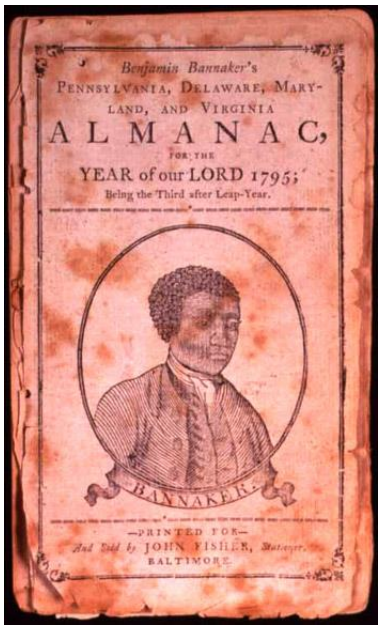
The following articles were published in the Spring 2016 edition (number 59) of SYMmetryplus, a 20 page journal that appears termly. It is published by The Mathematical Association.

Details at http://www.m-a.org.uk/symmetry-plus

BENJAMIN BANNEKER

From a humble background and largely self-taught, Benjamin Banneker became an accomplished mathematician and astronomer. He impressed his peers sufficiently to be selected as a member of the team who surveyed the land chosen by George Washington for the site of the capital city Washington. What was remarkable for the time was that Banneker was black.



Benjamin Banneker's maternal grandmother was Mollie Welsh, an English woman transported to America for stealing a bucket of milk from her employer (a cattle farmer); even though Molly claimed she was falsely accused. Molly served seven years' indenture on a tobacco plantation on the Patapsco River, after which she bought a farm and in 1692 purchased two slaves. One of these slaves was called Banna Ka, an intelligent and dignified man, reputedly the son of an African king; his name was subsequently altered to Bannaky and then Banneker. Mollie Welsh worked hard and became a successful farmer. She freed her two slaves and married Banneker almost immediately. They had four children, the eldest being Mary.

Mary Banneker also married a freed slave, Robert, from a nearby plantation. He took his wife's surname, and within a few years they were able to purchase a farm of around 120 acres, 10 miles from Baltimore. Robert and Mary had four children: one boy and three girls. Benjamin was the eldest, born on 9th November 1731. Benjamin was bright and his maternal grandmother taught him to read. Benjamin attended the small local school where he was the only black pupil. He read every avidly and, having exhausted the school's meagre library, he turned to observing everything around him, learning from nature and his community. Benjamin became famous locally for his vast expanse of general knowledge.

Benjamin's father died in 1759, leaving in his will 72 acres of the farm to Benjamin and his mother, and the remaining 28 acres split amongst his three daughters. Benjamin ensured that the farm prospered - it was well stocked, with fruit trees, an apiary and a strong herd of cattle. But Benjamin was more than just a farmer. His rapidity of solving complex mathematical puzzles was well-known - scholars in different parts of the country frequently posed him problems, which he answered promptly and correctly.

Having only seen a pocket watch, at age 30, Banneker built a clock, carved from wood using a pocket knife. It worked perfectly for the rest of his life. Such skill impressed the Ellicotts, a Quaker family from Pennsylvania who had arrived in Maryland in 1772, looking for a site for their flour mills. George Ellicott was also a mathematician and astronomer, and he and Benjamin became friends for life.

While building their mills, the Ellicotts purchased most of their workmen's provisions from Banneker's farm. The store that they built as part of the mill site soon became a meeting point for the whole community, to discuss the local news. Banneker won the respect of the audience with his clear and intelligent contributions to these discussions.

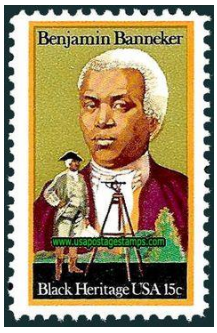
George Ellicott lent Banneker a number of mathematical texts and instruments, which Banneker used for self-study. Among these were books on astronomy and Banneker soon became totally absorbed by the stars. Lying on the

ground he would star-gaze until the small hours of the morning. By 1789 Banneker was so proficient in astronomical calculations that he accurately predicted a solar eclipse.

Banneker's reputation as an astronomer and mathematician reached George Ellicott's cousin, Major Andrew Ellicott, who invited Banneker in February 1791 to join his surveying team commissioned by President George Washington to lay out the boundary of the Federal territory, later known as the District of Columbia. Banneker unfailingly spoke of the kindness and courtesy of the team towards him. His duties included taking measurements of the land as well as regular observations of the Sun and the stars, which he used to ensure the accuracy of the survey's timepiece. The cold winter weather took its toll on Banneker's health, however, and in April 1791 he returned home to his farm.

In 1792, Banneker compiled an Almanac, entitled "Benjamin Banneker's Pennsylvania, Delaware, Maryland and Virginia Almanack and Ephemeris, for the Year of Our Lord, 1792; Being Bissextile, or Leap-Year, and the Sixteenth Year of American Independence". The almanac met with wide acclaim and a member of the Maryland Senate, James McHenry, organised its publication. In McHenry's letter to the publishers, while perhaps he embroidered the truth about Banneker's background, he spoke of Banneker's work being completely independent of any other person's contribution and only from texts loaned to him by George Ellicott. McHenry paid tribute to Banneker's cultural heritage, saying that his accomplishment was all the greater for having had a lesser educational experience than many of his white peers.

The almanac was well received by the most distinguished of American astronomers. Banneker sent a first edition to Thomas Jefferson, then Secretary of Science in Washington's cabinet, in order to promote the intellectual ability of African-Americans. He apologised in his letter for approaching Jefferson directly but said he wanted to bring to his attention the ability of his race and put to rest the false ideas and opinions that were prevalent at that time.



Jefferson was impressed by both the publication and Banneker's letter, to which he replied very positively. He sent the almanac to Condorcet, secretary of the Paris Academy of Sciences, in recognition of its quality and what it represented in the struggle for equality across the world of African people. Both Banneker's letter and Jefferson's reply were published in Banneker's 1793 almanac, which met with international acclaim. Banneker's almanacs were published until 1797, although he continued to make all the necessary calculations for almanacs until 1802, and fragmentary calculations thereafter until his death. It is believed that the publications stopped because of the demise of the anti-slavery movement: being a staunch anti-slavery campaigner, Banneker faced violence and threats after 1797.

Wanting to pursue more intellectual activities without having to work the farm as well, in the 1790s Banneker decided to sell his farm. He negotiated a deal with George Ellicott, who bought the property but allowed Banneker to remain on the farm and also gave him a yearly allowance of £12. Banneker's wider pursuits included appealing to the US Government to devise a strategy for worldwide lasting peace after war was declared in 1793. He wrote pamphlets in support of the anti-slavery movement. He used mathematics to show that locust plagues recur every 17 years and wrote a dissertation on bees. As relaxation, Banneker used to sit under a tree near his house and play the flute or violin, or cultivate his small garden.

When Banneker's health started to decline, he made preparations for his death. He gave his feather bed to one of his sisters (within which many years later she discovered a purse containing his savings), and he gave instructions upon his death to return all the books George Ellicott had lent him, along with his work table, his almanacs and his letters to Jefferson. A few years later, on the afternoon of Sunday 9th October 1806, while quietly resting under a tree beside his cottage, he suddenly rose and tried to go for a walk. Only a short time later, he sank to the ground, helpless. A neighbour helped him home but Banneker died later that evening.

Banneker's sisters, Minta and Mollie, carried out Banneker's instructions immediately after his death. Their speed of action was fortuitous, since two days later, on the day of his funeral, Banneker's cottage burnt to the ground. All his

other possessions were lost, including his clock. Because of that fire very little survives of Banneker's actual mathematics, other than what had been given to George Ellicott. One journal survived, containing six puzzles and two pages of mathematical writing. Graham Hoare's note looks at three of these puzzles.

Banneker's contribution to astronomy and mathematics were commemorated in 1977 in Maryland, with an obelisk near to his unmarked grave in Oella, Maryland. In 1980 he was commemorated on a US postage stamp. A park was created in his memory in Baltimore in 1988, with a gallery featuring his contributions to astronomy and mathematics. In 2009 a replica of his log cabin was created in the park on the 278th anniversary of his birth.

Jenny Ramsden

BENJAMIN BANNEKER'S BRAINTEASERS

I have selected three puzzles, the first of which appears in mathematical texts from time to time.

1 A gentleman sent his servant with £100 to buy 100 cattle, with orders to give £5 for each bullock, 20 shillings for cows, and one shilling for each sheep; the question is to find what number of each sort he brought to his master. (Sheep as cattle generated some bleating!)

Representing the numbers of bullocks, cows and sheep by B, C and S, respectively we can derive two equations, the first based on numbers and the second on values in pounds. (Remember that there are 20 shillings in £1 in imperial coinage).

$$B+C+S=100 \qquad\qquad 5B+C+\frac{1}{20}S=100$$

At first it seems we cannot make progress since we have three unknowns but only two equations. Recall, however, the condition that the answers for B, C and S must be whole numbers. Why not subtract the equations? This gives

$4B-\frac{19}{20}S=0$, or $80B=19S$

Now 80 must divide S since no prime factor of 80 is a divisor of 19 which is prime. We leave the rest to the reader.

2 Banneker often presented his puzzles in poetic mode. The puzzle of the hound and the hare is a nice example:-

When fleecy skies have Cloth'd the ground
With a white mantle all around
Then with a greyhound Snowy fair
In milk white fields we Cours'd a Hare
Just in the midst of a Champaign
We set her up, away she ran,
The Hound I think was from her then
Just Thirty leaps or three times ten
Oh it was pleasant to see
How the Hare did run so timorously

But yet so very Swift that I
Did think she did not run but Fly
When the Dog was almost at her heels
She quickly turn'd, and down the fields
She ran again with full Career
And 'gain she turn'd to the place she were
At every turn she gain'd of ground
As many yards as the greyhound
Could leap at thrice, and She did make,
Just Six, if I do not mistake
Four times She Leap'd for the dogs three
But two of the Dogs leaps did agree
With three of hers, nor pray declare
How many leaps he took to Catch the Hare.

Unpacking the arithmetic from this we note that while the hare is taking 4 leaps the dog takes 3 whilst the length of a dog leap is $1\frac{1}{2}$ times that of the hare. Thus, the dog's speed is $\frac{9}{8}$ times that of the hare. At each turn the hare, sneakily it seems, gains 3 dog leaps, so the hare gains 18 dog leaps by turning. Given that the hare has 30 dog leaps advantage at the start the dog has to gain a total of 48 dog leaps so the dog catches the hare after it has made $9\times 48 = 432$ dog leaps. (9 leaps of the dog reduces by one the 48 leaps to be made up.).

3 A, B and C are discussing their ages. A states that if I subtract twice the fourth root of C's age from twice the cube root of B's age, I get the fifth root of my age. B states that the square root of my age equals a quarter of A's age. C states that the square root of my age is one greater than the square root of B's age. How old are A, B and C?

Banneker assumed that each age was an integer and since the fifth root of A's age was used, the only reasonable value of A was 32. Finishing this off is straightforward.

Graham Hoare