Behind the Ink: Innovations in the Printing Process

In today's world, dominated by computers, the printer is no longer a newfangled contraption, but instead a necessity that impacts our daily lives. Without its help, newspapers, textbooks, and magazines would all be nonexistent, and digital pictures could never make it out of the camera. The printer is beginning to transform the scientific community as well. Recent modifications to the printing process have led to breakthrough developments in the biological sciences, material sciences, and energy technology.

The Basics: Inkjet and Laser Printing

Inkjet and laser printers are the two most commonly used printers in modern homes and offices. In order to create the final image, inkjet printers use tiny droplets of liquid ink that are positioned extremely close together on the paper. The ink is dispensed from the print head, which is a device containing hundreds of nozzles for the ink to flow through (Tyson). The most common technique of dispensing ink is referred to as "thermal bubble" or "bubble jet" technology. In this process, heat is used to fire droplets of ink out of the nozzles. The heat is created by tiny resistors, which then vaporize the ink to create a bubble. As the bubble becomes larger, a small amount of ink is pushed out onto the paper. When the bubble "pops," a vacuum is created, and more ink is pulled from the ink cartridge into the print head (Tyson).

Unlike the inkjet printers, laser printers use static electricity. Static electricity is defined as an "electrical charge built up on an insulated object" (Harris). The major component of the laser printer is the photoreceptor, which is usually a revolving drum or cylinder with a positive electrical charge (See Figure 1). During the drum's revolution, the printer uses a laser beam to strike certain points across its surface (Harris). Any area of the drum hit by the beam loses its positive charge. This creates the electrostatic image that will eventually be recreated on the paper. Next, toner (a fine, black powder with a positive charge) is spread on the drum. Because opposite charges are attracted to each other, the toner will coat the negatively charged areas of the drum, but not the positively charged space. Thus, the positively charged areas will become the white space on the paper. Before the drum is ready to roll over the paper, it is given an even stronger negative charge in order to get rid of excess toner powder.

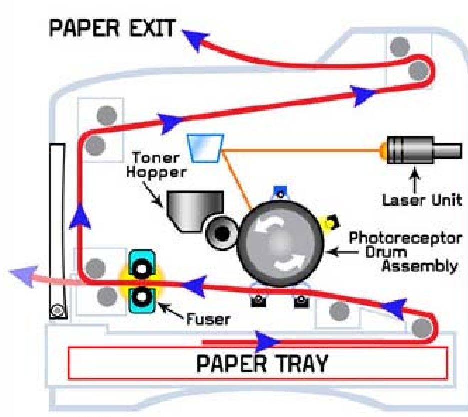

Figure 1: Laser Printer. The laser unit discharges certain points on the photoreceptor drum, and toner is spread evenly to create an image.

Inkless Printing

ZINK Imaging, which started as a company inside Polaroid, claims it has developed a process that would allow pictures to be printed without the use of ink (Hall). The technology is based on thermal printing, which uses heat to transfer color from a ribbon pressed onto the paper. In ZINK's printing technology, the photo paper is key. A white plastic sheet is used as the base, and thin layers of dye crystals are piled on top of one another. The crystals are layered starting with cyan on the bottom, magenta in the middle, and yellow on top. These dye crystals are clear at room temperature, and the molecules that compose the crystals are structured so that the crystal is transparent (Hall). The print heads are also modified so that when heat is applied, the "molecules change their physical orientation from a crystal to an amorphous glass" (Greene). Crystalline molecules have a definite melting point, but amorphous ones do not. This means that in order for the colors to be slowly released, the molecules must be in an amorphous structure.

Each print head contains 300 tiny heaters per square inch, and the temperature and time for each heater is carefully controlled. In order to bring out the yellow, for example, the heaters send out heat pulses at the highest temperature for the shortest amount of time. The cyan layer is activated using the lowest temperature for the longest period of time. For colors other than yellow, magenta, and cyan, the pulses are sent out in combinations (Greene). A quick, high-temperature pulse for yellow, followed by a longer pulse for cyan would result in green. Because the process is inkless, digital cameras with ZINK's technology would also act as printers, and have the capability to print pictures without the help of any other devices or docking stations.

Scientific Advancements

Cells

For years, scientists have had the capability of printing stem cells for research purposes. Now, modified ink-jet printers may assist in the creation of complex tissues and 3-D structures (Choi). First, ink cartridges are cleaned out and filled with suspensions of cells. Different types of cells can be placed in the ink cartridges in order to create structures with multiple cell types. Next, the printing software is reprogrammed. In order to get the cells to stick together, a "thermo-reversible" gel is used. The layers of gel are easy to

Figure 2. Printed Cells. Printed yeast cells are aligned to spell out "UMD" (University of Massachusetts Dartmouth), where they were created.

remove, and are made thin enough for the cells to fuse together and grow. The final step is to print alternate layers of gel and cell bundles onto glass slides, and allow the growing process to take place (Choi).

Skin

In addition to printing stem cells and complex cell structures, scientists have discovered a way to create new skin with the help of a printer. It is envisioned that doctors would "take cells from a patient's body, multiply them and suspend them in a nutrient-rich liquid similar to ink" (Carey). The computer connected to the printer would contain measurements of the patient's wound, and the cells would then be placed into the printer's cartridges. The printer would print the cells onto a plastic tissue scaffold, which would provide the figure and strength the skin needs to develop (See Figure 3). When the skin is ready to be placed back on the wound, the scaffold would act as an adhesive, and anchor the skin wherever it is applied. Over time, the scaffold would dissolve naturally, and the patient would only be left with the new skin.

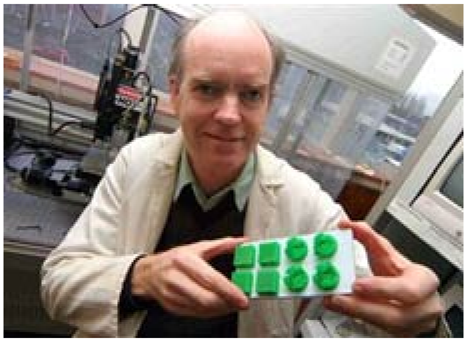

Figure 3. Tissue Scaffolds. Brian Derby, head of the "Ink-Jet Printing of Human Cells Project" is pictured holding model tissue scaffolds. The real scaffolds are clear, not green, and only 3mm in length.

Solar Panels

In an attempt to make energy production easier, researchers around the world have developed a process to print solar panels onto plastic. In Tokyo, a slightly modified ink-jet printer was used to place flat copper coils and plastic transistors onto flexible plastic sheets (Marks and McKenna). The coils and transistors deposited on the paper would work together to activate the solar panel. A team at the New Jersey Institute of Technology created solar panels by printing with carbon nanotubes. Carbon nanotubes are “molecular configurations of carbon in a cylindrical shape”, and conduct electricity even better than regular electrical wiring (“New Flexible Solar Panels Are Expensive and Easy to Make”). The University of Cape Town uses a procedure similar to how regular color images are printed. Four types of ink are used on “three or four separate print runs”, and each ink contains tiny silicon particles (Laumer).The amount of power in the solar panel all depends on the size of the paper. Eventually, inkjet printers will be able to print multiple solar panels at once, and consumers will be able to produce them in their own homes.

Making Our Lives Easier: Developments for Everyday Use

Batteries

Researchers at Rensselaer Polytechnic Institute have crafted a new type of battery made mostly of paper. Unlike traditional batteries, this one can be printed out onto sheets made of special paper infused with carbon nanotubes, which give it a black color. Normally, electrolytes like ionic liquid are soaked into the paper to provide it with an energy source (“Bendable Batteries”). However, it can also run with no artificial electrolytes after printing. Human sweat, blood, and, and urine are naturally occurring electrolytes in the human body, and any battery placed in the body will be able to run just as efficiently. This would prove to be especially helpful with heart patients who need batteries to keep their pacemakers working properly. The future goal is

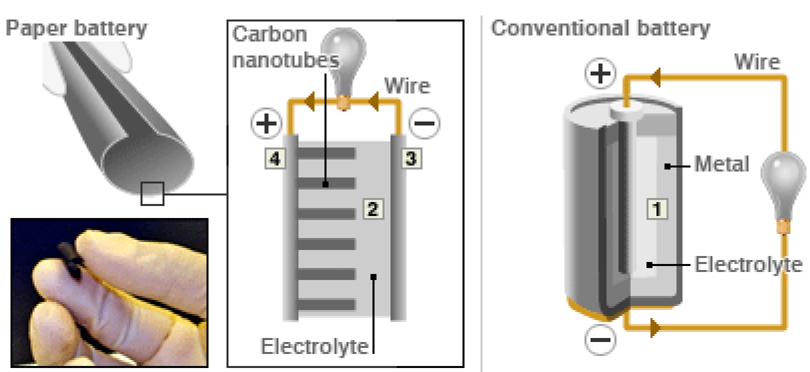

Figure 4: **Paper Batteries**. Thinner than conventional batteries, the printed paper battery is infused with carbon nanotubes and can be activated by electrolytes in the human body.

to be able to mass produce the paper batteries using a roll-to-roll system, which is similar to the way newspapers are printed. ("Bendable Batteries")

Food

At Moto, a revolutionary restaurant in Chicago, an ordinary printer has taken food to the next level. The Canon i560 inkjet printer is used to create the food items offered on the menu. First, paper made of soybeans and cornstarch is fed into the printer. The inks used are organic, food-based substances such as juiced carrots, tomatoes, and purple potatoes (Bernstein). Each printout is then flavored with powdered seasonings, ranging from seaweed to squash to sour cream. The final product is an edible 3-D paper model of the food item (usually sushi), with pictures of that particular food printed on every sheet of paper.

Figure 5: Sushi. A printed sushi roll flavored with powdered seasoning and covered with images of sushi.

Buildings

In a few years, it may be possible for construction workers to print out walls and doors, thus lessening the time needed for building. The technology uses techniques from "rapid prototyping" processes. In these processes, structures are drawn and developed with computer design software, and then each 3-D structure is sliced into 2-D layers. In the case of walls or doors, a room-size printer creates each layer using mineral-based material like cement, gypsum, clay, or lime placed in specific locations (Staedter). The layers are then arranged on top of each other to build up the final product. Rapid prototyping processes usually use lasers to bond each layer together, but the new technology would include materials that are designed to harden in the air. (Staedter)

The Future of the Printing Process

The computer printer started as a device designed solely to dispense ink onto blank paper. Now, thirty-one years after the first printer was created, it has been continually modified and rebuilt to work in a variety of ways. Ink is no longer necessary, and paper is not always the preferred base. Soon, consumers may be able to print off solar panels and batteries from their home computers. Construction workers may be able to build entire structures without ever picking up a hammer. A decade from now, a patient in need of an organ transplant might not have to wait for a donor, but instead receive an organ created with the help of a printer. The possibilities are endless, and as the needs of our society increase, so will the printer's ability to provide time and material-efficient services.

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