

Walter Sutton and the Chromosome Theory of Heredity

The dawn of the twentieth century was very auspicious for biology. The laws of heredity, proposed in 1865 by Gregor Mendel but unfortunately consigned to obscurity, were rediscovered independently by Hugo de Vries, Carl Correns and Erich von Tschermak in the year 1900. The rediscovery was the beginning of a string of remarkable syntheses. Walter Sutton, a versatile genius, was one of the earliest to discern the link between the abstract Mendelian factors of heredity and the tangible structures known as chromosomes observed by cytologists. The two seminal papers he published in 1902 and 1903 helped found the new discipline of cytogenetics by bridging the established field of cytology and the emerging study of heredity.

To fully appreciate Sutton's contributions in establishing the physical basis of heredity, one has to travel back in time to the second half of the 19th century. Though Mendel's laws were in oblivion, there were several significant conceptual advances being made in biology. The cellular basis of life had been established and cytologists had followed the details of the complex steps involved during cell division and fertilization. The role of the cell nucleus in fertilization was becoming increasingly apparent. The dance of the "coloured bodies" or chromosomes within the nucleus was documented during cell division. But the significance of their presence was unknown. Wilhelm Roux, considered the father of experimental embryology, was one of the earliest to speculate in 1883 that chromosomes may have significance in terms of heredity. The other intellectual giant at that time was August Weismann, who was the first to recognize the separation of the germ cells (sperm and ovum) from the somatic cells. He proposed that heredity is exclusively a job associated with the germ cells and the soma has no role in it. This proposal led to the overthrow of the idea of inheritance of acquired characters, since any change to the somatic tissues cannot be transmitted to the next generation as they play no part in heredity. Weismann further developed Roux's idea of chromosomes and proposed that they remain intact during successive generations and are transmitted from one generation to the next through the germ cells, a close parallel to the abstract hereditary



factors of Mendel. However, Weismann wrongly assumed that the different chromosomes in the nucleus are equivalent and each chromosome had the complete genetic information of the organism.

The authoritative account of chromosomes and heredity in 1900 was the second edition of the classic book by Edmund B Wilson, *The Cell in Development and Heredity*. By this time, it was known that chromosome numbers are constant and mostly even in a given species, made up of the two sets one received from each parent. That chromosomes come in distinct pairs was however not appreciated. In this backdrop, the first link between a hereditary trait and chromosomes was made by Clarence McClung, an American cytologist working with grasshoppers. McClung could show the association of sex with the presence of a special set of accessory chromosomes called X chromosomes. This was followed by a series of important discoveries by the brilliant students of McClung, the first among them being Walter Sutton.

Walter Stanborough Sutton was born in 1877 in Utica, New York, in an influential family. His father, who was a lawyer and judge, moved the family to a ranch near Russell in Kansas to lead the life of a farmer when Walter was ten years old. Even at a young age, Walter demonstrated a great liking for gadgets and was fond of tinkering with farm machinery. As a result of his interest in mechanics, in 1896, he joined the engineering school at the University of Kansas. However, a bout of typhoid fever in the family and the death of his brother made him change his focus to medicine and within a year he enrolled for a pre-med programme at the university. McClung, whose pioneering work on grasshopper cytology was being established, was one of his teachers at the university and soon Sutton became his student, collaborator, and friend. Sutton was also an excellent sportsman and played basketball, a young sport hardly ten-years-old started by Dr. James Naismith, who was the coach of the university team. After finishing his undergraduate degree in 1900, Walter joined McClung's lab as a graduate student in zoology.

With his experience in farm fauna, Sutton could identify the large "lubber" grasshopper *Brachystola magna* as an ideal research material as the testes and the germ cells of the insect were large and easy to study. Soon he started making cytological preparations of the insect testes. It was in the



course of these studies that Sutton made the important connection between chromosomes and the abstract Mendelian factors. The choice of the lubber grasshopper was largely responsible for his success. In 1900, he wrote a paper in which for the first time he provided evidence for the individuality of chromosomes. This work became his master's dissertation and he received his MA degree in 1901. The same year, McClung's paper on the involvement of the X chromosome in sex determination was also published. It is interesting to note that though the two were colleagues who collaborated a lot, each never took credit for the work of the other and published individual papers. Shortly after completing his master's work, on the advice of McClung, Sutton moved to the laboratory of Edmund B Wilson at Columbia University in New York to continue his graduate studies. It was while in Columbia that he completed the work he started in Kansas and published his two seminal papers in 1902 and 1903 in the journal *Biological Bulletin*.

In the first of these two papers entitled 'On the Morphology of the Chromosome Group in *Brachystola magna*' (reproduced in the Classics section), Sutton provided clear evidence that the chromosomes come in distinct pairs and deduced that the two partners in a pair are derived from the two parents. This followed careful tracking of the chromosomes through successive cell divisions during spermatogenesis ("...in each succeeding metaphase, the same number and size relations of the chromosomes may be observed"). He concludes the clearly written paper with the striking sentence "I may finally call attention to the probability that the association of paternal and maternal chromosomes in pairs and their subsequent separation during the reducing division as indicated above may constitute the physical basis of the Mendelian law of heredity". These conclusions were re-enforced in the subsequent essay entitled 'The Chromosomes in Heredity' published in the following year. The two papers firmly established the cytological basis of heredity. Montgomery and Boveri, two renowned cytologists also reached similar conclusions independently. In the case of Sutton, who was a 'rookie' (beginner) in comparison, reaching such a profound conclusion with a short but thorough study was indeed remarkable. Though most of his peers accepted his results, Bateson and Morgan were among the sceptics who had to finally concede with mounting evidence in favour of the theory. Further



confirmation of the theory came from the elegant work by another student of McClung, Eleanor Carothers. By following the segregation of the accessory X chromosome, Carothers could show that the X chromosome was present in 50% of the spermatids (in the grasshopper, there is no corresponding Y chromosome) demonstrating Mendel's law of segregation. She could identify a variant insect in which one of the chromosomes in a pair was shorter than its partner. She could also show that the X chromosomes could segregate either with the shorter or the longer version of the autosome with equal probability, demonstrating the law of independent assortment.

It is remarkable that someone who made such a lasting contribution to genetics published only three papers on the subject! Walter Sutton never completed his graduate studies. After a brief stint in oil exploration in the Kansas oil fields, he went on to obtain his MD from Columbia and became a renowned surgeon. His pioneering spirit helped him to devise new surgical procedures, medical equipment and methods of administering anesthesia. During World War I, he served in the army medical corps in France, attending to wounded soldiers. After the war, Sutton came back to his home town. But his health was deteriorating and he was feeling tired often. He was suffering from appendicitis and needed surgery. Though surgery was performed on him, the appendix had ruptured and he never recovered. Sutton died on Nov.10, 1916, three days after the surgery. He was only 39 years old.

The life of this gentle and extraordinarily creative individual, who accomplished so much within a short career, making lasting contributions to diverse fields, will continue to inspire many generations to come.

Suggested Reading

- [1] A H Sturtevant, *A History of Genetics*, Harper and Row, New York, 1966.
- [2] E W Crow and J H Crow, *Genetics*, Vol.160, pp.1–4, 2002.
- [3] S R Nelson and P S Nelson, 2002. (www.kumc.edu/research/medicine/anatomy/sutton/)

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