Student's z, t, and s: What if Gosset had R?

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OUTLINE

VOLUME VI MARCH, 1908 No. 1

BIOMETRIKA.

THE PROBABLE ERROR OF A MEAN.

BY STUDENT.

William Sealy Gosset, 1876-1937

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Annals of Eugenics
1939

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MR. W. S. GOSSET Obituary, The Times, 1937

THE INTERPRETATION OF STATISTICS

“E.S.B." writes:-

My friend of 30 years, William Sealy Gosset, who died suddenly from a heart attack on Saturday, at the age of 61 years, was known to statisticians and economists all over the world by his pseudonym “Student,” under which he was a frequent contributor to many journals. He was one of a new generation of mathematicians who were founders of theories now generally accepted for the interpretation of industrial and other statistics.

...

E.S.B.: Edwin Sloper Beaven (1857-1941): one of leading breeders of barley in first half of 20th century. 1894; purchased 4 acres of land at Boreham just outside Warminster & began to carry out experimental trials of barley. Associated with Arthur Guinness, Son & Co who took over his maltings and trial grounds after his death.

The eldest son of Colonel Frederic Gosset, R.E., of Watlington, Oxon, he was born on June 13, 1876. He was a scholar of Winchester where he was in the shooting VIII, and went up to Oxford as a scholar of New College and obtained first classes in mathematical moderations in 1897 and in natural science (chemistry) in 1899. He was one of the early pupils of the late Professor Karl Pearson at the Galton Eugenics Laboratory, University College, London. Over 30 years ago Gosset became chief statistician to Arthur Guinness, Son and Company, in Dublin, and was quite recently appointed head of their scientific staff. He was much beloved by all those with whom he worked and by a select circle of professional and personal friends, who revered him as one of the most modest, gentle, and brave of men, unconventional, yet abundantly tolerant in all his thoughts and ways. Also he loved sailing and fishing, and invented an angler's self-controlled craft described in the *Field* of March 28, 1936. His widow is a sister of Miss Phillpotts, for many years Principal of Girton College, Cambridge.

March 2, 1938

Dear Mrs Gosset,

I am preparing an obituary of Mr Gosset for the Annals of Eugenics, and should be glad to publish therewith a photograph of him if you could let me have one which you would judge suitable for this purpose.

Yours sincerely,

http://digital.library.adelaide.edu.au/coll/special//fisher/

March 8th 1938

DAVAN HOLLOW
DENHAM
BUCKS

Dear Dr Fisher

Thank you for your letter. Unfortunately my husband would never consent to be photographed during recent years. I have had some snapshots enlarged, but they are not sharp enough to be of any use for reproduction.

I have a fairly good photo of him taken about 1908, but I suppose that would not do?

My husband's brother who lives in Calcutta, sent me a cutting from an Indian paper, giving your speech at the Congress, & it was a great pleasure to me to read in it your tribute to 'Student's' work.

Yours sincerely
Marjory Gosset

The Gossets. . . [from Burke: *The Landed Gentry*]

- Of “Norman Extraction”
- **Coat of arms:** D’àgur, à un annulet d’or, et trois Goussés de fèves feuillées et tigées, et rangées, en pairle de même; au chef d’argent, chargé d’une aiglette de sable.
- 1555: Adopted Protestant faith $\rightarrow$ name removed from roll of nobles.
- 1685: Revocation of Edict of Nantes $\rightarrow$ Jean Gosset, a Huguenot, moved to Island of Jersey.
- Some of Jean Gosset’s family settled in England.

`http://www.geocities.com/Heartland/Hollow/9076/FOGp1c1.html`

http://www.guinness.com/

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T. B. Case becomes the first university science graduate to be appointed at the GUINNESS brewery.

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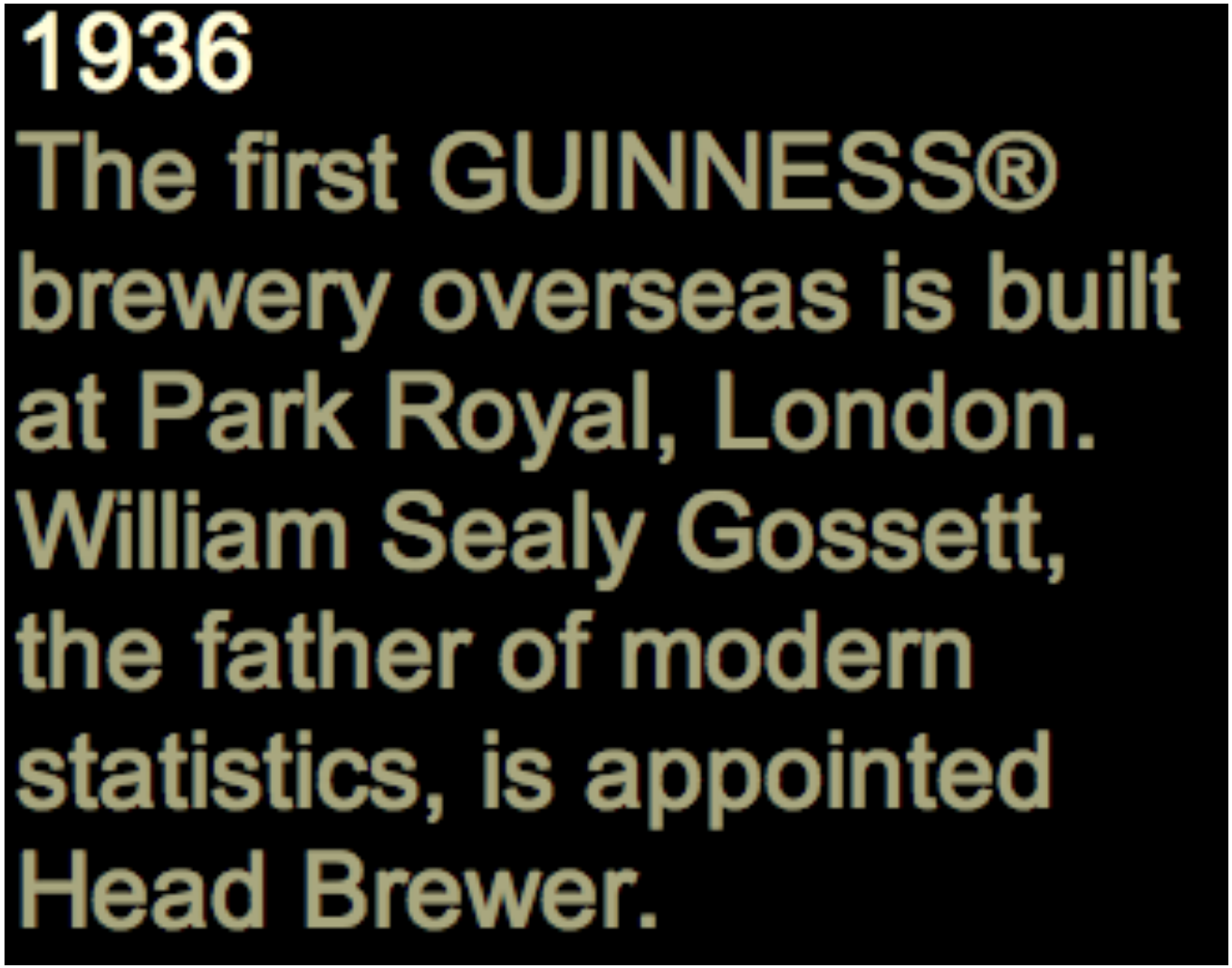

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Gosset's introduction to his paper

"Usual method of determining the probability that μ lies within a given distance of $\bar{x}$, is to assume ..."

$$\mu \sim N(\bar{x}, s/\sqrt{n}).$$

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Sampling distributions studied

$$\bar{x} = \frac{\sum x}{n}\ ; \qquad s^2 = \frac{\sum (x - \bar{x})^2}{n}.$$

"when you only have quite small numbers, I think the formula with the divisor of $n - 1$ we *used to use* is better"

... Gosset letter to Dublin colleague, May 1907

Doesn't matter, "because only naughty brewers take n so small that the difference is not of the order of the probable error!"

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Three steps to the distribution of z

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- Derived first 4 moments of s^2.
- Found they matched those from curve of Pearson's type III.
- "it is probable that that curve found represents the theoretical distribution of s^2." Thus, "although we have no actual proof, we shall assume it to do so in what follows."

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- "*No kind of* correlation" between $\bar{x}$ and s
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[pdf’s of s and z “are compared with some actual distributions”]

Before I had succeeded in solving my problem analytically, I had endeavoured to do so empirically.

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The measurements were written out on 3000 pieces of cardboard, which were then very thoroughly shuffled and drawn at random.

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The difference between the mean of each sample and the mean of the population was then divided by the standard deviation of the sample, giving us the z of Section III.

This provides us with two sets of 750 standard deviations and two sets of 750 z's on which to test the theoretical results arrived at.

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Inside cover of one of Gosset's notebooks...

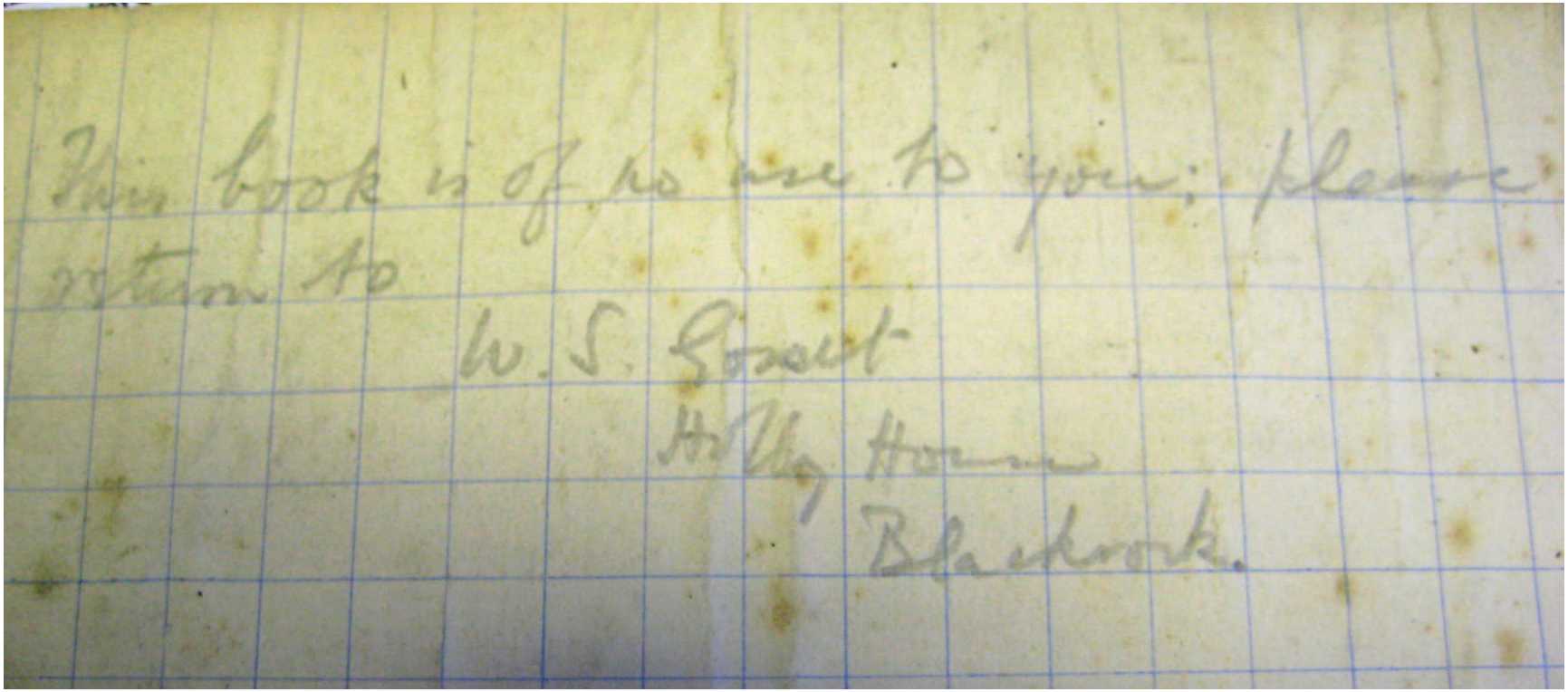

photo courtesy of Elizabeth Turner LSHTM, and UCL archives.

Macdonell's data

See HANDOUT & WEBSITE

Our simulations, 100 years later

- Reproduced means and sd's reported by Macdonell.
- Repeated Gosset's procedure to create 750 samples.
- Occasionally, all 4 persons from same 1" bin $\rightarrow s = 0$. Replaced $z = \pm\infty$ by $\pm$ largest observed $|z|$.
- X^2 goodness of fit statistic for 750 s/σ, and 750 z values.
- Repeated procedure 100 times:- 100 X^2 values :- check repeatability of Gosset's X^2 statistics; cards sufficiently shuffled?
- Single set of 75,000 samples of size 4, *sampled with replacement*, and with *Scotland Yard precision* (1/8 of 1"). How much more smooth/accurate might Gosset's empirical frequency distribution of s have been?

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RESULTS: his and ours

Shuffling:

	No. samples/750 with $s = 0$							
	0	1	2	3	4	5		All
Ours:	21	41	17	16	4	1		100
Gosset's:				1				1

Gosset's double precautions – very thorough shuffling *and* drawing cards at random – appear to have worked.

Unlike the 1970 U.S. draft lottery for military service in Vietnam

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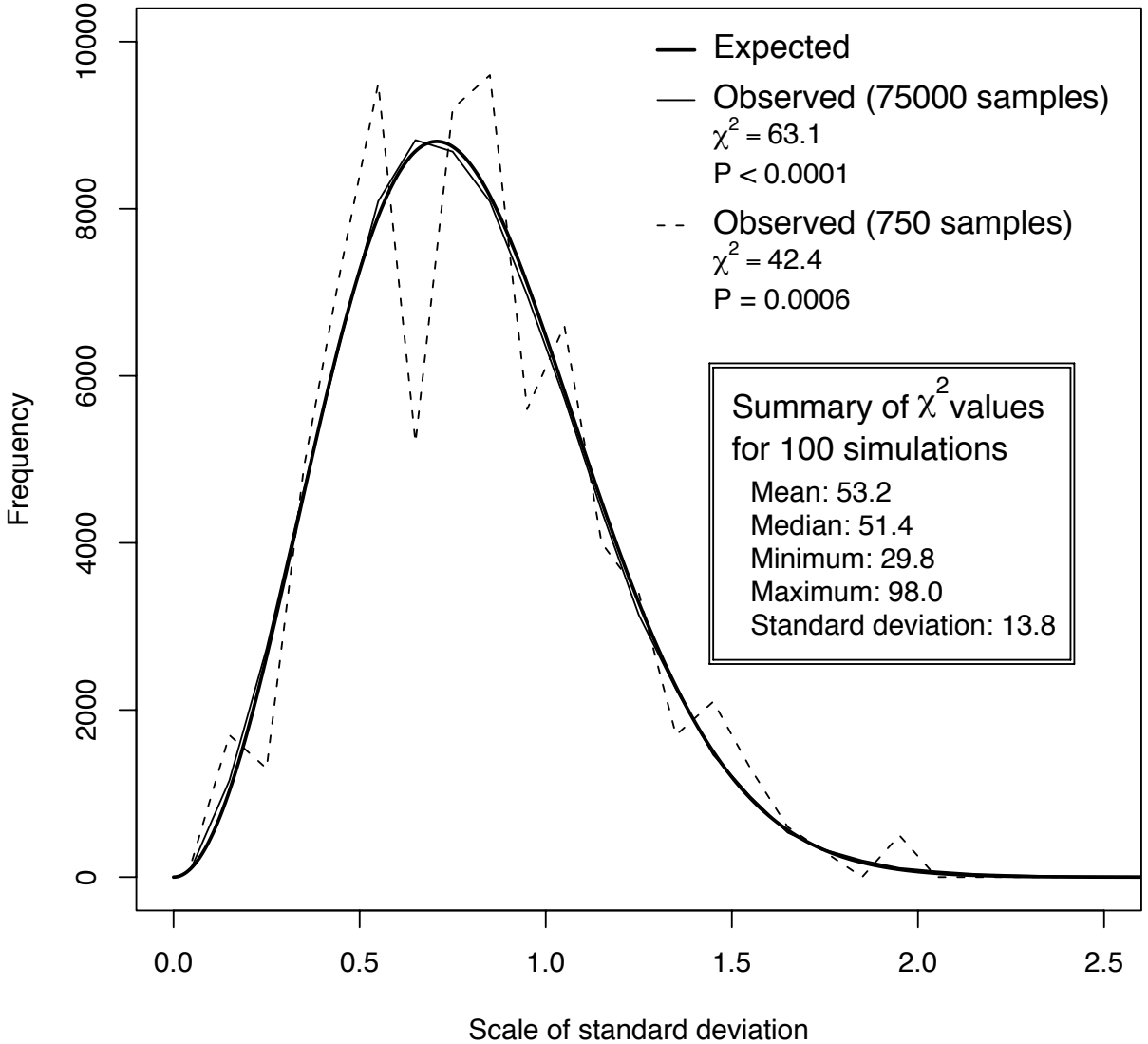
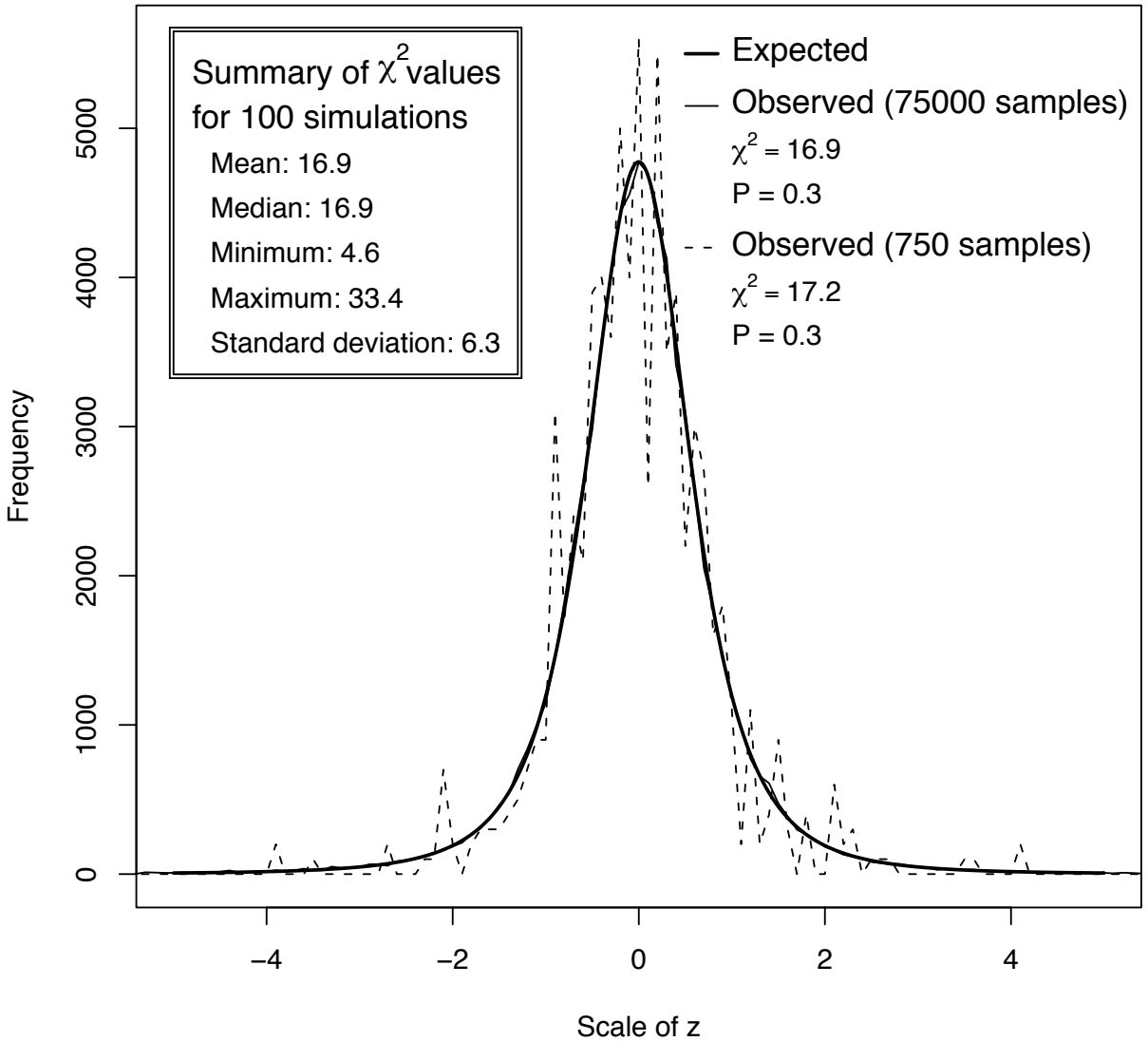
Distribution of s/σ



Dotted line: Sample statistics obtained from one set of 750 random samples generated by Gosset's procedure.
Inset: distr'n of 100 X^2 statistics (18 intervals).
Thin solid line: distr'n of statistics obtained from 75,000 samples of size 4 sampled with replacement from 3000 heights recorded to nearest 1/8".

Distribution of z



Dotted line: Sample statistics obtained from one set of 750 random samples generated by Gosset's procedure.

Inset: distribution of 100 X^2 statistics (15 intervals).

Thin solid line: distr'n of statistics obtained from 75,000 samples of size 4 sampled with replacement from 3000 heights recorded to nearest 1/8".

If Gosset had R :

"Agreement between observed and expected frequencies of the 750 s/σ's was not good". He attributed this to coarse scale of s.

Distribution of our 75,000 s/σ values also shows pattern of large deviations similar to those in table on p. 15 of his paper.

Scotland Yard precision and today's computing power would have left Gosset in no doubt that the distribution of s which he "assumed" was correct was in fact correct.

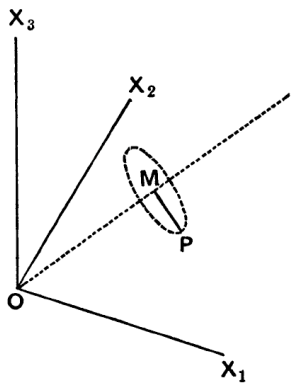
Grouping had not had so much effect on distr'n of z's: "close correspondence between the theory and the actual result."

FOR...

- Description of remainder of 1908 article
- Early extra-mural use of Gosset's distribution
- Fisher's geometric vision
- Fisher and Gosset , and transition $z \rightarrow t$

SEE..

- SLIDES FROM LONGER VERSION OF TALK
- ARTICLE in *The American Statistician*
- `http://www.epi.mcgill.ca/hanley/Student`



Triumphator A ser 43219

http://www.calculators.szrek.com/

Millionaire Ser 1200

To students of statistics in 2008 ... (I)

Fisher1939:

- "of (Gosset's) personal characteristics, the most obvious were a clear head, and a practice of forming independent judgements."
- The other was the importance of his work environment: "one immense advantage that Gosset possessed was the concern with, and responsibility for, the practical interpretation of experimental data."

Gosset stayed very close to these data.

We should too!

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- The other was the importance of his work environment: "one immense advantage that Gosset possessed was the concern with, and responsibility for, the practical interpretation of experimental data."

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We should too!

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The quality of writing – and statistical writing – is declining.

Today's students – and teachers – would do well to heed E.S. Pearson's 1939 advice regarding writing and communication.

E.S. Pearson on Gosset's 'P.E. of Mean' paper...

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