Educational Resources for Epigenetics

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Abstract

Epigenetics can appear as an impenetrable subject; not just to those encountering it for the first time, but to those within the field too. However, epigenetics, like any subject can be made easier to understand using a combination of clear language, creative illustrations and even animations and film clips. This chapter aims to point readers of all experiences towards helpful and easy-to-read resources that educate about epigenetics. It is split into two main sections, the first aimed at a lay audience including teachers and high school students and the second, at graduate and postgraduate students and beyond. Each section contains summaries of published articles and web sites. The chapter ends with a short section on epigenetic societies and research networks and a summary table of resources. It is intended to provide a sample of some of the best short to medium length reviews on general topics within the field of epigenetics and while we cover a wide variety of themes, we apologise for any areas not covered. We cite the URLs of freely available articles wherever possible, but many articles will require library access. We also urge readers to contact authors or publishers if they wish to distribute any of the articles for teaching purposes.

Easy-to-read articles and web sites aimed at a broad audience

'Epigenetics' by Brona McVittie (McVittie, 2006; http://www.scienceinschool.org/2006/issue2/epigenetics)

This is an excellent two-page article about epigenetics by a member of the Epigenome Network Of Excellence (see below). It is aimed at an audience from school student to lay person and begins by likening the DNA code as a musical score being played by an orchestra of cells conducted and played by epigenetic factors. It introduces chromatin and DNA methylation in simple terms and focuses on how the environment can influence epigenetics as exemplified by studies in plants and animals, and by recent findings that genetically identical twins can have different epigenetic marks, especially as they age. The article also introduces the idea of epigenetic mutations causing a 'hazardous cacophony' in cancers and the possibility of epigenetic therapies.

'Evolution, Epigenetics, and Maternal Nutrition' by Asim K. Duttaroy (Duttaroy, 2006; http://www.mukto-mona.com/Special_Event_/Darwin_day/evolution_asim120206.htm)

This is a simple yet comprehensive review of evolution, epigenetics and the influence of nutrition on epigenetics. The review starts with an

introduction of Darwin's theory of evolution, followed by a link to the influence of epigenetics in evolution. The author provides a good explanation of epigenetics, covering the most widely studied mechanism, DNA methylation. Duttaroy then concentrates on how epigenetics influences gene expression and to illustrate this brings in the topic of imprinted genes, which are expressed depending whether they are inherited from the mother or father. The author provides many interesting examples of epigenetic phenomena, alongside clear illustrations. Find out how there is a 'battle of the sexes' within the genes under the control of epigenetics. The author also gives a good account on the link between maternal nutrition and epigenetics, and how maternal nutrition can influence the epigenetics of their offspring. References are included and it is a good read for those who want to know more than just the basics of epigenetics.

'Epigenetics: genome, meet your environment' by Leslie Pray (Pray, 2004; http://www.the-scientist.com/article/home/14798/)

This is an excellent summary of how the environment can affect epigenetics. It provides a good historical background on how the study epigenetic s came about and even compares current epigenetic theories to that of Jean-Baptise Lamarck 200 years ago. Pray presents a comprehensive comparison of current theories from renowned epigeneticists some of which may support Lamarck's theory of the inheritance of acquired traits. The article covers a wide range of early experimental evidence to introduce how environment can be a major factor contributing to the establishment of epigenetic patterns in an organism and its offspring. It gives a brief introduction and explanation of the mechanisms of epigenetics, focusing on DNA methylation, histone modification, and imprinting. The author also discusses how epigenetics is an important part of cancer studies and concludes with an emphasis that epigenetics works hand in hand with genetics. This article is a broad overview on the subject of environment and epigenetics and provides a good platform for anyone who wishes to read further into this area.

Molecular Development – Epigenetics by Mark Hill (http://embryology.med.unsw.edu.au/MolDev/epigenetic.htm)

This excellent web site is maintained by Dr Mark Hill from the University of New South Wales, Australia, containing many resources centred round epigenetics and mammalian development. It gives a broad coverage of quite a number of aspects of epigenetics, ranging from a brief introduction to its mechanisms, to more specific aspects of epigenetics such as twins' epigenetics and the relationship between epigenetics and expression of imprinted genes. Aside from epigenetics, the web site also gives a good coverage of developmental insights by providing basic introductions to different developmental stages of humans. The web site also has a section on how environmental factors can cause abnormalities in offspring. An introduction to statistics can also be found in this web site, which is very user friendly as it has links that easily lead the reader to the required information. It also contains fun illustrations for easy learning, and most importantly, the author structures the web site in a way where there is a compilation of updated resources and references for each section.

NOVA scienceNOW: Epigenetics (http://www.pbs.org/wgbh/nova/teachers/activities/3411_02_nsn.html)

This is a classroom activity and teachers' guide to epigenetics based on the *Nova Epigenetics* documentary originally aired in 2007. It expands the readers' knowledge from genetics to epigenetics, by offering epigenetics-related resources, including some useful definitions of key terms, a streamed version of the show, an audio slide show about how the epigenome produces epigenetic differences in identical twin mice, and an 'Ask the Expert' area where site visitors can ask researcher Randy Jirtle questions about epigenetics. The practical illustrations and activities suggested in this web site promote active and fun learning for students to understand the concept of epigenetics. The questions in the activity challenge them to think about how epigenetics works, and how it differs from genetics. Printable worksheets and activities are also available for student handouts.

Epigenetics? (http://epigenome.eu/)
This is a multilingual public science web site set up by the European Epigenome Network of Excellence (see below). Features short, easy-to-read articles on epigenetics aimed at laypeople and school/university students. The titles and the contents of the articles are structured in a narrative form, which allow readers to better understand the different aspects and influences of epigenetics in daily living. With just a click on the user-friendly hyperlinks, the site expands the reader's mind on epigenetics and covers a wide range of relevant and recent epigenetic topics, ranging from stem cells to epigenetics in the human immunodeficiency virus (HIV). Find out how epigenetics can also be a way to overcome drug addiction too! The reader gets to find out about different aspects on epigenetics with the help of simple illustrations. The web site also contains fun animations for school students, allowing them to appreciate the essence of Darwin's theory of evolution. This online-magazine-look-alike web site is highly recommended to read for people of all ages and disciplines.

Epigenetics and Imprinted Genes (http://www.hopkinsmedicine.org/press/2002/November/epigenetics.htm)
This is a short and understandable article that concentrates on genomic imprinting, originating from the Johns Hopkins Medical Institute, Baltimore, MD, USA. Readers are able to quickly grasp the simple concepts linking epigenetics and imprinted genes. The unnamed author presents the article in a 'Frequently Asked Question' format which contains basic questions with comprehensive answers. The author covers the topic by defining epigenetics, linking how imprinted genes come into the picture of epigenetic modification, and the consequences of these modifications. The explanations are fairly simple and it is suitable for readers who have very little background in this area.

What is it? A simplified description of DNA methylation (http://es.landesbioscience.com/pub/faq/)
This is an excellent review about DNA methylation from the Epigenetics Society (see below). The unnamed author starts by giving a brief introduction of genetics and epigenetics with the use of simple terms. They describe how the regulation of DNA methylation completes the picture of the development and phenotype of an organism. The author also succeeds in inserting an example in almost every paragraph, providing a good platform for the reader to understand the hows, whys and whats of DNA methylation. In addition, the article introduces the enzymes that are involved in the establishment and maintenance of DNA methylation discusses how the malfunction of these enzymes can be detrimental to the organism. It is stated that as one ages, the chance of having abnormality in DNA methylation increases too. The article ends with the discussion of the consequences of abnormal DNA methylation, but also concludes nicely by highlighting how the scientific community is focused on research into this area.

Learn.Genetics' epigenetics page (http://learn.genetics.utah.edu/content/epigenetics/)
An excellent interactive web site from the University of Utah, that contains lots of visual aids to assist readers new to epigenetics in grasping the basic concepts. The site covers topics including the effect of nutrition on the epigenome, differences between the epigenomes of identical twins, and epigenetic mechanisms. All information is illustrated in a simple manner, accompanied by video clips and interactive games to allow a better understanding of the topic. The site also cites numerous examples of animal and human studies as a good source of evidence for each concept. Find out interesting facts like why queen bees are different from other female bees, or how our grandparents' diet could affect our own health. This it is a good site for educators to obtain ideas and resources for their teaching of epigenetics as it contains lesson plans and suggestions to creatively teach this topic.

Epigenetics news – iscoveries and advances (http://www.epigenetics-news.com/tag/epigenetics/)

A blog maintained by Trevor Covert, a Research Associate in the laboratory of Dr Michael Skinner at Washington State University in Pullman, WA, USA. The blog focuses solely on reviewing epigenetics-related articles from various sources of scientific and popular press. It contains compilations of different opinions and views on the latest advances of epigenetics from researchers all over the world, ranging from discussions of how epigenetics is linked to cancer, to the influences of environment on epigenetics. Apart from human studies, the author also covers discussions on plant and stem cell epigenetics studies. All opinions and information are cited together with a link to the original article. There are also tags and links to other blogs that allow readers to obtain opinions and information from other relevant epigenetics researchers.

Epigenie (http://epigenie.com/index.html)

EpiGenie is not only an excellent resource on everything epigenetics but will also keep you in touch with updated epigenetics news and events if you subscribe to their newsletter. Also available on this web site are sections separated into 'product and method reviews', 'interviews with leading researchers in the field', 'upcoming conferences', and 'epigenetics background'. In the 'epigenetics background' section, brief summaries and reviews of epigenetics can be obtained to assist readers who are new to the field, and each summary is linked to another page with more comprehensive information if the readers wish to know more about the topic. Databases and online tools relevant to epigenetics work are available in this section too. The links created in this site makes it very user-friendly as they categorize each section to 'DNA methylation', 'chromatin', and 'non-coding RNA', allowing the reader to access relevant updated information promptly.

A (mostly) nontechnical glossary of epigenetics (http://www.natureinstitute.org/txt/st/mqual/glossary.htm)

This excellent, simply written glossary from the Nature Institute, a small, independent not-for-profit research and education organization, covers everything from acetylation to zygote.

Scholarly review articles aimed at a broad scientific audience

'Controlling the double helix' by Gary Felsenfeld and Mark Groudine (Felsenfeld and Groudine, 2003)

This article from *Nature* is from before era of epigenomics and non-coding RNAs but is nevertheless an excellent comprehensive and relatively brief overview of epigenetics. Felsenfeld and Groudine focus on the constituents of chromatin including chromatin remodellers and histone variants. The authors also discuss specialized chromatin structures such as centromeres, telomeres and the inactive mammalian X chromosome, and the mechanisms of propagation of epigenetic marks along chromatin and across cell division. The article also contains excellent, simple figures summarizing chromosome structure and histone modifications.

'Reading signals on the nucleosome with a new nomenclature for modified histones' by Brian Turner (Turner, 2005)

Short review from *Nature Structural Biology* on histone modifications from a leading figure in the field. In this article, Turner proposes a nomenclature for histone modifications that is now universally used in the field. In this nomenclature, the histone comes first, then the modified amino acid residue, then the epigenetic mark, noting that some amino acids can have more than one copy of that mark. For example, H3K4me3 describes histone H3 modified at lysine 4 with 3 methyl groups. The article also includes references to the original histone code hypothesis which posited that combinations of histone modifications dictate chromosomal activity.

'Perceptions of epigenetics' by Adrian Bird (Bird, 2007)

Adrian Bird, who has been a leading figure in the field of epigenetics for over 20 years, discusses how the definitions of epigenetics have been stretched

to encompass phenomena such as short-lived changes to chromatin structure. In this 'Insight' article in *Nature*, he suggests a widening of definition of epigenetics to 'the structural adaptation of chromosomal regions so as to register, signal or perpetuate altered activity states'. This definition is meant to unite disparate views of epigenetic phenomena (e.g. Ptashne, 2007) and reconcile the contrasting findings that histone modification can have a rapid turnover whereas DNA methylation can be stable over many cell cycles. This definition also views epigenetic changes as being responsive and not proactive; they are responsible for registering a change imposed by other events. Bird reviews some of the more controversial findings in the field and concludes that more work is needed to resolve some disparate findings. For example, while one study concluded that twins drift apart epigenetically over time (Fraga *et al.*, 2005), another non-twins study, found strong evidence for stability of epigenetic marks over time (Eckhardt *et al.*, 2006). Bird also summarizes epigenetics as 'encompass[ing] some of the most exciting contemporary biology and is portrayed by the popular press as a revolutionary new science – an antidote to the idea that we are hard-wired by our genes.'

'Epigenetics: The Science Of Change' by Bob Weinhold (Weinhold, 2006; http://www.ehponline.org/members/2006/114–3/ehp0114-a00160.pdf)

Excellent open-access article on epigenetics by Bob Weinhold that briefly covers topics such as epigenetic mechanisms, involvement in disease, epigenetic therapies, environmental effects, the human epigenome project and epigenetic organizations. It is accompanied in the same issue by an open access guest editorial entitled 'Epigenetics: environmental instructions for the genome' by Paul Wade and Trevor Archer (Wade and Archer, 2006; http://www.ehponline.org/docs/2006/114–3/EHP114pa140PDF.PDF).

'Epigenetics: unfinished symphony' by Jane Qiu (Qiu, 2006) and 'Moving AHEAD with an international human epigenome project' by the American Association for Cancer Research Human Epigenome Task Force and the European Union Network of Excellence Scientific Advisory Board (Jones PA, 2008)

These two short feature articles from the journal *Nature* from 2006 and 2008 focus on the Human Epigenome Project (HEP) and the more formalized Alliance for the Human Epigenome and Disease (AHEAD). The Qiu article provides the better introduction to the subject of epigenetics and cites striking examples of epigenetic effects such as epigenetically different 'identical' twins and the role of epigenetics in programming future health. The AHEAD article goes into more detail about the aims and scope of the HEP, which will provide reference epigenomes from healthy cells with which to compare with those from cells from cancer and other diseases. There is tremendous potential to use the data generated to develop diagnostic and prognostic tests for specific diseases in addition to pointing towards targeted epigenetic therapies. The HEP will involve a scale of magnitude larger than the genome project because of two major factors. Firstly, as different cell types have different sets of epigenetic marks, there will be multiple epigenomes to decode. Secondly, as diseases such as cancer can develop from poorly differentiated cells, epigenomes will need to be studied longitudinally in cell lineages as they develop from stem cells. The HEP aims to characterize epigenetic marks such as DNA methylation and multiple covalent histone modifications in each of these dimensions. The AHEAD article presents an overview of US, European, Asian and Australian strategies to advance the HEP and stresses the need for an interdisciplinary approach, including the importance of bioinformatic data processing. This article also summarizes some of the methods used to define epigenomes and adds another dimension to the picture with the sequencing of the epigenomes of 'model' organisms such *Drosophila* and *Arabidopsis*. The AHEAD article also summarizes the recommended histone markers to study for transcriptional activity, silencing elongation, chromosomal organization and stress/damage response. Finally, both articles include the same simple figure summarizing epigenetic

modifications, with the addition of non-coding RNAs in the later article.

'Epigenetics: a landscape takes shape' by Aaron Goldberg, David Allis and Emily Bernstein (Goldberg et al., 2007)

An excellent article from *Cell* that reviews the mechanisms of epigenetics and how they interact. The authors introduce Conrad Waddington's 'epigenetic landscape' in which a ball (representative of a cell) is shown to navigate a landscape hills and valleys representing preferred developmental channels overlaid with potential changes in developmental trajectory. The authors also adapt and update this 'landscape' to a pinball machine in which a pinball (cell) is buffeted around an epigenetic landscape by changes to different classes of epigenetic modifications.

'Epigenetics in human disease and prospects for epigenetic therapy' by Gerda Egger and colleagues (Egger et al., 2004)

This excellent 'Insight' review article from *Nature* from Jones and colleagues<Is the article by Jones or Egger? Please clarify> summarizes what is known about the role of epigenetics in human disease and details the different ways in which drugs that can reverse disease-associated epigenetic marks could reverse those marks and restore health. The authors discuss the different classes of epigenetic drugs including nucleoside analogue inhibitors of DNA methylation and histone deacetylase inhibitors (HDACi) and describe how they could be used in combination. Jones and colleagues also discuss the potential pitfalls of epigenetic therapies, such as off-target affects.

Epigenetics and child health: basic principles by Alix Groom and colleagues (Groom et al., 2010)

This is an excellent medium-length article focusing on studies of the roles of epigenetic events in early mammalian development and how epigenetic marks can be altered by the environment and in turn 'programme' future health. It touches on the ideas that mammalian genomes may be more susceptible to environment-induced change in early life and the 'neo-Lamarckian' concept of environmental exposure in one generation leading to epigenetic changes inherited by the next. Relton and colleagues present short but informative summaries of the major classes of environmental factors shown to affect epigenetic marks for example nutrition, stress, smoking and infection in addition to summarizing the influence of age and genetic factors on the epigenome. They discuss controversial findings of epigenetic consequences of *in vitro* fertilization and the involvement of epigenetic in cancer and diseases such as autism spectrum disorders. The authors make the important distinction between cause and consequence of disease, which can be solved only by conducting longitudinal studies. Importantly, they conclude that as DNA methylation can be seen as a phenotype, then smaller sample sizes are required in genome-wide searches for disease-associated epigenetic change, compared with genome-wide association studies (GWAS). Finally, this article contains a useful flow chart for such studies and a summary of methods used to study the epigenetic mark of DNA methylation.

'Epigenetic inheritance in plants' by Ian Henderson and Steven Jacobsen (Henderson and Jacobsen, 2007)

In this 'Insight' article from *Nature*, Henderson and Jacobsen present a compact and comprehensive review of epigenetic phenomena in plants, focusing on the model organisms *Arabidopsis thaliana* and maize. The authors also focus on non-coding RNAs and their role in phenomena such as RNA-directed DNA methylation, in which genomic sequences sharing homology with viral RNAs are methylated. They also discuss how the RNA interference (RNAi) machinery can guide plant DNA methyltransferases (DNMTs) to specific regions of the genome, shedding light on an important part of the epigenetic puzzle. Plants share most of their epigenetic mechanisms with animals, examples being silencing-associated gene promoter methylation and genomic imprinting, which in plants is needed for proper seed development. However, this article also discusses some of the differences. The first example given in paramutation (see also the chapters in this book by Arteaga and McGinnis), first described in maize, in which allelic interactions cause a meiotically heritable

change in the expression of one of the alleles. Henderson and Jacobsen also discuss Polycomb group (Pc-G) proteins, which, while present in plants and animals, exhibit a greater variation in subunits in plants. Pc-G proteins also play a role in the plant-specific phenomenon of vernalization, in which exposure to long periods of low temperature in winter facilitates flowering in the spring. The authors finish by stressing that studying epigenetic mechanisms in plants has led to the wider understanding of epigenetic phenomena in other organisms, particularly through high-throughput sequencing approaches to epigenomics.

'Tools and landscapes of epigenetics' by Alexander Tarakhovsky (Tarakhovsky, 2010)

In this 'Commentary' article from *Nature Immunology*, Tarakhovsky starts by tipping his hat to Aristotle and Conrad Waddington. The former invented the term 'epigenesis' to describe the idea that development proceeded from the simple zygote through successive stages of differentiation towards the complex organism. The latter first defined epigenetics as 'the interactions of genes with their environment, which bring the phenotype into being'. The authors discuss the important point that although changes to marks such as DNA methylation require cell division for propagation, epigenetic marks such as histone modifications can still be in a state of flux within terminally differentiated cell types such as neurons. Importantly, Tarakhovsky succinctly summarizes the roles of epigenetic 'writers', such as histone acetyltransferases, which add epigenetic marks, 'erasers' such as histone deacetylases that can remove epigenetic marks and 'readers' that recognize a particular epigenetic mark and nucleate macromolecular complexes around it, which either promote or repress gene expression. Emphasis is also put on the role of non-coding RNAs in establishing epigenetic marks and the possibility that histone-modifying enzymes can affect targets other than histones. The author then discusses evidence that microbes can directly interfere with epigenetic readers and suggests that that some microorganisms influence epigenetic marks to the extent that they actually prevent the onset of some disease such as diabetes and allergies, which may go some way to explaining the 'hygiene hypothesis' of increased incidence of such diseases.

'The seductive allure of behavioural epigenetics' by Greg Miller (Miller, 2010)

This 'News Focus' article from *Science* focuses first on the work of Canadians Michael Meaney and Moshe Szyf, who have shown that the way that rat mothers interact with their new-born offspring can programme their future behaviour though epigenetic modifications of genes within pathways such as those involved in stress response (also reviewed in Szyf *et al.*, 2008). Studies from other groups have implicated epigenetic mechanisms in response to stress in adult mice and in influencing expression levels of a neural growth factor gene in the offspring of stressed mouse mothers. The author then raises the question of how relevant such studies are for human behavioural research. Certainly, early life experiences such as child abuse and being raised in a family with low socioeconomic status can influence future mental and physical health. However, studies have found evidence both for and against involvement of epigenetic mechanisms in these phenomena in humans (also covered in an excellent recent 'News' feature in *Nature*; Buchen, 2010). Nevertheless, this area of research remains a very active one for many reasons including the potential, revealed in animal studies, for epigenetic drugs to counteract the effects of adverse social conditions in early life and to even reverse ageing-associated phenomena such as a reduced capacity for learning and memory formation.

'Epigenomics reveals a functional genome anatomy and a new approach to common disease' by Andrew Feinberg (Feinberg, 2010)

In this short article from *Nature Biotechnology*, Andrew Feinberg discusses how genome-scale studies of epigenetics have transformed our understanding of the genome. Technologies such as microarrays and next generation sequencing have enabled researchers to map the positions of DNA methylation, chromatin proteins and non-coding RNAs in cell types from stem cells to cancer cells. Such research has led to some unexpected findings.

For example, in cancer, methylation changes can occur in blocks of large genomic regions spanning many genes, and in the 'shores' or flanking regions of promoter-associated CpG islands (Irizarry *et al.*, 2009). Another unexpected finding from genome-scale studies was the discovery of widespread interaction between distant genes on the same chromosome and between genes on different chromosomes (van Steensel and Dekker, 2010). Feinberg also discusses his own the findings that some genes may be prepared to respond to environmental influence by tolerating a larger range of epigenetic states and that although this could provide an evolutionary advantage in the long term, these regions may be more susceptible to short-term changes in environment such as the post-war Western diet. The author finishes by stressing the need for the marriage of epigenetics and epidemiology, at the centre of which is the collection and storage of biological samples.

'What is epigenetics?' by Guy Riddihough and Laura Zahn (Riddihough and Zahn, 2010)

This one-page summary that introduces a special section on epigenetics in a recent issue of the journal *Science*. Riddihough and Zahn discuss definitions of epigenetics, the diversity of which is illustrated by an accompanying video in which leaders in the field each provide their own definition (http://videolab.sciencemag.org/Featured/650920373001/1). Interestingly, one of the accompanying articles defines an epigenetic system as 'heritable, self-perpetuating and reversible' (Bonasio *et al.*, 2010), a definition that may surprisingly exclude histone modifications and include prions (Halfmann and Lindquist, 2010). Other articles in this special issue focus on developmental reprogramming (Feng *et al.*, 2010), small RNAs (Bourc'his and Voinnet, 2010), paramutation in plants (Chandler, 2010) and epigenetic cancer therapies (Kaiser, 2010).

Special epigenetics edition of Peanuts, the newsletter from Zymo Research (http://www.zymoresearch.com/zrc/pdf/peanuts6.pdf)

Compiled in 2009, this freely available resource contains four 3–4-page review articles on epigenetics. The introduction by Jason Goia provides an excellent summary of epigenetic mechanisms and phenomena in diverse organisms from *Drosophila* to the fungus *Neurospora crassa*. This is followed by a review by Alexander Meissner focusing on epigenetics and development. This article discusses epigenetic properties of stem cells and has summary paragraphs on imprinting, X inactivation and the role of non-coding RNAs in epigenetic regulation. Jaroslav Jelinek and Jean-Pierre Issa then provide an excellent summary of epigenetics and cancer, which includes sections on the interaction between genetics and epigenetics and the relationship between stem cells and cancer. Finally, Xi Yu Jia provides a great review of epigenetic regulation of gene expression in insects and plants. The author focuses on research involving *Drosophila* and Honeybees for insects and on *Arabidopsis thaliana* for plants. The newsletter also contains an epigenetics glossary.

'Histone Modifications: A Sampler' by Steve Talbott (http://natureinstitute.org/txt/st/mqual/histone_mods.htm)

Talbott presents a brief but informative point-form summary of histone modifications and their functional and structural consequences. Data reviewed are mainly from studies of mammals, although other organisms such as yeast are covered briefly. The author presents recent findings in a simple manner while acknowledging that we still have a long way to go to be able to put together a complete picture of histone modifications, their interactions with one another and with other chromatin proteins.

Epigenetics societies and research networks

The Epigenetics Society (http://es.landesbioscience.com/index.php).

The Epigenetics Society, associated with Landes Bioscience, is an international scientific society open to all those interested in any aspects of DNA methylation. The 'members-only' section contains contact information of other members of the society as well as updated information on recently published papers and topical reviews from some

of the foremost scientists interested in this area. The 'public' page contains a simple description of DNA methylation and a summary of the activities held for members of the society. The site also has some useful links to epigenetic resources such as a catalogue of imprinted genes, a CpG island search algorithm and to MethDB, a database of gene-specific DNA methylation.

The Epigenome Network Of Excellence (http://epigenome-noe.net/)

The Epigenome Network Of Excellence (NOE) describes itself as the focal point for the European epigenetics research community. The site contains links to epigenetics groups, protocols, tools, resources, news and events. It also contains some excellent educational pages including the multilingual public science site 'Epigenetics?' (http://www.epigenome.eu/), which contains news and articles aimed at a broad public audience. It also has an 'Educational Tools and Resources' page which contains videos, webcasts and articles about epigenetics and related fields, with articles tagged with the recommended age range of readership (e.g. 5–11, 11+, 18+). Other useful, easy-to-read pages include 'A short introduction to epigenetics', 'Frequently asked questions' and a glossary of epigenetics.

The Australian Epigenome Alliance (www.epialliance.org.au)

The Australian Epigenome Alliance (AEpiA) aims to provide an avenue for Australasian research groups to share expertise and insights in the area of epigenetics. The homepage of the site contains information about the latest conferences and workshops, together with highlights of previous events. This site also contains links to other useful epigenetic resources such as blogs and highlights of epigenetic articles in journals and magazines, along with a brief explanation of the basics of epigenetics. In addition, it compiles a list of references published by AEpiA members. A list of AEpiA members and their research interests is also provided, nicely grouped according to states and countries, with links to laboratory web pages.

Table 26.1 Summary of educational resources<Please provide a citation in the text for this table>

Reference/title/URL	Content
Easy-to read articles and web sites aimed at a broad audience	
McVittie (2006) (http://www.scienceinschool.org/2006/issue2/epigenetics)	Introduction to epigenetics for students and those with limited knowledge of the area
Duttaroy (2006) (http://www.mukto-mona.com/Special_Event_/Darwin_day/evolution_asim120206.htm)	Good article linking the relevance of evolution, nutrition, and imprinted genes to epigenetics
Pray (2004) (http://www.the-scientist.com/article/home/14798/)	Comprehensive article featuring evidence of how the environment has an active role in shaping the epigenome
'Molecular Development – Epigenetics' (http://embryology.med.unsw.edu.au/MolDev/epigenetic.htm)	Gives a broad coverage of and illustrations relating to epigenetics, ranging from its mechanisms to its role in human development
NOVA scienceNOW: Epigenetics (http://www.pbs.org/wgbh/nova/teachers/activities/3411_02_nsn.html)	Interactive web site with great teaching resources to assist in a classroom setting
Epigenetics? (http://epigenome.eu/)	Multilingual site suited for students and lay people to learn how epigenetics plays an active role in our lives
'Epigenetics and Imprinted Genes' (http://www.hopkinsmedicine.org/press/2002/November/epigenetics.htm)	Short article centred on explaining the link between epigenetic modifications and imprinted genes
'What is it? A simplified description of DNA methylation' (http://es.landesbioscience.com/pub/faq/)	Review with good examples explaining the concept of DNA methylation
Learn.Genetics, epigenetics page (http://learn.genetics.utah.edu/content/epigenetics/)	Web site that creatively presents the basic concepts of epigenetics by including video clips and interactive games

Table 26.1 continued

Reference/title/URL	Content
Epigenetics news – discoveries and advances (http://www.epigeneticsnews.com/tag/epigenetics/)	Compilation of opinions and information about epigenetics from researchers from all over the world
Epigenie (http://epigenie.com/index.html)	User-friendly site containing reviews on epigenetics and information about relevant upcoming conferences
'A (mostly) nontechnical glossary of genetics, epigenetics and molecular biology' http://www.natureinstitute.org/txt/st/mqual/glossary.htm	Glossary of terms used in epigenetics research.
Scholarly review articles aimed at a broad scientific audience	
Felsenfeld and Groudine (2003)	Comprehensive overview of epigenetics with a focus on chromatin remodellers and histone variants
Turner (2005)	Review of how histone modifications are involved in epigenetic change
Bird (2007)	Successful attempt by the author to reconcile disparate epigenetics views by widening its definition
Weinhold (2006)	Open access article that summarises the implications of epigenetic regulation in living organisms
Qiu (2006)	Introduction to epigenetics and the implications for future health
Rine and Wu (2008)	Article presenting the aims and advances of the Human Epigenome Project (HEP)
Goldberg, Allis, Bernstein (2007)	Review of how epigenetics shapes the phenotypes of living organisms
Egger, Liang, Aparicio, Jones (2004)	Review of how drugs could restore health by reversing disease-associated epigenetic marks
Groom, Elliott, Embleton, Relton (2010)	Article focusing on the susceptibility to epigenetic change in early mammalian development via environmental exposures.
Henderson, Jacobsen (2007)	Compact and comprehensive review of epigenetic phenomena in plants, focusing on non-coding RNA
Tarakhovsky (2010)	Discusses epigenetic 'writers', 'readers' and 'erasers', non-coding RNAs and how microorganisms can affect the host epigenome
Miller (2010)	Review of animal studies in which maternal interactions can 'reprogramme' epigenetics in offspring and discussion of relevance to humans
Feinberg (2010)	Review of genome-scale epigenetic studies and the unexpected results they have revealed
Riddihough, Zahn (2010)	One-page summary from a special edition of Science, accompanied by reviews on developmental reprogramming, small RNAs, paramutation in plants, and cancer
http://www.zymoresearch.com/zrc/pdf/peanuts6.pdf	Contains short review articles on epigenetic mechanisms, development, cancer, insects and plants
http://natureinstitute.org/txt/st/mqual/histone_mods.htm	Summary of histone modifications
Epigenetics societies and research networks	
http://es.landesbioscience.com/index.php	International DNA methylation society with members' and public pages, including resources
http://epigenome-noe.net/	Links to European epigenetics researchers, protocols, news and educational pages
http://es.landesbioscience.com/index.php	Links to Australian epigenetics researchers, meeting reports, epigenetics resource

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