POINTS OF VIEW

Arrows

Arrows are one of the most commonly used graphical devices in scientific figures. In the July 2011 issue of *Nature Methods* alone I counted nearly 300 instances of arrows; more than half of the figures contain them. Given the widespread use of arrows, it is worthwhile to take a closer look at this privileged class of diagrammatic form and how we might benefit from its use.

Arrows can be highly efficient instruments of visual communication because they guide us through complex information. Typically arrows are used to point out relevant features, order sequences of events, connect elements and indicate motion. In molecular biology, there are several conventions involving the arrow that are generally recognized (**Fig. 1a**). For example, an arrow with a right-angle line segment is understood as a transcription start site or promoter, and a short arrow placed parallel to a line usually indicates a PCR primer. Several other common conventions are shown in **Figure 1a**. But authors also use arrows to illustrate other concepts, some of which are easily understood, whereas others may be less intuitive.

In his thorough survey of diagrams Robert E. Horn documented hundreds of meanings for arrows, including metaphorical uses such as increases and decreases[1]. An arrow's geometric shape can tell us something about its purpose (**Fig. 1b**), but its meaning is refined and interpreted in context. Arrows are a special class of symbols that can have multiple meanings even when used in the same figure. A recently published figure has many arrows that are used to label parts, convey mechanical motion and show reagent flow (**Fig. 1c**).

When arrows are added to diagrams, they are most readily interpreted as conveying change, movement or causality (**Fig. 2a**). In one study, researchers asked college students to evaluate mechanical diagrams with and without arrows. Participants who saw diagrams

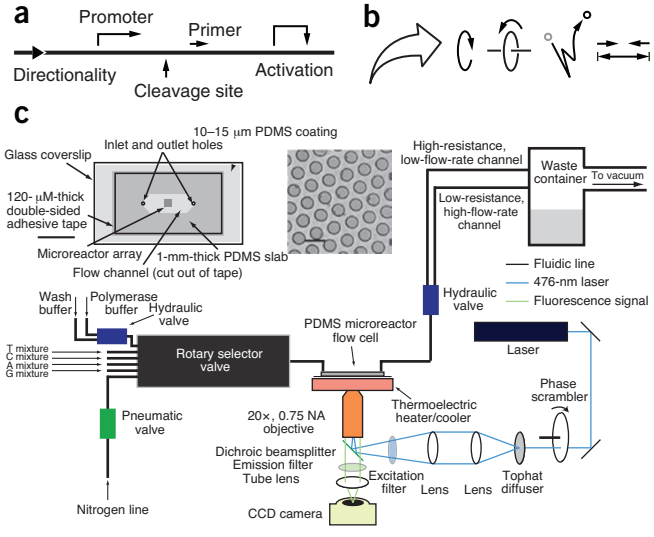

Figure 1 | Arrows in scientific diagrams. (**a**) Well-understood conventions in molecular biology indicated by arrows. (**b**) Arrows are defined loosely by their geometric shapes and more definitely in context. (**c**) A diagram with 19 arrows used as leaders, to indicate reagent flow and to show mechanical movement. Reprinted from *Nature Methods*[3].

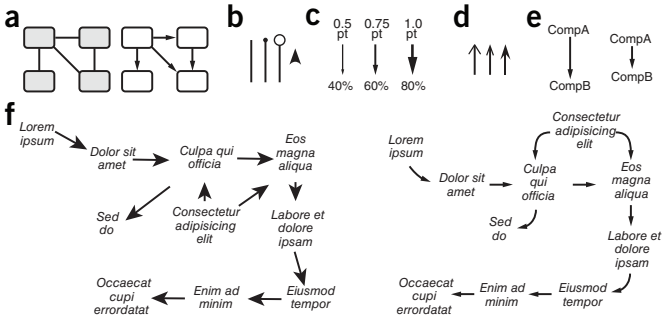

Figure 2 | Functional qualities of arrows. (**a**) The use of arrows versus lines as connectors suggests a certain functional relationship. (**b**) Alternatives to arrows as leader lines. (**c**) Reasonably sized arrows clearly indicate direction without being a distraction. (**d**) Trapped whitespace in 'open' arrowheads creates optical illusions that can attract unwanted attention. (**e**) Whitespace at the ends of the arrows makes them easy to discriminate from other content. (**f**) Orienting arrows in similar directions creates natural visual flow.

with arrows included twice as much functional information in their descriptions as those who saw diagrams without arrows[2]. Arrows are therefore most effectively used to focus attention on the functional relationships between elements rather than the elements themselves.

A goal in producing effective figures might be to use arrows sparingly and clearly. One way to do this is to reserve the use of lines with heads shaped like arrows for indicating direction or sequence and use other well-known graphical marks for other purposes. To emphasize the structure of a system—that is, spatial, as opposed to functional, inter-relatedness of the parts—we should use lines instead of arrows to connect the elements (**Fig. 2a**). For example, leaders are lines used to point at, or lead to, labeled or important parts of an illustration. Leaders used for labels should have either no head or only a bullet: either a small ball or open circle (**Fig. 2b**). One exception is the well-understood arrowhead commonly used in micrographs or other imaging to indicate salient features.

The arrow's distinctiveness comes from its asymmetric form. As such, arrows should be well-proportioned so that their directionality is easy to recognize but not be so big as to distract us from reading the content they intend to illuminate. I prefer Adobe Illustrator for drawing arrows because the software offers fine control of size and shape. For print publication, an arrow with a stem weight of 0.75 points and arrowhead scaled to 60% produces a balanced arrow (**Fig. 2c**). Also, I avoid open arrowheads (that is, the letter V on a stick) and those with sweeping wings because the trapped whitespace produces the optical illusion of 'sparkle', adding visual noise (**Fig. 2d**). Finally, arrows should be strung together as a continuous wireframe upon which to hang content. This can be achieved by avoiding sharp opposing arrow orientation and allowing for whitespace at the ends of the arrows (**Fig. 2e,f**).

Used most effectively, arrows are the 'verbs' of visual communication, describing processes and functional relationships. Next month, I will focus on layout.

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1. Horn, R.E. *Visual language: global communication for the 21st century* (MacroVU, Inc., Bainbridge Island, Washington, USA, 1998).
2. Hesier, J. & Tversky, B. *Cogn. Sci.* **30**, 581–592 (2006).
3. Sims, P. *et al. Nat. Methods* **7**, 575–580 (2011).

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