

# **Leonardo and the motion of fluids**

(water, air and blood)

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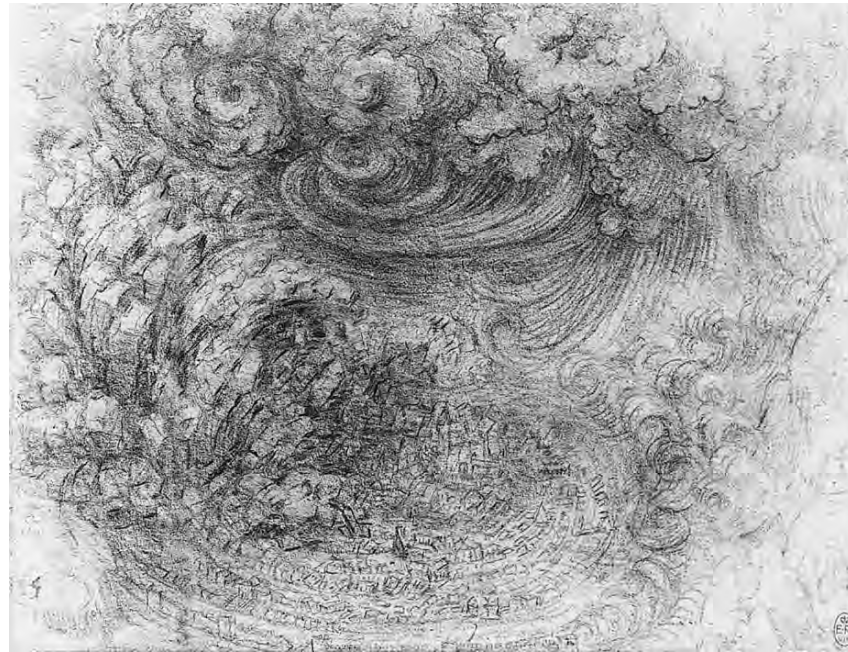


Plate 81 *A Deluge, with a Falling Mountain and Collapsing Town* (c. 1515), black chalk, Windsor, Royal Library (12378)

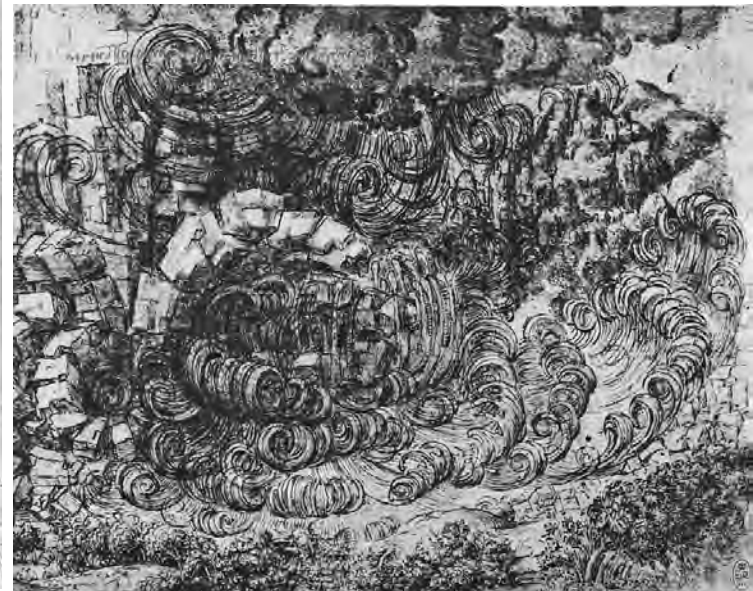


Plate 82 *A Deluge, Formalized* (c. 1515), black chalk, pen and ink, Windsor, Royal Library (12380)

Plate 80 *Studies of Hydrodynamic Turbulence* (c. 1508–9), pen and ink, Windsor, Royal Library (12660V)

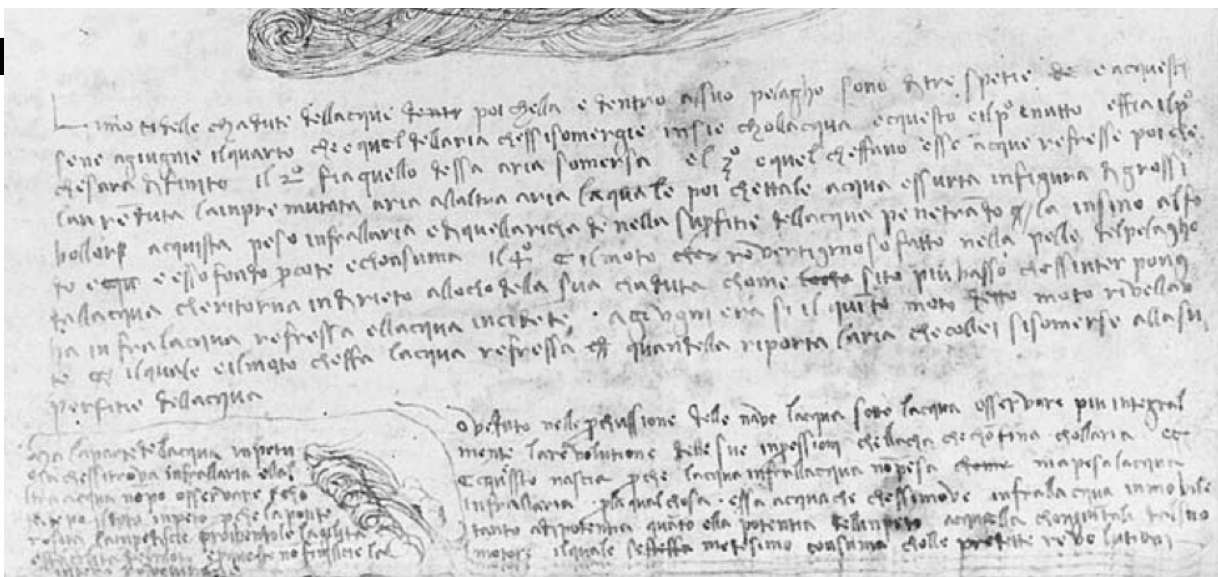


Plate 65 *The Trachea and Bronchi Studied in Isolation and a Study of Thoracic and Abdominal Organs* (c. 1508), black chalk, pen and ink, Windsor, Royal Library (15034V)

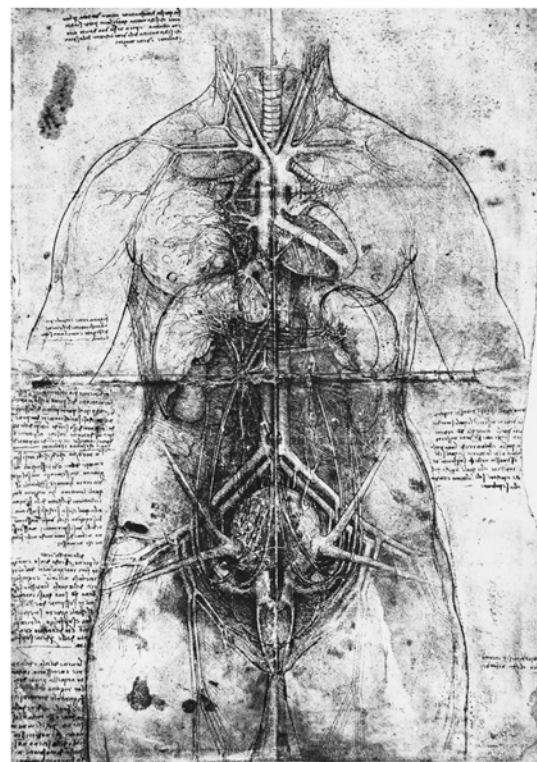


Plate 66 *Composite Study of the Respiratory, Vascular and Urino-genital Systems in a Female Body* (c. 1508), black chalk, pen and ink and wash, Windsor, Royal Library (12281)

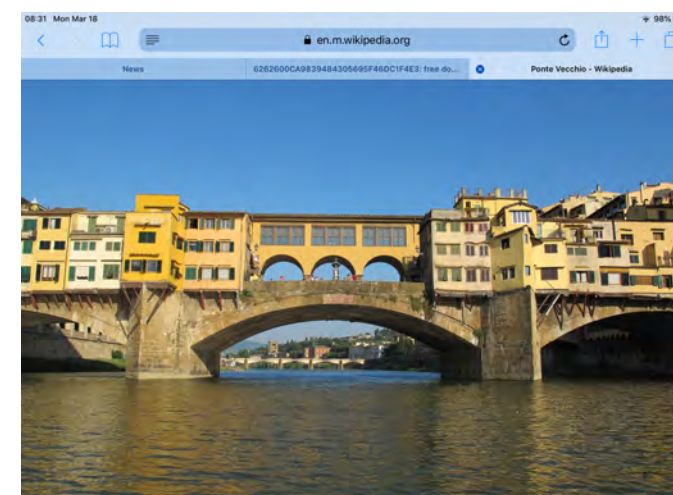


# Codex Atlanticus (Biblioteca Ambrosiana, Milano)

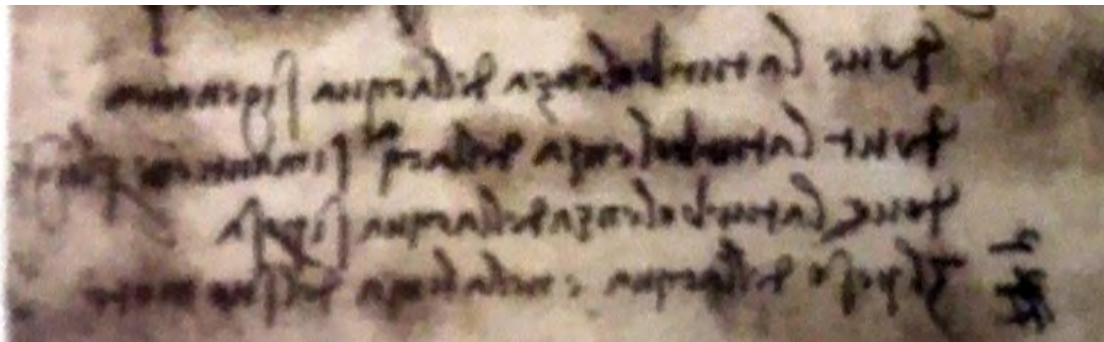


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DESEGNI DI MACHINE ET DELLE ARTI SECRETI ET ALTRE COSE DEI DI LEONARDO DA VINCI RACCOLTA DA POMPEO LEO



# Turbulence along the river Arno



In English

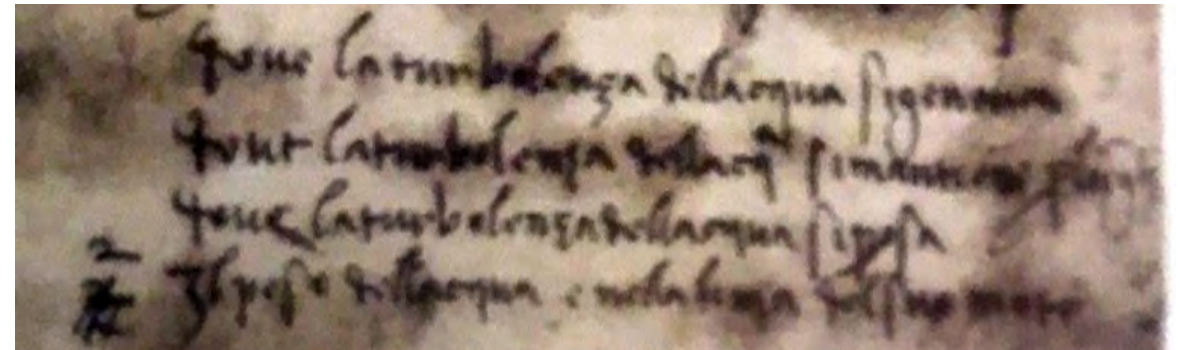
where the turbulence of water is generated  
where the turbulence of water maintains for long  
where the turbulence of water comes to rest

Modern phenomenological approach

Low Reynold number:  $R = LV/\nu \ll 1$

$$\frac{dU}{dt} = -\frac{\nu}{L^2}U$$

$$U(t) = U(0) e^{-\frac{\nu}{L^2}t}$$



In modern italian

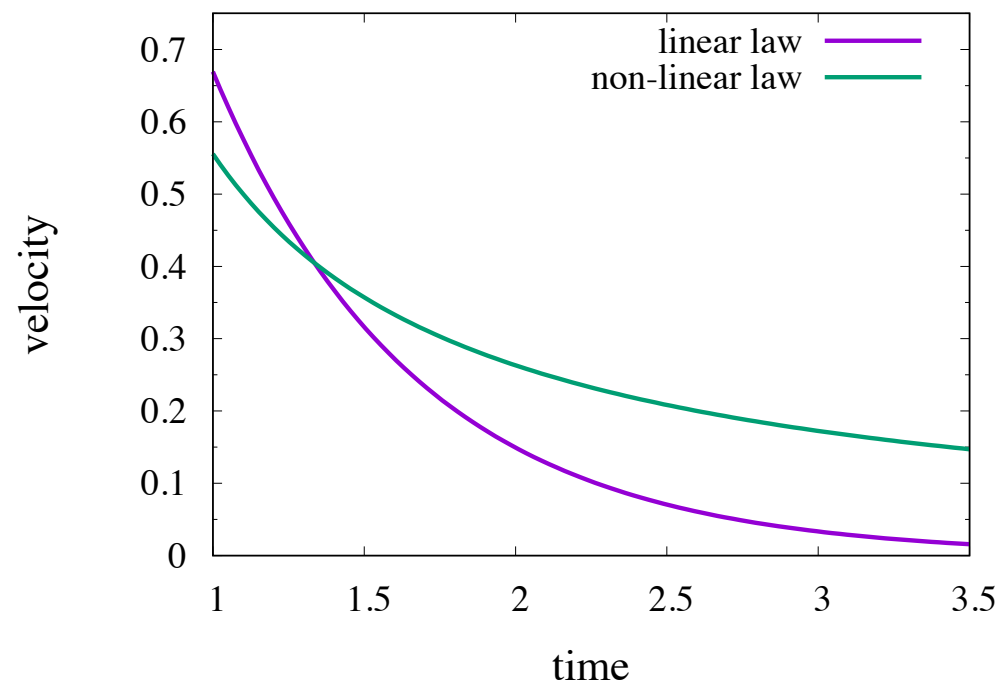
dove la turbolenza dell'acqua si genera  
dove la turbolenza dell'acqua si mantiene per lungo  
dove la turbolenza dell'acqua si posa

Phenomenological approach (Kármán 1938)

High Reynolds number:  $R = LV/\nu \gg 1$

$$\frac{dU}{dt} = -\frac{U}{L/U}$$

$$U(t) = \frac{L}{t - t_0}$$



Leonardo and the word “turbulence”...



# “Turbulence”. Leonardo and latin. “Omo senza lettere”. Leonardo, mathematics and hydrodynamics.

- Where did Leonardo find the word “turbulence”? In Latin ? Probably not.
- Leonardo liked to define himself as a man without literature (*Omo senza lettere*), that is a man without Latin.
- In the middle ages, in vulgar latin, that is the common speech used in France and Italy, *turbulent* designated the trouble makers. Stemming of course from the Latin *turba*, the disordered motion of a crowd.
- Although Leonardo understood very little Latin, he had a real passion for mathematics. His notebooks make this clear from the beginning: “Who is not a mathematician should not read the elements of my work.”
- At the time of Leonardo mathematics included mostly geometry and algebra. Leonardo preferred geometry naturally associated with his brush. According to Martin Kempf “Leonardo da Vinci. The Marvellous Works of Nature and Man” (2006), here is how Leonardo imagined the motions shown above (this text is mostly a translation of Leonardo’s own).
- *Running water has within itself an infinite number of movements which are greater or lesser than its principal course. This is proved by [watching] the things supported within two streams of water which are the same weight as the water.’ The revealed motions of such things were ‘sometimes swift, sometimes slow, and sometimes turning to the right and sometimes to the left, at one instant upwards and at another downwards, turning over and back on itself, now in one direction and now in another, obeying all the forces that have power to move it, and in the struggles perpetrated by the mobile forces always as the booty of the victor’*