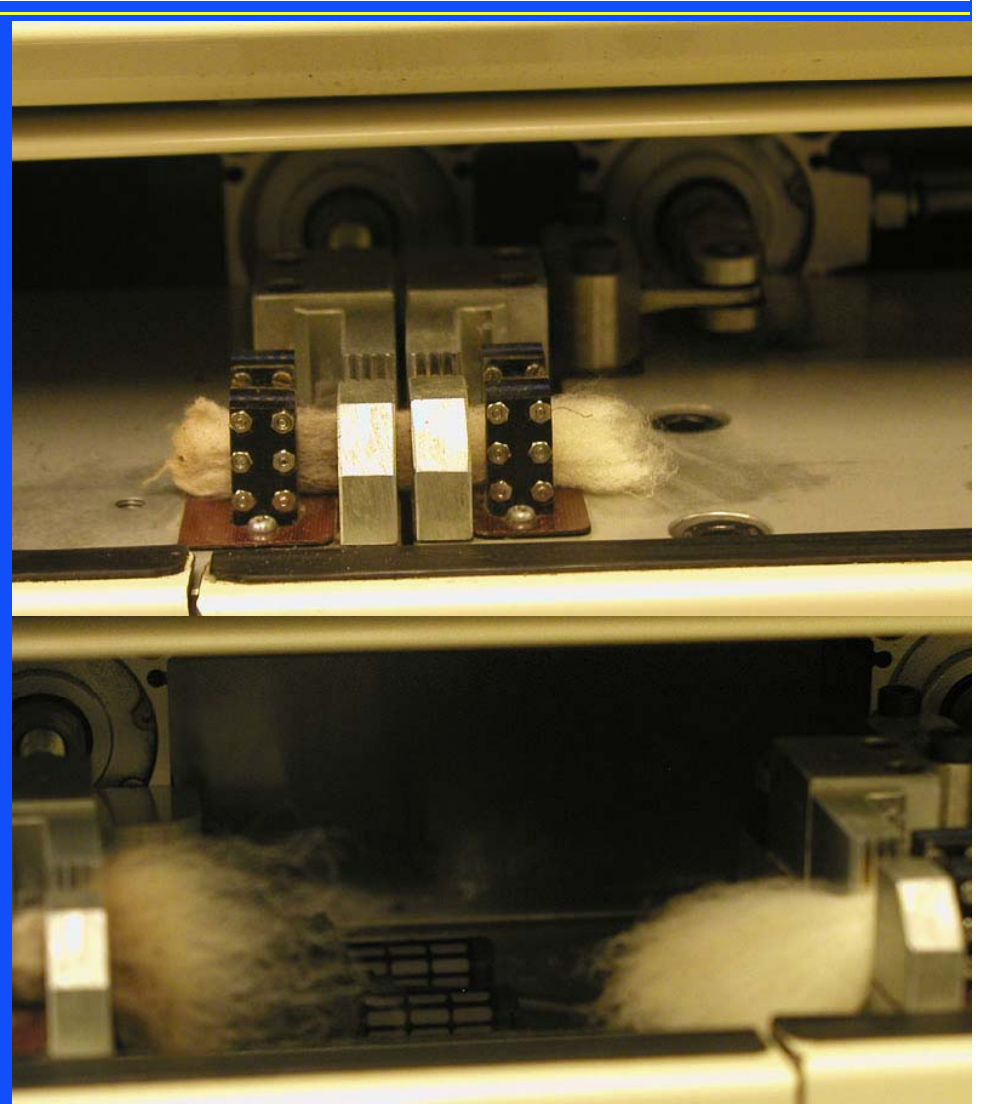
Average staple strength, SD and CV of staple strength,
Position of break, and % tip, middle and base breaks



Strength Measurement, contd.



**Agritest
Staple
Breaker 2**



ATLAS

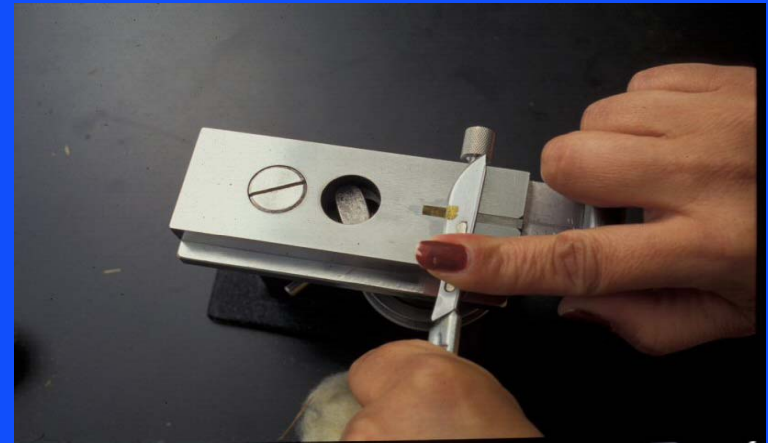
Fleece and fiber characteristics that are measured or calculated (contd.)

- ✓ **Average fiber diameter, SD, microns, CV, %**
- ✓ **Comfort factor, % fibers \leq to 30 microns**
- ✓ **Spinning fineness, microns**
- ✓ **Average fiber curvature, SD, deg/mm, CV, %**
- ✓ **Medullated fibers (white and pastel fibers only), total medullation, flat fibers, and objectionable fibers, % or number / 10,000.**
- **Dark and medullated fibers and contaminants (in white fleeces), number / 10,000 or number / unit weight**
- **Resistance to compression, kPa**
- **Color, tristimulus values, brightness or yellowness**

Fiber diameter measurement

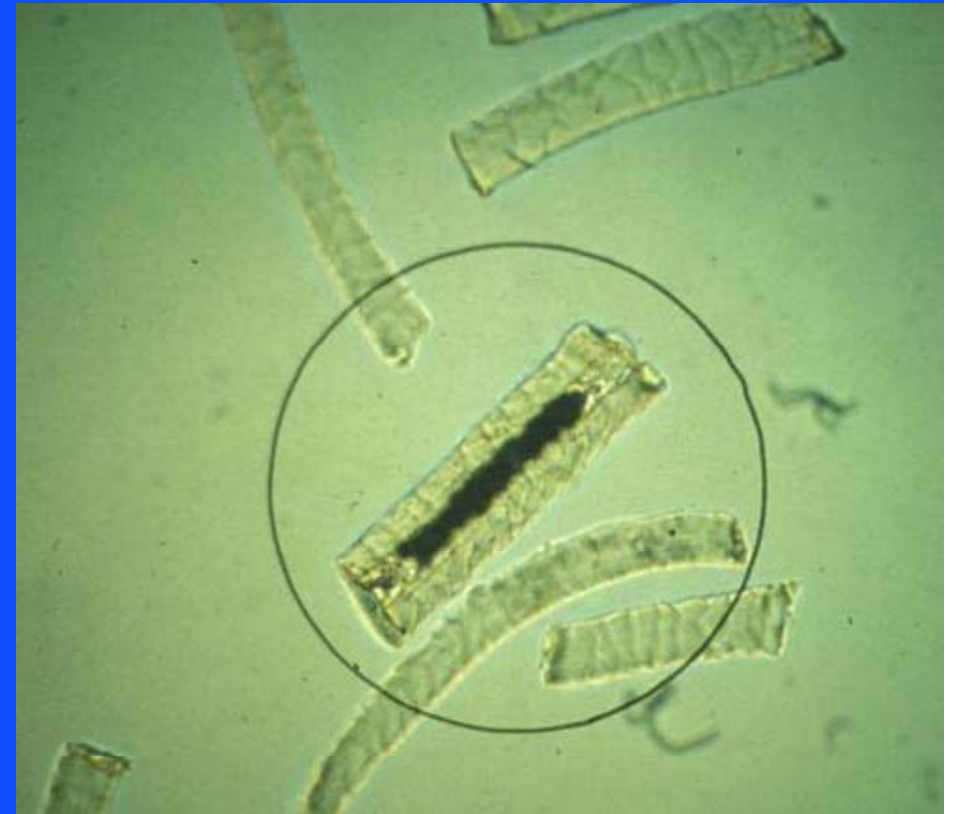
- **Projection microscope (PM)**
- **Sirolan Laserscan (LS)**
- **Optical Fiber Diameter Analysers (OFDA 100 and 2000)**
- **Sirolan Fleecescan**
- **Airflow**

Projection Microscope



Courtesy:
Yocom-McColl
Testing Labs, Inc.

Microprojection



Courtesy:
Yocom-McColl
Testing Labs, Inc.

One Micron Equals...

1/25,400 of one inch

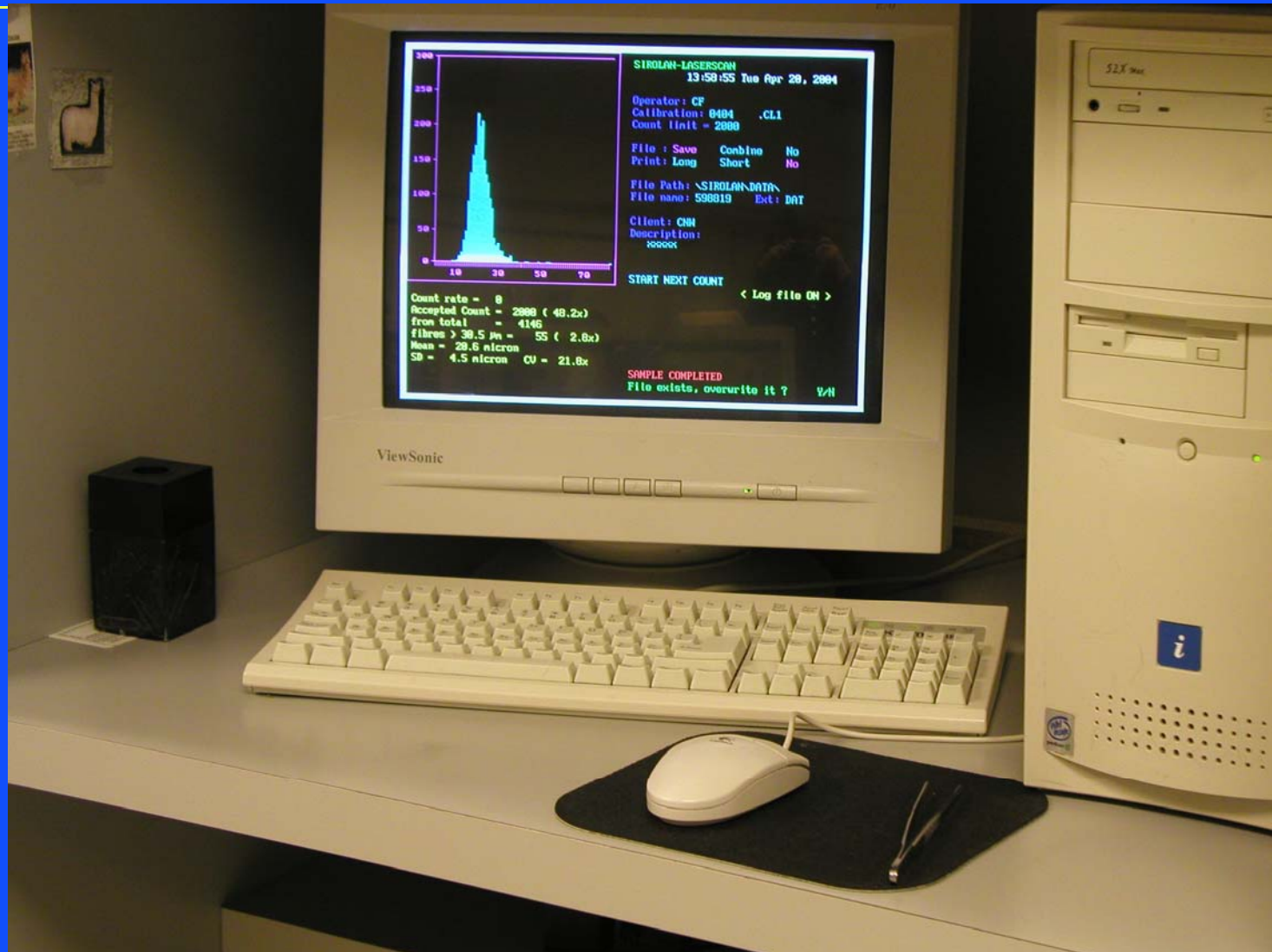
or

**1/1,000,000 of one
meter**

Sirolan LaserScan Sample



LaserScan Display



Courtesy:
Yocom-McColl
Testing Labs, Inc.

OFDA 100 Optical Fibre Diameter Analyser



OFDA slide on stage



Courtesy:
Yocom-McColl
Testing Labs, Inc.

OFDA2000



Sirolan Fleecescan

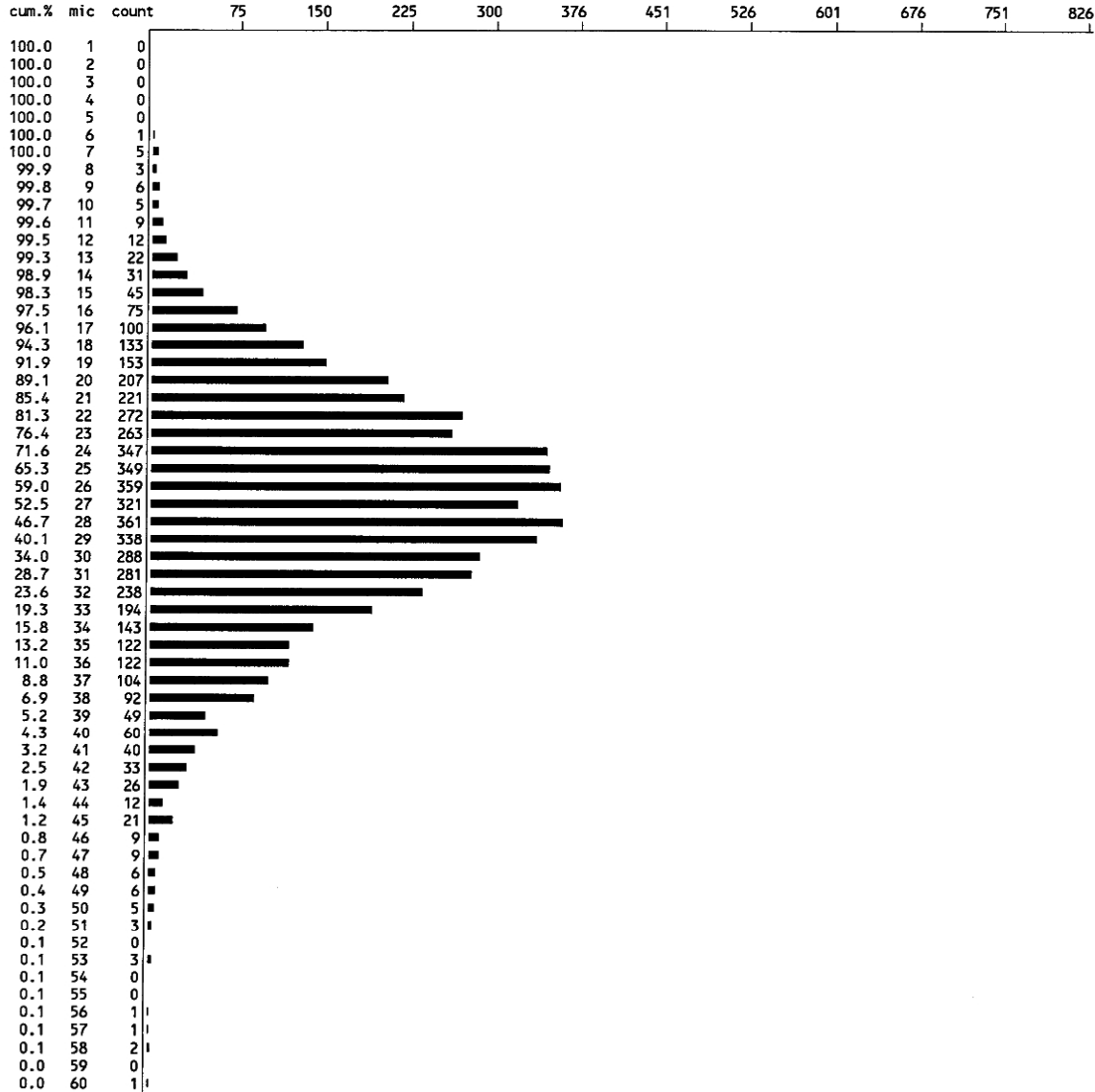


Sirolan Fleecescan



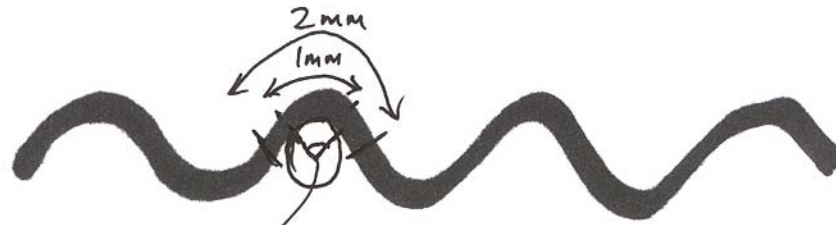
Texas Agricultural Experiment Station

Date : 13Feb07 Mean = 27.3 u
 Sample ID : ALPACA SD = 6.6 u
 Description : 232 CV = 24.3 %
 Lot/Client : ALPACA FARMS Sample size = 5509
 Operator : CJL Spin fineness= 27.3 u
 5% of fibres 12.0 u above mean. Comfort factor= 71.3 %
 Curve= 66.8[43] deg/mm Curve number = 3045
 OFDA030:2.14 Cal: D=5.4121*WH -3.80, wV= 1.4680*wH+ 0.08, DkFlash= 77.5



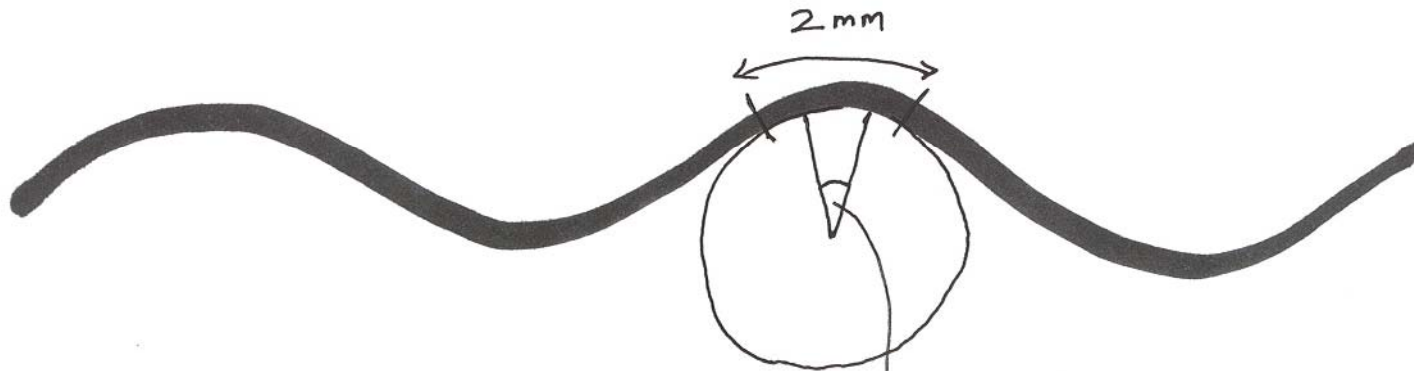
Curvature

- Is a measurement of the **fiber** crimp. Does not indicate the type of staple crimp (i.e., uniform staple crimp (like most fine wools) or crinkle (like cashmere)).
- Is correlated with Bulk and Resistance to Compression
- Generally, worsted processors (lean yarns for fine suitings) prefer less crimp, woolen system spinners prefer more crimp (bulkier yarns for knitwear).



Angle of curvature, $^{\circ}/\text{mm}$

Large angle, small crimp



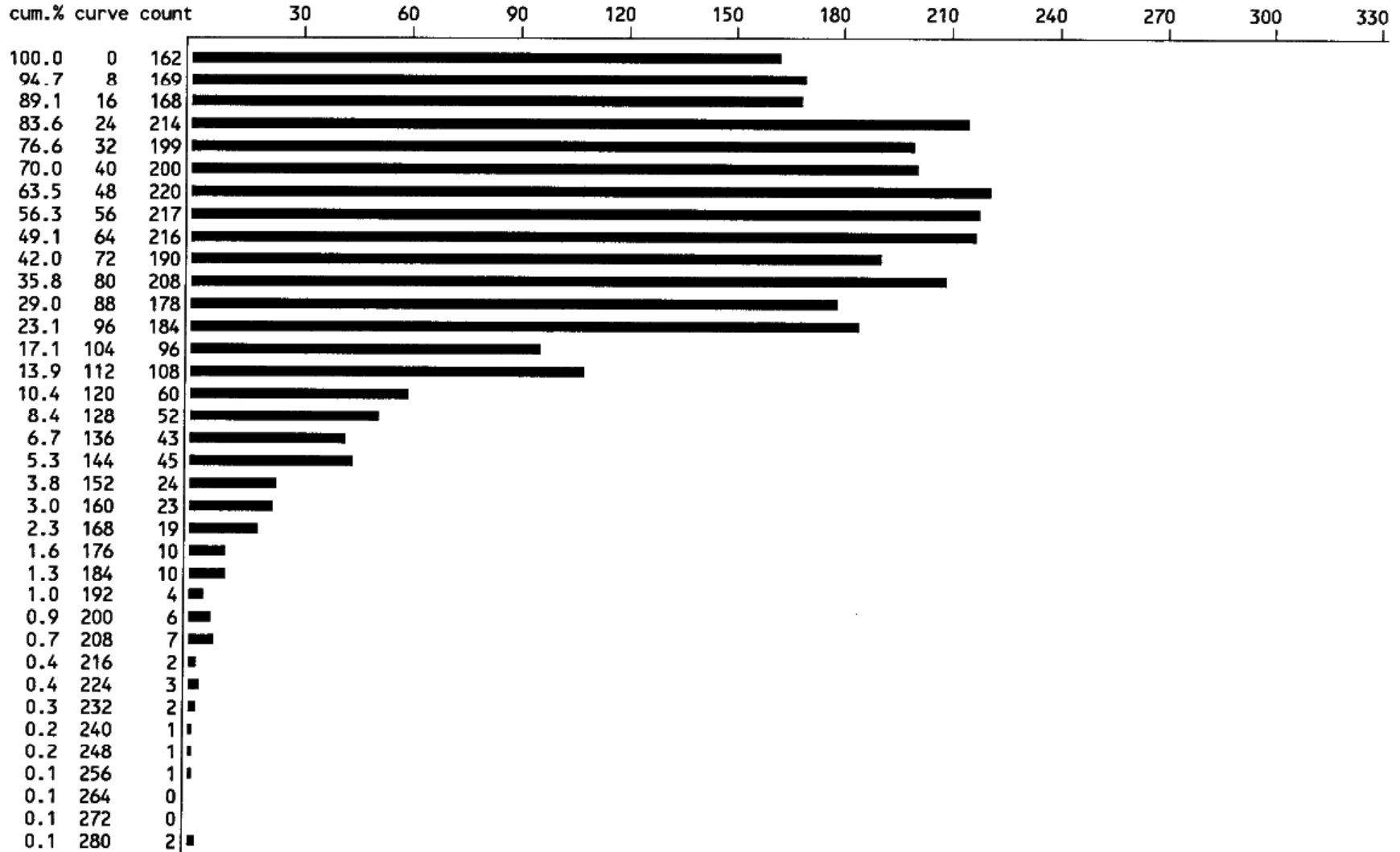
Angle of curvature, $^{\circ}/\text{mm}$

Small angle, bold crimp

Frequency
Amplitude

Curve Histogram

Date : 13Feb07 Diam = 27.3 [6.6] u
 Sample ID : ALPACA Curve = 66.8 [43] deg/mm
 Description : 232 Sample size = 5509
 Lot/Client : ALPACA FARMS Curve size = 3045



Fiber crimp

- Fiber crimp (visual or measured as average fiber curvature, AFC) is **not** an accurate indicator of average fiber diameter.

Curvature ranges

- **Low:** < 50 deg/mm, crossbred wool, mohair (~2 crimps per inch). Alpaca 15-55 deg/mm.
- **Medium:** 60-90 deg/mm, 21 micron Merino and Rambouillet wool (~4 crimps per inch)
- **High:** >100 deg/mm, 16-18 micron superfine Merino and Rambouillet wool (~7 crimps per inch)

Spinning fineness

- Used by textile processors, a better indicator of processing performance than MFD alone, particularly in spinning.
- $SF = 0.881 * MFD * (1 + 5 * [CVD\%/100]^2)^{1/2}$
- For a given MFD, spinnability \uparrow as CV \downarrow

Coarse Edge Micron (CEM)

- The number of microns above the MFD where the coarsest 5% of fibers lie
- Another statistic used by textile processors
- Smaller = more uniform

Degrees of medullation

(ASTM nomenclature, med, kemp, medullated fiber)

Longitudinal Section



(a)



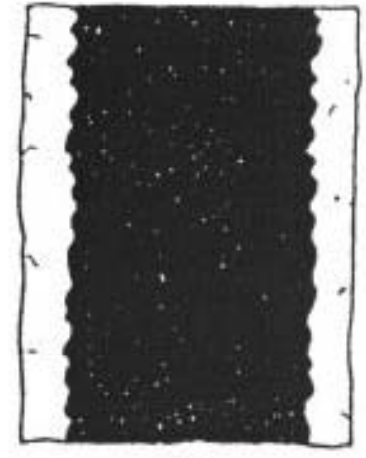
(b)



(c)



(d)



(e)

Cross Section



(a) Non-medullated



(b) Fragmented med fiber



(c) Interrupted med fiber



(d) Continuous med fiber



(e) Continuous kemp fiber

Microprojection



Dark and medullated fibers and contaminants (especially polypropylene) in white fleeces



OFDA 100 - Opacity



Medullation

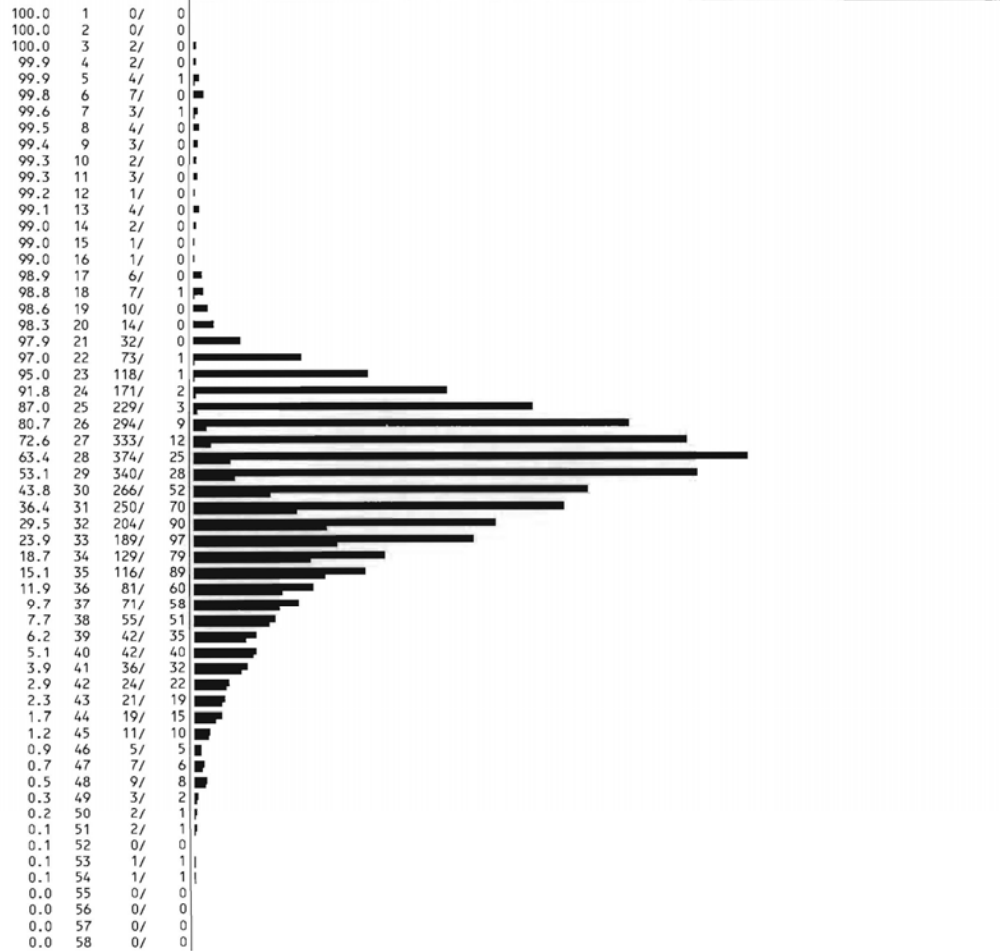
(IWTO [OFDA100] nomenclature)

- Total medullated fibers
- Flat fibers
- Objectionable fibers
- Units: per 10,000 or %
- AFD, SD of medullated fibers
- White and pastel fibers only

Texas Agricultural Experiment Station

Date : 18Nov04 Mean = 29.50 u
 Sample ID : 024L SD = 5.64 u
 Description : S CV = 19.1 %
 Lot/Client : TAMU Sample size = 3627
 Operator : FP Spin fineness= 28.3 u
 5% of fibres = 10.6 u above mean. Comfort factor= 63.6 %
 Num med= 929 (2561/10K) inc 0flat, 482obj/10K Mean opacity= 66.6 [16.1] %
 Mean med diam= 35.0 [5.4] u % med by vol= 35.7%, by wt= 23.8%
 Op num/10K>= 80 82..100: 2561 2396 2225 1980 1668 1337 943 496 229 110 72
 Obj/10K= >0 >50 >100 >150 >200um Flat/10K= >0 >50 >100 >150 >200um
 482 6 3 0 0 0 0 0 0 0 0
 Curve= 32.9 [23] deg/mm Curve number = 2397

Along: num= 2435 Mn= 29.5 [5.2] Sd= 0.56 [0.6] Min= 28.6 [5.2] blob= 0.90 [0.8] % Sml= 0.60 [0.3] % Lge= 0.29 [0.7] %
 OFDA030:2.12 Cal: D=5.1397*WH -2.69, wV= 1.4708*wH+ -0.08, DkFlash= 70.5
 cum.% mic count/ med 54 109 163 218 272 326 381 435 490 544





0.5	63	1/	1
0.5	64	6/	6
0.3	65	2/	2
0.3	66	1/	1
0.2	67	1/	1
0.2	68	2/	2
0.2	69	0/	0
0.2	70	2/	2
0.1	71	1/	1
0.1	72	0/	0
0.1	73	1/	1
0.1	74	1/	1
0.1	75	0/	0
0.1	76	0/	0
0.1	77	1/	0
0.0	78	0/	0
0.0	79	0/	0
0.0	80	0/	0
0.0	81	0/	0
0.0	82	0/	0
0.0	83	0/	0
0.0	84	0/	0
0.0	85	0/	0
0.0	86	0/	0
0.0	87	0/	0
0.0	88	0/	0
0.0	89	0/	0
0.0	90	0/	0
0.0	91	0/	0
0.0	92	0/	0
0.0	93	0/	0
0.0	94	0/	0
0.0	95	0/	0
0.0	96	0/	0
0.0	97	0/	0
0.0	98	0/	0
0.0	99	0/	0
0.0	100	0/	0
0.0	101	0/	0
0.0	102	0/	0
0.0	103	0/	0
0.0	104	0/	0
0.0	105	0/	0
0.0	106	1/	1
0.0	107	0/	0
0.0	108	0/	0
0.0	109	0/	0
0.0	110	1/	1

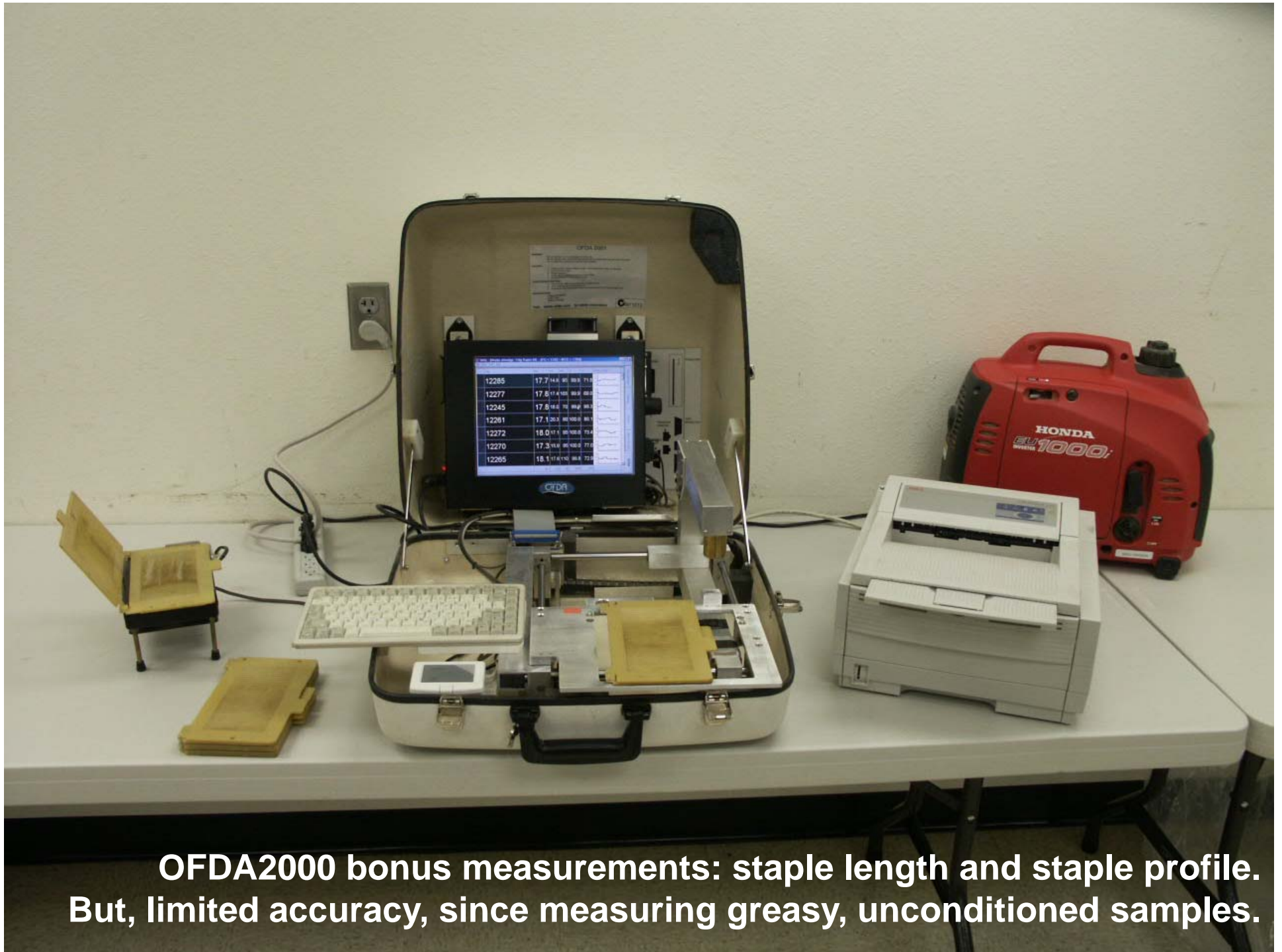


μm



Number of fibers



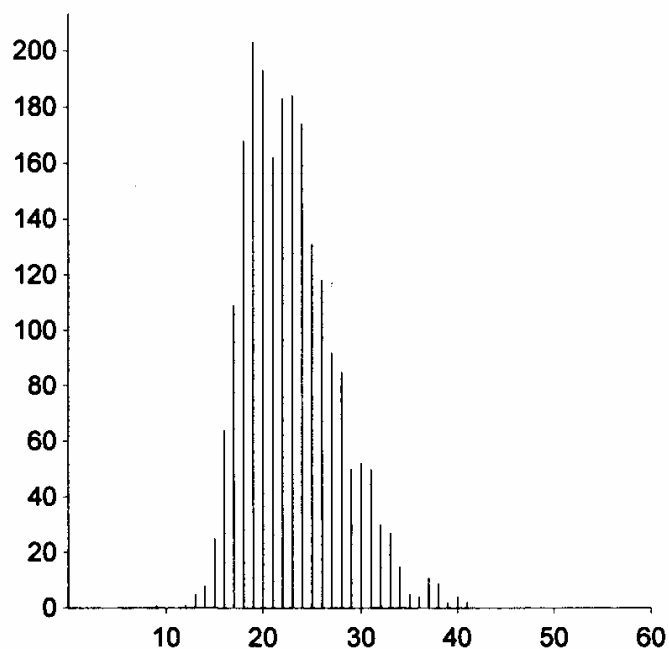


Staple Profile (OFDA2000 only)

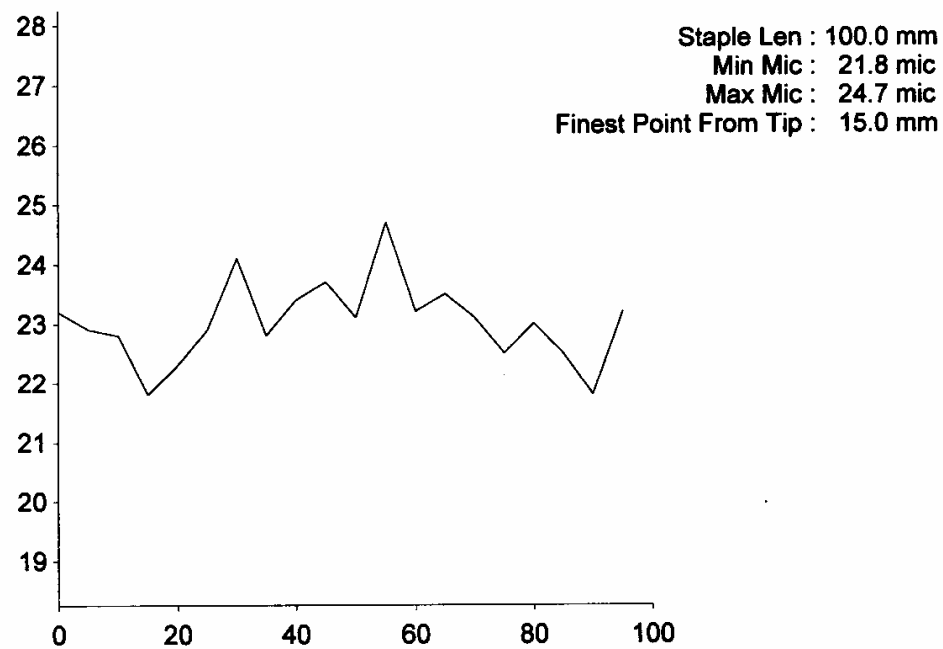
- **Fiber diameter measured along the staple**
- **Left side tip, right side base of staple**
- **Can see how MFD changes during the growing season.**

Histogram and staple profile

OFDA 2000 REPORT : SORTED BY TAG alpaca 2004 (16Records)



EarTag : 051L
Micron : 22.9 mic
SD : 4.7 mic
CV : 20.6 %
CF : 92.7 %
SF : 22.2 mic
CRV : 28.8 Dg/mm
SDC : 20.5 Dg/mm



Staple Len : 100.0 mm
Min Mic : 21.8 mic
Max Mic : 24.7 mic
Finest Point From Tip : 15.0 mm

Staple profile (contd.)

FPFT – Finest Point From Tip

Used to indicate where the MFD is the smallest and most likely to break during processing

MFE – Mean Fiber Ends

MFD at the ends of the staple

Relationship to comfort factor?

Minimum and Maximum MFD along staple

Excellent for selection purposes

% fibers < 15 microns

Staple profile (contd.)

- **Drastic changes in diameter can cause a weakness in the staple strength and can impact processing ability (breaks).**
- **Use the information to make management decisions to grow sound fiber**
 - **Shearing in relationship to parturition, lactation, etc.**
 - **Supplemental feeding strategies**

Airflow (WIRA)



- Measures flow of air through fiber sample
- Indirect measurement of AFD
- Does not measure SD, CV, curvature, or medullation.

Resistance to Compression



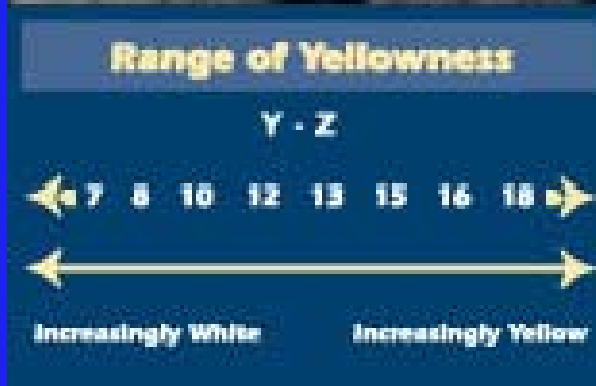
Colorimeter

Tristimulus values

Whiteness

Yellowness

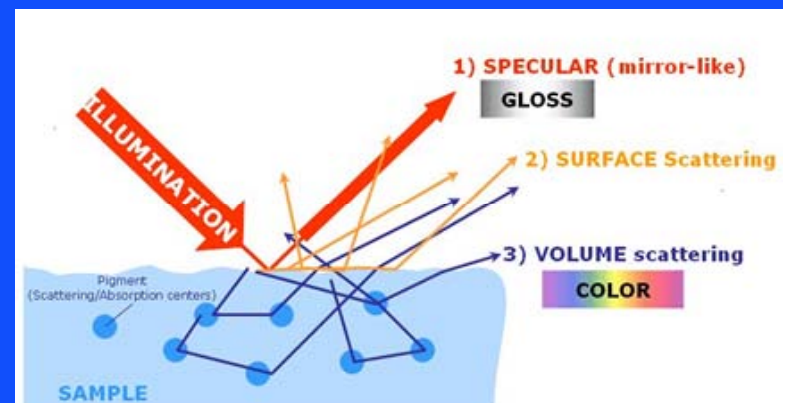
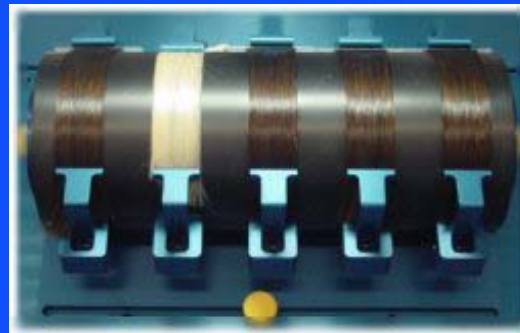
Brightness





Luster

- Goniophotometer. Single fibers, slow, expensive.
- Opacity (OFDA 100) and NIRS.
- SAMBA Hair System. Very promising.



Of great interest to breeders (but not the textile industry)

- **Body weight**
- **Fleece weight**
- **Fiber density (fibers per unit area of skin)**

Fibers per unit area

- Traditionally determined using histological / staining methods. Not particularly accurate and requires removal of multiple skin samples using trephine.
- However, skin sections capable of revealing additional information.

Fibers per unit area

- **Alternatively, and less invasively, a known area can be shorn from the mid-side.**
- **Knowing staple length, clean weight, average fiber diameter, and density of alpaca fibers, can calculate fibers/unit area.**

Accuracy of objective measurements

- Don't get carried away with the second number after the decimal place!!

95% confidence limits

- Fiber base (clean yield): 1 to 2%
- VM Base: 0.1 to 2%
- MFD: 0.2 (15 micron) to 0.9 (40 micron)
- Staple length: 5 mm
- Staple strength: 6 N/ktex

Current research objectives

1. Develop and evaluate *near-infrared reflectance spectroscopy* and *automatic image analysis* for more rapid, less expensive, objective evaluation of animal fibers.
2. Use objective measurements to improve fiber and / or meat production, quality, and income to producers through improved selection, nutrition, management, and marketing efficiency.

I. Current projects at the Wool and Mohair Research Lab, Texas AgriLife Research, San Angelo

- Near-infrared reflectance spectroscopy for measuring clean yield and fiber properties of raw wool and mohair.



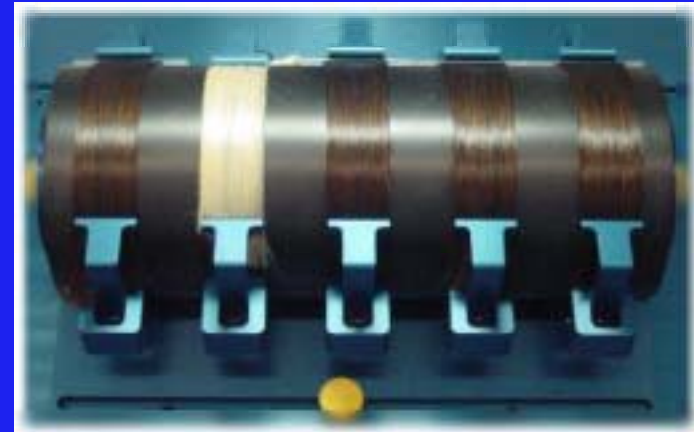
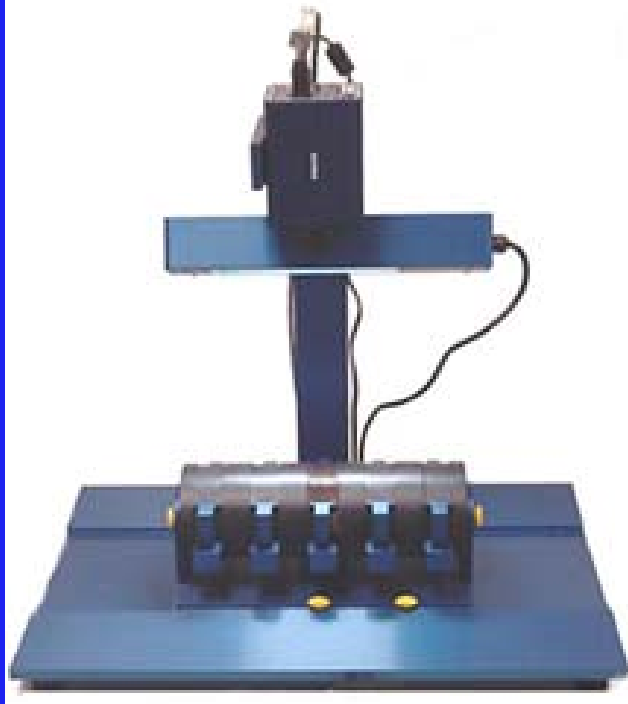
NIRS Programs

- **Monitoring juniper consumption in free-ranging goats.**
- **Monitoring algae growth.**
- **Measuring “energy content” of cattle manure from feedlots.**
- **Estimating average fiber diameter directly on Angora goats.**
- **Estimating protein and energy content of forages and feeds.**

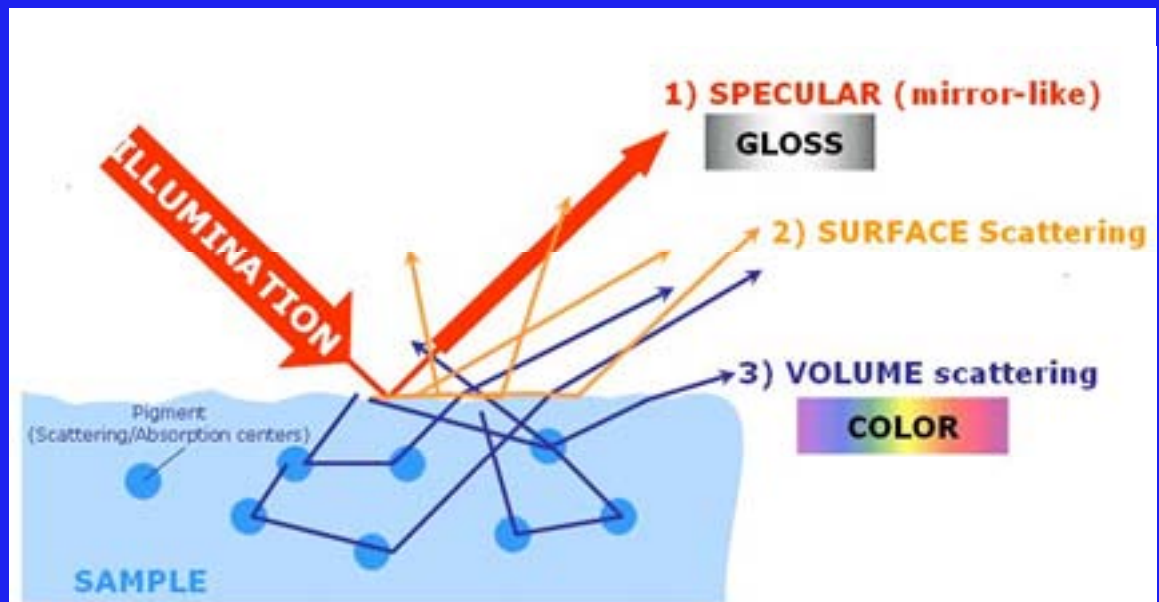
Current projects at the Wool and Mohair Research Lab, Texas AgriLife Research, San Angelo

- Using automatic image analysis (OFDA2000) to measure fiber characteristics on the ranch





The SAMBA System (AIA)
for measurement of fiber
luster



Current projects at the Wool and Mohair Research Lab, Texas AgriLife Research, San Angelo

- **Comparison of Texas Rambouillet with Australian Merino F1 crosses**



Current projects at the Wool and Mohair Research Lab, Texas AgriLife Research, San Angelo

- Rambouillet ram and Angora goat central performance tests



Kuebel 1830, Fritz Kuebel jr. and David Steinberg

Current projects at the Wool and Mohair Research Lab, Texas AgriLife Research, San Angelo

- Genetic selection to improve the use of goats to manage juniper



Current projects at the Wool and Mohair Research Lab, Texas AgriLife Research, San Angelo

- Genetic selection to develop a more profitable dual-purpose (fine wool and meat) sheep. The Texas Rambouillet Superior Genetics Cooperative Breeding Program / National Sheep Improvement Program.



Long-term, low intensity project with alpacas

- Evaluation of alpaca castrates and dogs as guard animals for sheep and Angora goats



Nutrition effects on fiber properties

- Numerous projects being conducted by Dr. Whitney...juniper, distillers dried grains, etc. in sheep and goat diets.
- All have a fiber component.



Animal fiber program

- **We recognize the great need to increase sheep and goat numbers before excessive infrastructure is lost.**
- **Develop technologies and / or animals capable of increasing producers' income.**

Service work for breeders

- Provide measurements on individual animal fleeces and technology that permits producers to compete better in world markets.
- Small scale scouring.







Questions?