

CG020 Genomika

Přednáška 12

Praktické aplikace genomiky

Jan Hejátko

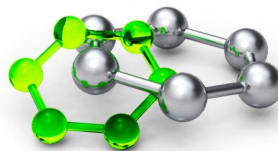
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Literatura

- Literární zdroje ke kapitole 12:

Broughton, J.P., Deng, X., Yu, G., Fasching, C.L., Servellita, V., Singh, J., Miao, X., Streithorst, J.A., Granados, A., Sotomayor-Gonzalez, A., Zorn, K., Gopez, A., Hsu, E., Gu, W., Miller, S., Pan, C.Y., Guevara, H., Wadford, D.A., Chen, J.S., and Chiu, C.Y. (2020). CRISPR-Cas12-based detection of SARS-CoV-2. *Nat Biotechnol* **38**, 870-874.

Dietel, M., and Sers, C. (2006). Personalized medicine and development of targeted therapies: The upcoming challenge for diagnostic molecular pathology. A review. *Virchows Arch* **448**, 744-755.

Gaudelli, N.M., Komor, A.C., Rees, H.A., Packer, M.S., Badran, A.H., Bryson, D.I., and Liu, D.R. (2017). Programmable base editing of A*T to G*C in genomic DNA without DNA cleavage. *Nature* **551**, 464-471.

Goh, K.I., Cusick, M.E., Valle, D., Childs, B., Vidal, M., and Barabasi, A.L. (2007). The human disease network. *Proc Natl Acad Sci U S A* **104**, 8685-8690.

Chen, J.S., Ma, E., Harrington, L.B., Da Costa, M., Tian, X., Palefsky, J.M., and Doudna, J.A. (2018). CRISPR-Cas12a target binding unleashes indiscriminate single-stranded DNase activity. *Science* **360**, 436-439.

Koblan, L.W., Erdos, M.R., Wilson, C., Cabral, W.A., Levy, J.M., Xiong, Z.M., Tavarez, U.L., Davison, L.M., Gete, Y.G., Mao, X., Newby, G.A., Doherty, S.P., Narisu, N., Sheng, Q., Krilow, C., Lin, C.Y., Gordon, L.B., Cao, K., Collins, F.S., Brown, J.D., and Liu, D.R. (2021). In vivo base editing rescues Hutchinson-Gilford progeria syndrome in mice. *Nature*.

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Osnova

- Lékařství
 - Molekulární diagnostika
 - Individualizovaná medicína
 - Genová terapie
- Biotechnologie
- Geneticky Modifikované Organismy
 - Transgenóza
 - Editování genomu
- Modelové organismy
- Principy PCR

Osnova

- **Medicine**
 - Molecular Diagnosis

Molekulární Diagnostika

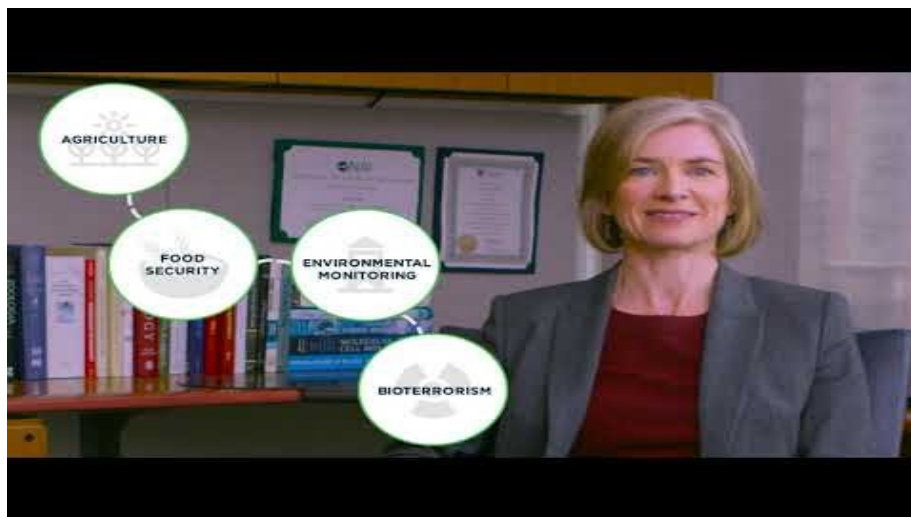
- Cca 10,000 onemocnění u člověka je podmíněno mutací v jediném genu
 - cystická fibróza
 - srpkovitá anémie
 - svalová dystrofie
 - β -talasémie
 -
- Časná molekulární diagnostika
 - mutace nebo infekce
 - PCR
 - Hybridizace na DNA čipu hybridization
 - Cas-based

Molekulární Diagnostika

- Mammoth Biosciences

- Spoluzakladatelka Jenifer Doudna

<https://youtu.be/1Pe4ldgKgDQ>



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It has been found that binding of gRNA=targeted CRISPR to the target sequence activates ssDNA cleavage activity of Cas12. “By combining Cas12a ssDNase activation with isothermal amplification, we create a method termed DNA endonuclease-targeted CRISPR trans reporter (DETECTR), which achieves attomolar sensitivity for DNA detection. DETECTR enables rapid and specific detection of human papillomavirus in patient samples, thereby providing a simple platform for molecular diagnostics.” (Chen et al., 2018). The approach was used also for designing the CRISPR-based detection of SARS-CoV-2 (Broughton et al., 2020).

Outline

- Medicine
 - Molecular Diagnosis
 - Personalized Medicine

Individualizovaná Medicína

- Využívá znalost **genomu** pro:
 - Předpověď zdravotních rizik
 - Diagnostiku
 - Výběr **nejvhodnějšího** typu léčby
 - minimalizuje nežádoucí efekty léčby
 - **prevence**

Individualizovaná Medicína

What is Personalized Medicine?

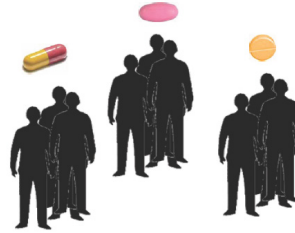
Current Practice



One size fits all

Trial and error

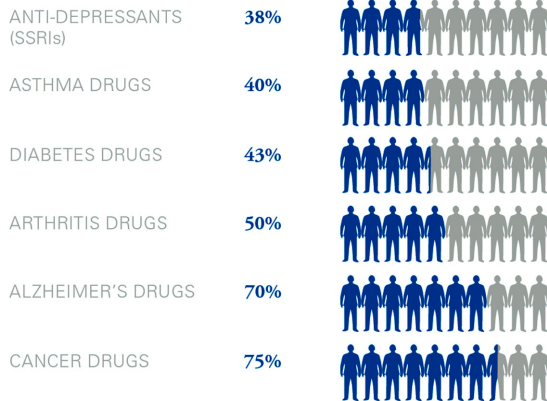
Personalized Medicine



The **right treatment** for
the **right person** at the
right time

Individualizovaná Medicína

PERCENTAGE OF THE PATIENT POPULATION FOR WHICH A PARTICULAR DRUG IS INEFFECTIVE, ON AVERAGE



• Just in hospitals: about 6.7% of patients (2.2 million) experience serious adverse drug reactions



Serious adverse drug reactions in even smaller percentages of treated populations have led to the withdrawal of several drugs from the market

Zelnorm Vioxx Cylert

"Are good drugs going to the wrong people?"

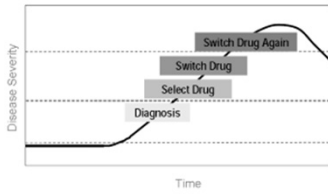
Rezulin Baycol Lotronex*

Source of data: Brian B. Spear, Margo Heath-Chiozzi, Jeffery Huff, "Clinical Trends in Molecular Medicine," Volume 7, Issue 5, 1 May 2001, Pages 201-204.

Individualizovaná Medicína

The Old Paradigm: Treatment of Disease

Reactive Medical Care



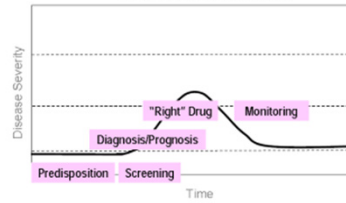
Diagnose Disease; Treat Symptoms; Costly, Trial and Error Treatment

<http://www.personalizedmedicinecoalition.org>

PMC

Personalized Medicine Paradigm: Health Management

Efficient Medical Care



**Health Management; Molecular Screening; Early Detection;
Rapid Effective Treatment; Improved Quality of Care**

<http://www.personalizedmedicinecoalition.org>

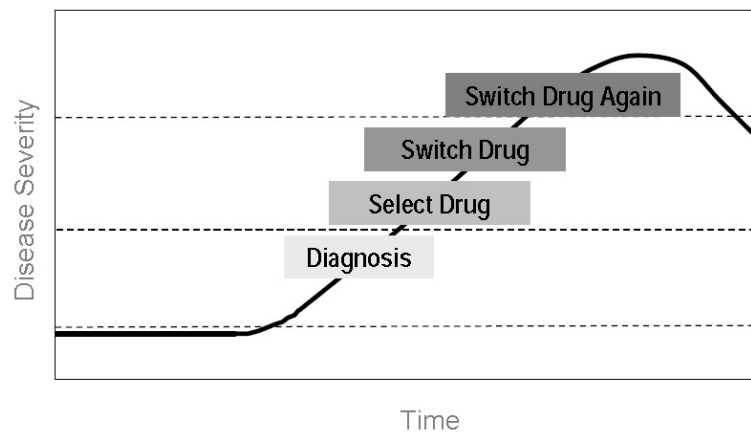
PMC

<http://www.personalizedmedicinecoalition.org/>

The Old Paradigm: Treatment of Disease



Reactive Medical Care

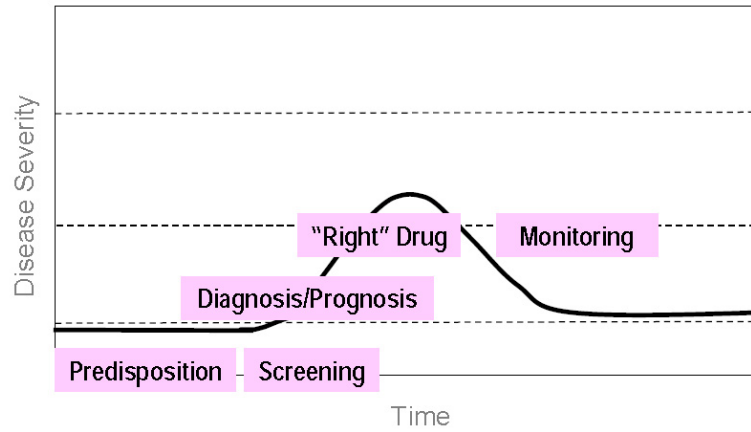


Diagnose Disease; Treat Symptoms; Costly, Trial and Error Treatment

Personalized Medicine Paradigm: Health Management



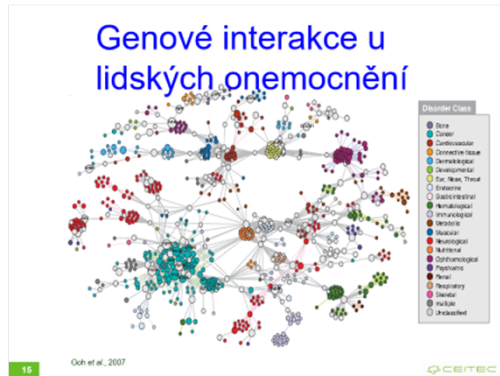
Efficient Medical Care



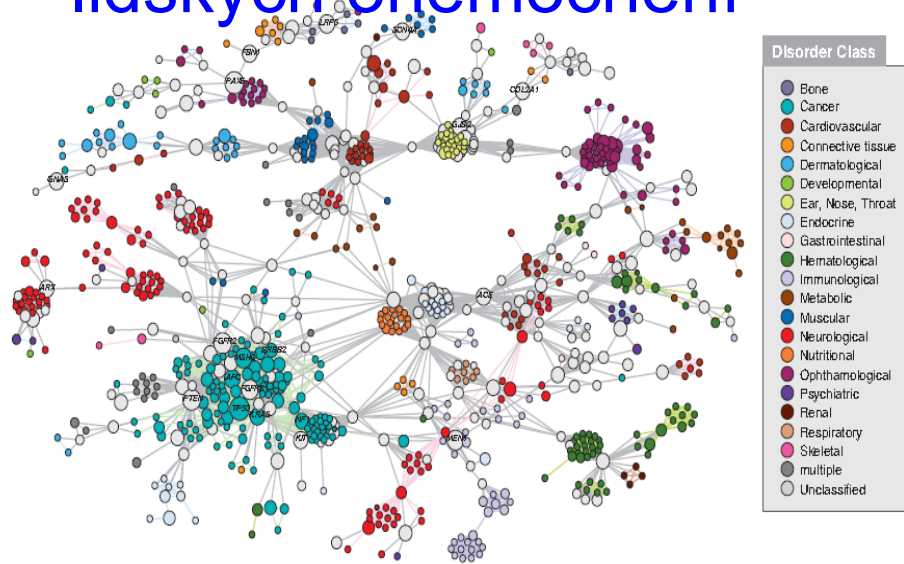
**Health Management; Molecular Screening; Early Detection;
Rapid Effective Treatment; Improved Quality of Care**

Individualizovaná Medicína

- Problém:
 - Mnohofaktoriální podmíněnost většiny lidských onemocnění

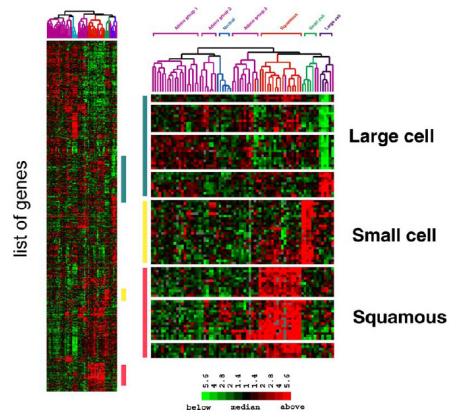


Genové interakce u lidských onemocnění



Individualizovaná Medicína

- Řešení problému:
 - **Systémová biologie** – využívá např. **genové klastrování** k identifikaci genů asociovaných s pozorovaným jevem (nemocí, poruchou, ..)



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Dietel and Sers, 2006

Hierarchical clustering analysis exemplified for Topotecan-resistant (R) and Topotecan-sensitive (S) cell lines. All cell lines resistant to Topotecan (left panel) and all cell lines sensitive to Topotecan (right panel) express a unique set of genes. Each row in the cluster indicates the expression profile of a specific gene across all 19 cell lines. Each column indicates the individual cell line in which the gene is expressed.

Red, green, and black squares indicate that expression of the gene is greater than, less than, or equal to the median level of expression across all cell lines, respectively. The scale bar reflects the fold increase (red) or decrease (green) for any given gene relative to the median level of expression across all samples. Dietel and Sers, 2006.

Individualizovaná Medicína

- Řešení problému:
 - biomarkery
 - testy

Table: Selected Personalized Medicine Drugs, Treatments and Diagnostics as of September 2011*

Indications in quotes and otherwise unattributed, are cited from the therapeutic or diagnostic product label.

Therapeutic product labels contain pharmacogenomic information as:

- Information only
- Recommended
- Required
- Unhighlighted products have no pharmacogenomic information, recommendations or requirements in the label.

THERAPY	BIOMARKER/TEST	INDICATION
Mivacron® (mivacurium)	Cholinesterase gene	Anesthesia adjunct: "Mivacron is metabolized by plasma cholinesterase and should be used with great caution, if at all, in patients known to be or suspected of being homozygous for the atypical plasma cholinesterase gene."
Ansaid® (flurbiprofen)	CYP2C9	Arthritis: "In vitro studies have demonstrated that cytochrome P450 2C9 plays an important role in the metabolism of flurbiprofen to its major metabolite, 4'-hydroxy-flurbiprofen."
Dipakote® (divalproex)	UCD (NAGS, CYP5, ASS, OTC, ASL, ARG)	Bipolar disorder: "Hyperammonemic encephalopathy, sometimes fatal, has been reported following initiation of valproate therapy in patients with urea cycle disorders [UCDs], particularly ornithine transcarbamylase deficiency [OTC]."
Aromasin® (exemestane) Arimidex® (anastrozole) Nolvadex® (tamoxifen)	Estrogen Receptor (ER)	Breast cancer: Exemestane is indicated for adjuvant treatment of post-menopausal women with ER-positive early breast cancer. Anastrozole is for treatment of breast cancer after surgery and for metastases in post-menopausal women. Tamoxifen is the standard therapy for estrogen receptor-positive early breast cancer in pre-menopausal women.
Chemotherapy	MammaStrat®	Breast cancer: Prognostic immunohistochemistry (IHC) test used for postmenopausal, node-negative, estrogen receptor-expressing breast cancer patients who will receive hormonal therapy and are considering adjuvant chemotherapy.
Chemotherapy	MammaPrint®	Breast cancer: Assesses risk of distant metastasis in a 70-gene expression profile.
Chemotherapy	Oncotype DX® 16-gene signature	Breast cancer: A 16-gene signature (plus five reference genes) indicates whether a patient has a low, intermediate, or high risk of having a tumor return within 10 years. Low-risk patients may be treated successfully with hormone therapy alone. High-risk patients may require more aggressive treatment with chemotherapy.
Chemotherapy	CompassDx® 31-gene signature	Breast cancer: The test predicts "time to event" for metastasis of breast cancer, following surgery or biopsy.
Falodex® (fulvestrant)	Hormone Receptor (HR)	Breast cancer: Fulvestrant is indicated for the treatment of hormone receptor positive metastatic breast cancer in post-menopausal women with disease progression following anti-estrogen therapy.
Herceptin® (trastuzumab) Tykerb® (lapatinib)	HER-2/neu receptor	Breast cancer: "...for the treatment of patients with metastatic breast cancer whose tumors overexpress the HER-2 [Human Epidermal growth factor Receptor 2] protein and who have received one or more chemotherapy regimens for their metastatic disease." High levels of HER-2 expression have been associated with increased disease recurrence in breast cancer, but show a better response to trastuzumab.
Pharmaceutical and surgical prevention options and surveillance	BRCA 1/2	Breast cancer: Guides surveillance and preventive treatment based on susceptibility risk for breast and ovarian cancer.
Nolvadex® (tamoxifen)	Breast Cancer Index® (BCI) (HXB13, IL17BR)	Breast cancer: Calculates a combined risk analysis for recurrence after tamoxifen treatment for ER-positive, node-negative breast cancer.

Aplikace přístupů systémové biologie (včetně genového klastrování na předchozím snímku) pak umožní identifikovat specifické markery a testy, které umožní testovat odpověď na různé typy terapií.

Individualizovaná Medicína

- Další problémy
 - Etické otázky
 - Možnost zneužití znalosti genomu
 - riziko: nedostatečná ochrana dat
 - V některých zemích je uzákoněn omezený přístup pro určité typy zaměstnanců nebo pojišťovací společnosti
 - Vysoké náklady
 - Dělení medicíny na **first-class** and **low-class** služby
 - Zvětšování problému **globalizačního handicapu** – chudé země si nemohou takto pokročilý typ léčby dovolit
 - Soukromí
 - Zásadní a komplikovaná otázka
 - Jakou informaci lze považovat za soukromou?

Outline

- Medicine
 - Molecular Diagnosis
 - Personalized Medicine
 - Gene Therapy

Gene Therapy

Procedure in which the DNA sequence is inserted into the patient genome to replace or supplement the original gene

- Options:
 - replace the mutated gene
 - repair the mutation
 - deliver DNA encoding a therapeutic protein
 - antisense therapy
- In the future useful for treating e.g. hereditary diseases
- Types:
 - somatic gene therapy
 - gene therapy of germ cells

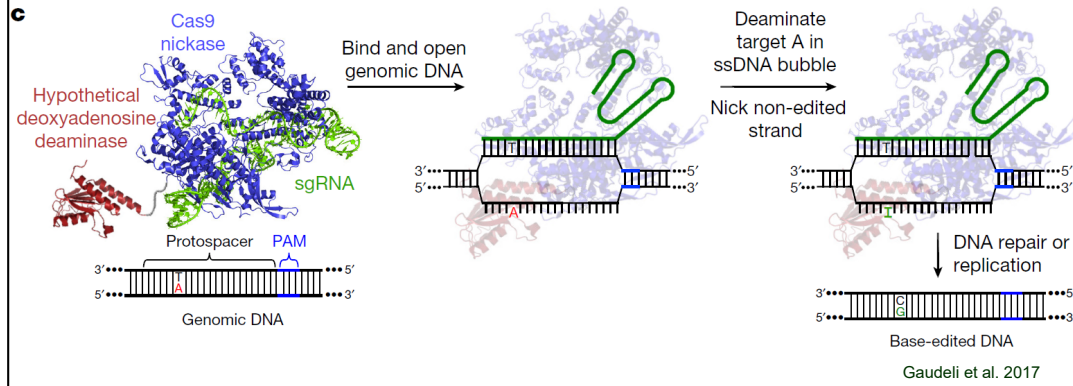
Gene Therapy



■ Hutchinson–Gilford progeria syndrome

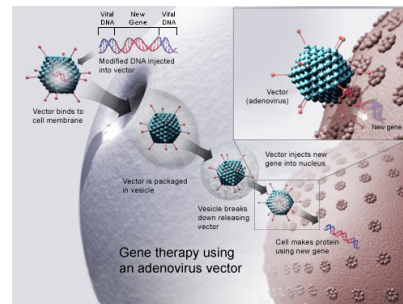
- C•G-to-T•A mutace (c.1824 C>T; p.G608G) v genu pro laminin (*LMNA*)
- Defekt v sestřihu RNA vede k tvorbě toxického proteoinu **progerinu**
- Věk dožití cca 14 let
- **In vivo oprava** pomocí ABEs potvrzena u **myši** a **lidských fibroblastů** (Koblan et al., 2021)

Adenine Base Editors



Gene Therapy

- **Methods**
 - **viral vectors**
 - retroviruses
 - adenoviruses
 - herpes simplex virus
 - **non-viral methods**
 - injection of plasmid DNA into muscle
 - increased efficiency of DNA delivery
 - electroporation
 - sonoporation
 - „gene gun“ (biolistic)
 - magnetofection
 - **genome editing**



Ethical Issues

- Regulace editace genomu v zemědělství a lidském zdraví
 - <https://crispr-gene-editing-regs-tracker.geneticliteracyproject.org/>
- International Commission on the Clinical Use of Human Germline Genome Editing
 - convened by the U.S. National Academy of Medicine (NAM), the U.S. National Academy of Sciences (NAS), and the Royal Society of the U.K. ...
 - ...to identify a number of scientific, medical, and ethical requirements that should be considered, and could inform the development of a potential pathway from research to clinical use — if society concludes that heritable human genome editing applications are acceptable
 - more details at <https://nationalacademies.org/gene-editing/international-commission/index.htm>

Ethical Issues

- Alliance for Regenerative Medicine

- international group representing the cell and gene therapy sector
- put out a “statement of principles” on genome editing endorsed by 13 of the most active companies in this field
- changing heritable DNA in sperm, eggs or a new embryo — came true in November 2018 when He Jiankui, a Chinese biophysicist, said that his lab had edited two baby girls to make them resistant to HIV infection. This mutation will be inherited by their descendants.
- 31 clinical trials for gene edited therapies are in progress around the world, 20 of which are in oncology. None is yet close to commercialisation. The US has the largest number of trials (19) followed by China (10) and the UK (6)

FT, Clive Cookson, Science Editor August 27 2019



Outline

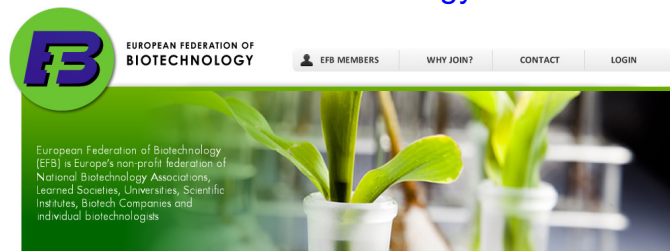
- **Medicine**
 - Molecular Diagnosis
 - Personalized Medicine
 - Gene Therapy
- **Biotechnology**

BIOTECHNOLOGY

- It uses living organisms, cells or parts of cells (enzymes) for research, leading to new products and applications in medicine, agriculture, food, environmental protection
- Also used in developing better/sustainable production methods for the chemical industry and other industrial processes
- An **interdisciplinary approach** requiring knowledge of chemistry, biology, physics, material sciences, engineering and informatics
- The origin of biotechnology can be traced 4,000 years back, when the Sumerians (although not knowingly) used microbes for the production of alcoholic beverages.

BIOTECHNOLOGY

- **Examples**
 - effective utilization of **plant biomass** for **fuel production**
 - acquisition of starting material (**monomers**) for the **production of polymers** from living organisms instead of from fossil sources
 - **phytopharmaceuticals** – using plants in new vaccination methods such as expression of **antibodies** or **antigens** suitable for **immunization**
- **European Federation of Biotechnology**



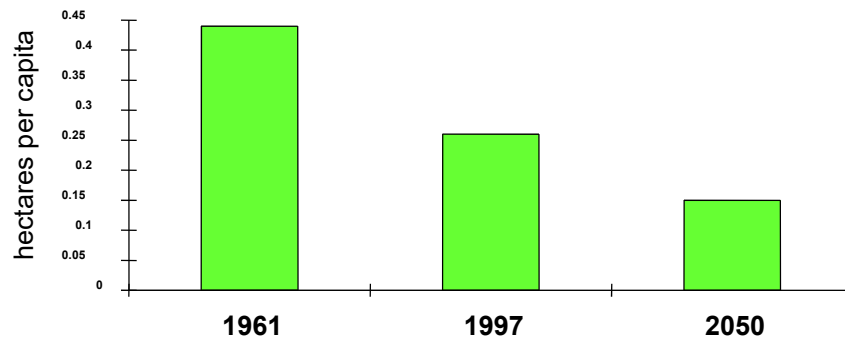
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<http://www.efb-central.org>

Outline

- Medicine
 - Molecular Diagnosis
 - Personalized Medicine
 - Gene Therapy
- Biotechnology
- **Genetically Modified Organisms**
 - Transgenesis

Human Population vs Arable Land Availability



Source: UN Millennium Ecosystem Assessment

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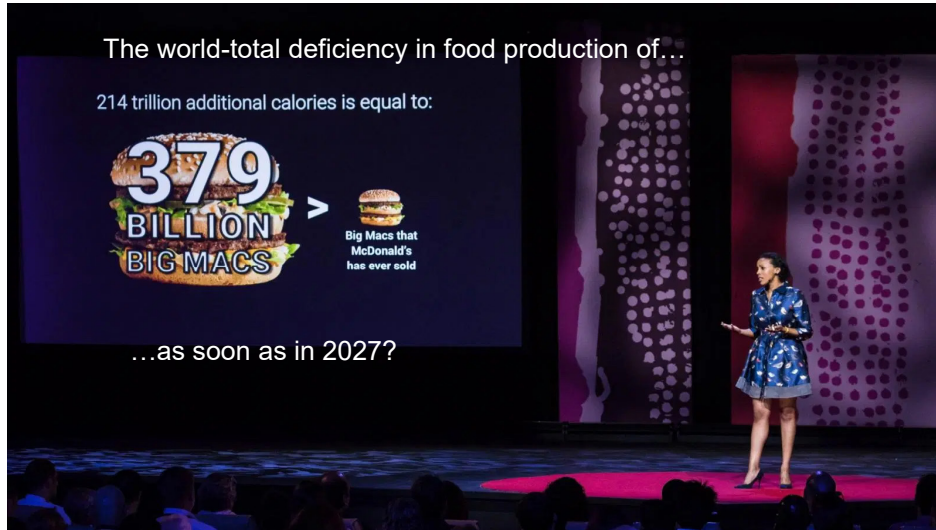
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Our civilization is built on farming, the surface area needed for feeding people has decreased by 90% over 10,000 years .

To prevent collapse, it is necessary to reduce this area from the current 0.45 ha/person to 0.2 ha/person by the year 2050. Return to original methods of agriculture would be a return to the original demands on area and therefore would be unsustainable Intensive farming = conversion of water and oil into food.

goal of plant biotechnology is to use all the available scientific knowledge to **breed varieties with higher yield** with lower inputs (of land, water, fertilizers, sprays ...)

Nutrition Deficiency



<https://qz.com/africa/1064653/the-world-could-run-out-of-food-two-decades-earlier-than-thought/>

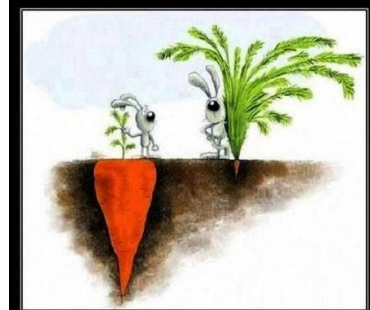
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Announced recently by Quartz server, the world could be facing a 214 trillion calorie deficit in the food production (announced **as soon as in 2027**).

Breeding

- organisms naturally vary due to **mutations**
- before the era of genetic engineering - **question of chance**
- breeding tools
 - **selection** and **crossing**
- **modern breeder** learned to **change hereditary information** – **increase the mutants allele frequency**
 - chemicals, radiation ...
- results are **incidental/non-targeted**



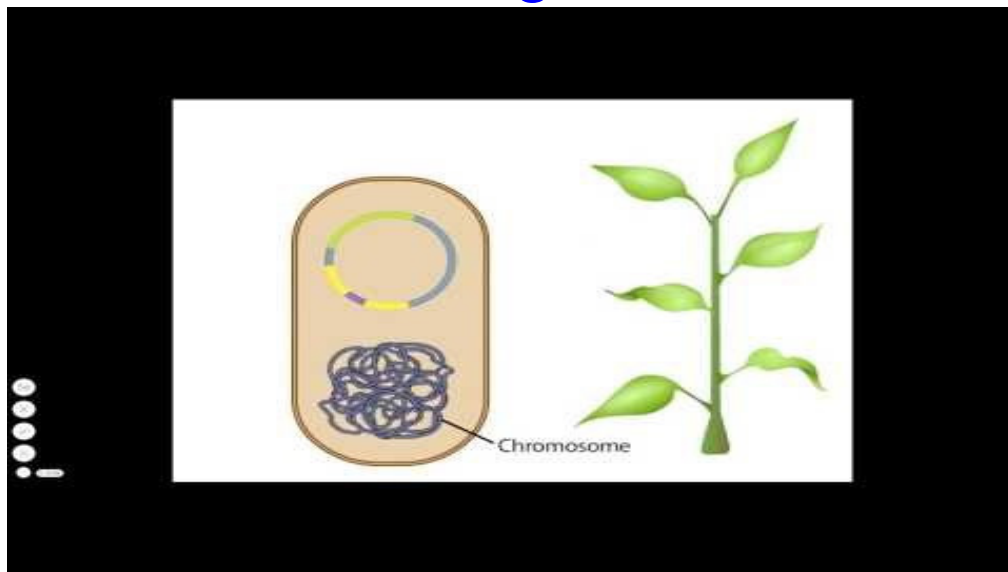
Success
is not always visible at a glance

Genetic Engineering

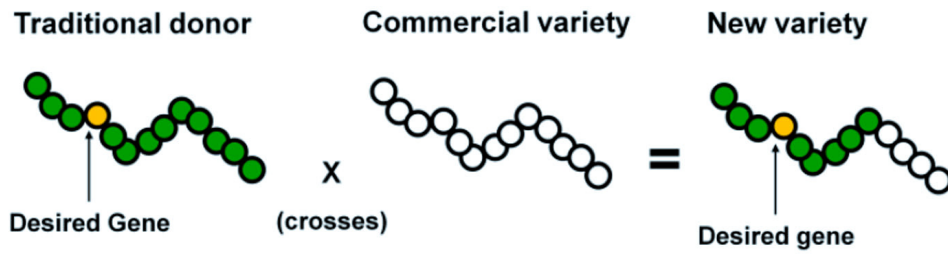
- Targeted modification ("targeted breeding")
 - ability to transfer genes = **transgenesis**
- the first practical application: production of **human insulin** in bacteria - 1978

Boyer a Swanson – firma Genentech

Plant Transgenesis



Breeding Vs. Genetic Engineering



Genetically Modified Organisms (GMOs)

- Organisms carrying **modified genetic information** – either **own** or **foreign** (from another organism), enabling **targeted changes** in the organism and its use for **specific purposes**
- **GMOs**
 - plants
 - bacteria
 - animals

<http://www.gmo-compass.org/>

Genetically Modified Plants

- resistance to **pests**
- **herbicide** resistance
- resistance to **drought**
- resistance to **cold**
- resistance to **salinity**
- more efficient **nitrogen utilization**
- increasing **nutritional quality**



<http://ipbo.vib-ugent.be/>

Bt Plants

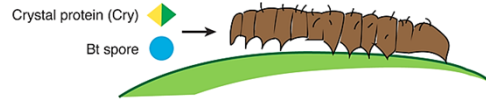
- resistance to insect pests
- corn, cotton, rice
- genes from *Bacillus thuringiensis* (**Bt**)
- Expression of crystalline delta-endotoxins - **Crystal (Cry)** proteins
- increasing yields, reducing the amount of chemical sprays



European corn borer damage and fungal infection in non-Bt (left) and Bt hybrids (right)

Bt Plants

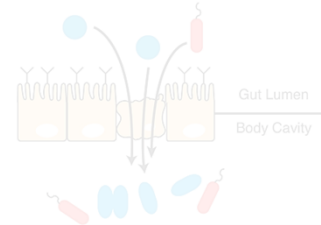
(A) Larvae ingest Bt spores and Cry proteins



(B) In larval midgut, proteolytic digestion of proteins release Cry toxins, which bind to epithelial receptors



(C) Toxin binding causes cell lysis destroying barrier to body cavity



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When the Cry protein reaches the gut, it is partially degraded, releasing a smaller and potentially toxic part of the protein [6]. But this toxin will only be active if it finds the right matching protein receptor sticking off the cells lining the gut of a larval insect. This is the most important aspect of the Cry toxin mechanism. Much in the same way that a certain key will only open a certain lock, the Cry toxin can only exert its toxic effect on a particular cell receptor. Consequently, the toxin tends to only impact insects within a particular taxonomic order.

Once the toxin is bound, the process is fairly straightforward. The toxin recruits other Cry toxins to the same cell and together they form a hole in cell's membrane that ultimately causes the cell to burst [6]. The cumulative effect of this happening to many cells is the irreversible destruction to the midgut membrane, compromising the barrier between the body cavity and gut. Without this barrier, *Bt* spores and other native gut bacteria can infiltrate and grow within the nutrient-rich body of the insect [4-5].

What makes *Bt* such a great candidate for pesticide and GM applications is that while these Cry toxins are highly effective against insects, they have been shown to be safe for consumption by mammals. Tests by the EPA have demonstrated that Cry proteins, like any other benign dietary protein, are very unstable in the acidic stomach environment. Furthermore, an oral toxicity test, which involves giving mice exceptionally high doses of purified toxic *Bt* proteins, showed no significant health impacts. In their 2001 reassessment of several *Bt* Cry proteins, the EPA concluded from these findings that "there is reasonable certainty that no harm will result from aggregate exposure to the U.S. population, including infants and children, to the Cry1AB and Cry1F proteins and the genetic material necessary for their production." Similar conclusions were drawn about the Cry1Ac protein of *Bt* cotton [7]. Other mouse studies on have shown that even high doses of truncated Cry proteins, such that only the toxic region is conserved, have no deleterious effects [8]. A paper in Annual Review of Entomology from 2002 also makes the strong point that, in addition to no demonstrated toxicity of *Bt* toxins, their use provides important health benefits to livestock and humans by preventing certain insect-caused crop diseases that produce toxic and carcinogenic compounds [13].

Ht Plants

- resistance to systemic herbicides
- glyphosate
 - interferes with the synthesis of aromatic amino acids; animals without the appropriate enzymatic apparatus = harmless
 - blocks the enzyme 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) in chloroplasts – affects green plants
 - ineffective for bacterial EPSPS - evolutionarily divergent
 - soya, maize, sugar beet, canola, cotton, alfalfa - added enzyme for tolerance
 - company Bayer (Monsanto), trade name Roundup

Ht Plants

- resistance to systemic herbicides
- glufosinate (phosphinothricin)
 - prevents processing of ammonium - toxic
 - *Streptomyces hygroscopicus* synthesizes and transforms it: acetylation by the enzyme phosphinothricin acetyltransferase – coding gene isolated in 1987 - named *bar*
 - trade names: **Basta**, Liberty, Finale, Radical ...

Multiresistant Plants

- Bt resistance + herbicide
- multiresistant corn - the majority of total production in the USA
- example of multiresistant corn:
 - three Bt genes for resistance to air pests
 - three Bt genes for resistance against soil pests
 - two genes for herbicide resistance

Disease-Tolerant Plants

- **viruses** - no chemical agents available
- gene encoding **non-infectious viral envelope** protein - increases resistance to viral infection
 - **banana; papaya** - Hawaii, Southeast Asia
 - **cassava** - a basic food ingredient for more than **500 million people** + animal feed



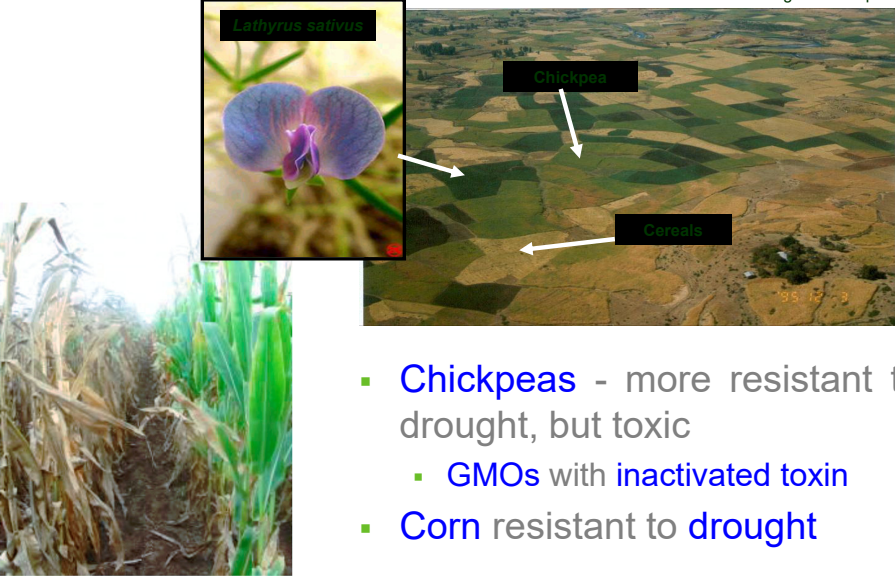
Left: Papaya with Papaya ringspot disease
Right: Biotech Papaya resistant

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Hlízy manioku (cassava) tvoří základní potravinovou složku pro více než 500 milionů lidí. Rovněž se využívá jako krmivo - zkrmuje se v podobě maniokové moučky hlavně prasatům, skotu, ovcím a kozám.

Disease- and Stress-Tolerant Plants

Drought in Ethiopia



- **Chickpeas** - more resistant to drought, but toxic
 - **GMOs** with **inactivated toxin**
- **Corn** resistant to **drought**

New drought-tolerant maize (right) needs less water.

CEITEC

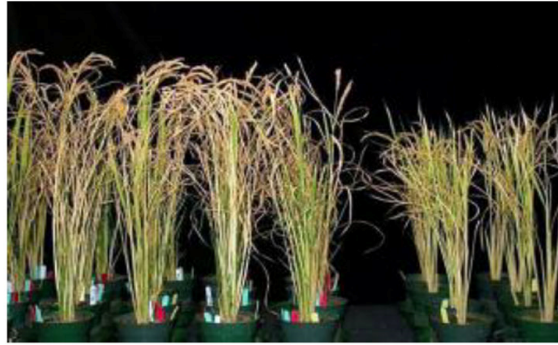
Hrachor – *Lathyrus sativus*

Cizrna – Chickpea

Obiloviny - Cereals

Nitrogen Use Efficiency

- use of **nitrogen** from **fertilizers**
 - **rice with gene from barley** - 3x higher nitrogen utilization under oxygen deficiency



The effect of Nitrogen Use Efficiency (NUE) in rice growth with reduced N applications. Left: rice engineered

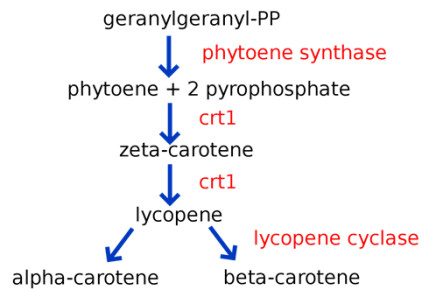
45

When crops are supplied with excess nitrogen fertilizer to gain maximal yields the excess nitrogen is converted into the gas nitrous oxide (N₂O) and also leaches into rivers. N₂O has 300x the Global Warming Potential of CO₂ and nitrogen fertilizer runoff creates marine dead zones, such as in the Gulf of Mexico at the mouth of the Mississippi river. Crops that have the ability to grow well with less nitrogen, because of enhanced uptake or similar characteristics, result in less N₂O release and less N runoff. This lessens the effect of fertilizer nitrogen on global warming and lake and marine pollution.

Improved Nutrition Value

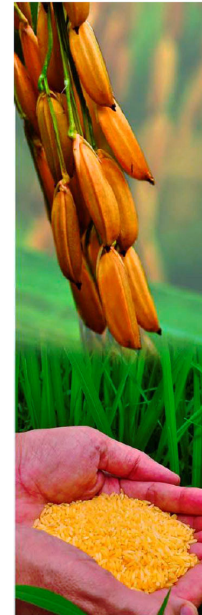
- **Golden rice**

- several genes from maize encoding enzymes for the biosynthesis of β -carotene (precursor of vitamin A)



- **Canola and Soybean**

- improved oil properties: stable, resistant to high temperatures, long storage



Golden Rice
شیرین

While most biotech crops have characteristics that enhance their cultivation, those with enhanced consumer characteristics are being developed. For example many children in SE Asia develop blindness because of a deficiency of vitamin A. Golden rice is engineered with genes from maize to be high in the precursor of vitamin-A that when eaten is converted to vitamin-A in order to prevent blindness in developing countries. High oleic soybean and canola oil are now available. Oil with this fat profile is more stable, allowing for greater heat tolerance and longer shelf life.

GMO Animals

- Transgenic cats
 - lentiviruses are sensitive to restriction factors
 - specific restriction factor: rhesus macaque TRIMCyp + eGFP
 - uniform expression, no mosaicism and no silencing in F1 generation
 - lymphocytes of transgenic animals resistant to replication of FIV

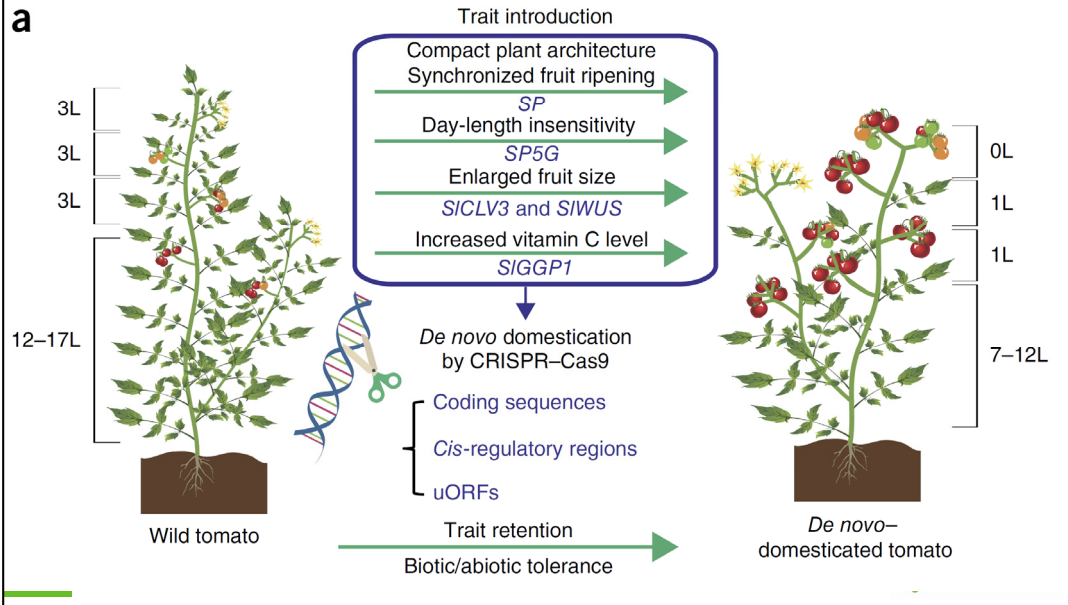


Wongsrikeao *et al.*, 2011, Nature Methods

Outline

- **Medicine**
 - Molecular Diagnosis
 - Personalized Medicine
 - Gene Therapy
- **Biotechnology**
- **Genetically Modified Organisms**
 - Transgenesis
 - **Genome Editing**

Gene Editing in Plant Domestication



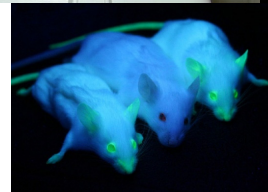
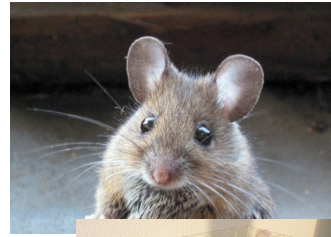
Outline

- **Medicine**
 - Molecular Diagnosis
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 - Genome Editing
- **Model Organisms**

Mus musculus

house mouse

- Low requirements for area
- Relatively large number of offspring (3-14, 6-8 on average)
- Genome size is close to the size of human genome (about 3000 Mbp), the number of genes as well (about 24K)
- 20 chromosomes (19+1)
- Suitable for a wide range of physiological experiments (anatomical and physiological similarity to human)
- Possibility to obtain (quite easily) KO mutants and transgenic lines



More info about mouse at <http://www.informatics.jax.org/greenbook/index.shtml>.

Mus musculus

house mouse

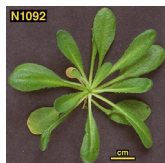
- Genome known since 2002 (<http://www.ncbi.nlm.nih.gov/projects/genome/assembly/grc/mouse/>)

The screenshot shows the 'Mouse Genome Overview' page from the Genome Reference Consortium. The page features a navigation bar with links for 'GRC Home', 'Data', 'Help', 'Report an Issue', 'Contact Us', 'Credits', and 'Curators Only'. Below the navigation bar, there are tabs for 'Mouse Overview', 'Mouse Issues under Review', 'Mouse Assembly Data', and 'Report a Problem'. The main content area is titled 'Mouse Genome Overview' and includes an ideogram of the mouse genome with chromosomes 1 through 19, X, and Y. A legend indicates that red triangles represent regions containing alternate loci and orange triangles represent regions containing fix patches. A text box explains that the GRC is working to provide the best possible reference assembly by generating multiple representations for complex regions. A 'Next assembly update' box states that the next update (patch release 2) will be a minor update (only patches) and will happen in March 2013. The page also includes a 'Getting Data' section with links to the latest minor and major releases, and a 'GRC Blog' section with recent news items. The footer of the page shows the current release as 'GRCm38.p1' with a release date of 23 Aug 2012 and a release type of 'minor'.

Arabidopsis thaliana

mouse-ear cress

- **Low requirements** for cultivation area
- High **number of seeds** (20.000 per plant and more)
- **Small and compact genome**, (125 MBp, about 25.000 genes, average size 3 kb)
- **5 chromosomes**
- Suitable for **wide range of physiological experiments**
- **High natural variability** (approximately 750 ecotypes (Nottingham Arabidopsis Seed Stock Centre))



Columbia 0

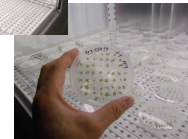
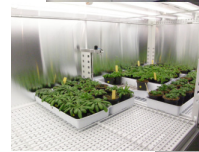


Landsberg 0



Wassilewskija 0

<http://seeds.nottingham.ac.uk/>



Arabidopsis thaliana


mouse-ear cress

- Genome known since 2000 (<http://www.arabidopsis.org/>)

The screenshot shows the homepage of the Arabidopsis Information Resource (TAIR). The page features a navigation menu with links for Home, Help, Contact, About Us, and Login/Register. Below the navigation is a search bar and a list of menu items: Search, Browse, Tools, Portals, Download, Submit, News, and ABRC Stocks. The main content area is titled "The Arabidopsis Information Resource" and provides a detailed description of the database, including its scope and the types of data it contains. A prominent banner in the center of the page encourages users to "Click here to try our new online submission form" and lists the types of data that can be submitted, such as molecular function, biological process, and localization. To the right of the main content, there is a "Breaking News" section with several recent updates, including the availability of a new set of confirmed T-DNA lines and the release of a new protein chip. The page also includes a footer with contact information and a link to the TAIR funding page.

Outline

- **Medicine**
 - Molecular Diagnosis
 - Personalized Medicine
 - Gene Therapy
- **Biotechnology**
- **Genetically Modified Organisms**
 - Transgenesis
 - Genome Editing
- **Model Organisms**
- **Principles of PCR**



Polymerase Chain
Reaction

Polymerase Chain Reaction

Klíčové koncepty

- Techniky využívající pokročilé přístupy zásadním, způsobem mění naše možnosti v medicíně i zemědělství
- Možnost programovatelné editace genomu slibuje zásadní obrát v léčbě zejména dědičně podmíněných chorob a ve šlechtění nových odrůd i ras
- Je nezbytná přísná kontrola s jasně nastavenými pravidly pro všechny, ale nikoliv úplný zákaz

Diskuse