Table S1: Scientific Advisory Committee

Member	Affiliation	Area of Expertise
Bruce Blumberg, PhD	University of California, Irvine	Endocrine Disruption
Terrence Collins, PhD	Carnegie Mellon University	Green Chemistry
David Crews, PhD	University of Texas at Austin	Endocrine Disruption
Peter L. deFur, PhD	Environmental Stewardship Concepts, LLC	Endocrine disruption
Andrea C. Gore, PhD	University of Texas at Austin	Endocrine Disruption
Lou Guillette, PhD	Medical University of South Carolina	Endocrine Disruption
Jerrold Heindel, PhD	National Institute of Environmental Health Sciences	Endocrine disruption
John Peterson Myers, PhD	Environmental Health Sciences	Endocrine disruption
Kristina A. Thayer, PhD	Center for the Evaluation of Risks to Human Reproduction, National Toxicology Program	Endocrine Disruption
Frederick S. vom Saal, PhD	University of Missouri	Endocrine Disruption
John Warner, PhD	Warner Babcock Institute for Green Chemistry	Green Chemistry
Cheryl S. Watson, PhD	University of Texas Medical Branch	Endocrine Disruption
R. Thomas Zoeller, PhD	University of Massachusetts, Amherst	Endocrine Disruption

Table S2: Tools available for in-house computational-based assessments of EDC activity

Database	Website	Summary
FDA Endocrine Disruptor Knowledge Base (EDKB)	http://edkb.fda.gov/webstart/edkb/	Approximately 3300 records for over 1800 EDCs from different assays. Data can be cross-linked to other publicly available databases including TOXNET
MOLE db	http://michem.distat.unimib.it/mole_db/	Molecular Descriptors Database by Milano Chemometric and QSAR Research Group. The MOLE bd is a free online database of molecular descriptors calculated for 243773 molecules.
TOXNET	http://toxnet.nlm.nih.gov/	Databases on toxicology, hazardous chemicals, environmental health, and toxic releases.
VEGA	http://www.vega-qsar.eu/	Free platform for QSAR modeling
CAESAR (Computer Assisted Evaluation of industrial chemical Substances According to Regulations)	http://www.caesar-project.eu/	**CAESAR** was formed to develop QSAR models for REACH legislation. Five endpoints: • bioconcentration factor • skin sensitization • carcinogenicity • mutagenicity • developmental toxicity
VirtualToxLab	http://www.biograf.ch/	Tool for predicting the toxic potential (endocrine and metabolic disruption) of drugs, chemicals and natural products. It simulates and quantifies their interactions towards a series of proteins known to trigger adverse effects using automated, flexible docking combined with multi-dimensional QSAR (mQSAR).
3D QSAR	www.3d-qsar.com	3D QSAR Models Database
Open3DQSAR	www.open3dqsar.org	Open-source tool aimed at pharmacophore exploration by high-throughput chemometric analysis of

		molecular interaction fields (MIFs).
EPA ACTor	http://actor.epa.gov/actor/	ACToR aggregates data from over 500 public sources on over 500,000 environmental chemicals searchable by chemical name, other identifiers and by chemical structure.
NTP CEBS	http://www.niehs.nih.gov/research/resources/databases/cebs/index.cfm	The CEBS database houses data on chemical effects on biological systems that have been deposited by academic, industrial and governmental laboratories.
PubChem GeneGO	http://www.genego.com/	Data mining tools and databases help to capture and define the underlying biology behind different types of high-throughput experimental data and understand the effects of small molecule drug compounds in human tissues.
Comparative Toxicogenomics Database	http://ctdbase.org/	CTD includes curated data describing cross-species chemical–gene/protein interactions and chemical– and gene–disease associations to illuminate molecular mechanisms underlying variable susceptibility and environmentally influenced diseases.
Leadscope	http://www.leadscope.com/	Incorporates chemically based data mining, visualization and advanced informatics techniques.
OECD QSAR Toolbox	http://www.oecd.org/document/54/0,3746,en_2649_34379_42923638_1_1_1_1,00.html	A software application designed to fill in gaps in (eco)toxicity data needed for hazard assessment of chemicals.
OpenTox	http://www.opentox.org/	Tools for the integration of data from various sources to generate and validate computer models for toxic effects

Table S3: Receptors and other endpoints that can be assessed using Tier 2 high-throughput screening

Androgen receptor
Aryl hydrocarbon receptor
Estrogen receptor alpha
Estrogen receptor beta
Farnesoid X receptor
Glucagon receptor
Glucocorticoid receptor (GR)
Liver X receptor β (LXRβ)
Melanin-concentrating hormone receptor 1 (MCHR1)
Membrane estrogen receptor (mER/GPR30)
Mineralocorticoid receptor
Peroxisome proliferator-activated receptor a, δ, γ (PPAR a, PPARδ , PPARγ)
Pregnane X receptor
Prolactin receptor (PRLR)
Prostaglandin agonism through EP1 receptor
Retinoic acid receptor (RAR)
Retinoid X receptor α (RXRα)
Retinoid-related orphan receptor gamma (RORγ)
Thyroid hormone receptor b (TRb)
Vasopressin V3 (V1B) Receptor
Vitamin D receptor (VDR)

Table S4: Examples of current assays, biological endpoints, and references, available for Tier 3 screening

Hypothalamic-Pituitary-Adrenal (Stress) Axis				
Assay	**Receptor**	**Cell Type**	**Endpoints**	**Reference(s)**
Glucocorticoid responsive assay	GR	Human breast cancer cells (MDA-MB-453) stably transfected with an MMTV.luciferase.neo reporter gene construct	Activation of MMTV luciferase reporter occurs via treatment with glucocorticoids or androgen receptor agonists. Treatment with anti-androgens allows GR-agonists to be examined separately	[59]
Hypothalamic-Pituitary-Gonadal (Reproductive) Axis				
Assay	**Receptor**	**Cell Type**	**Endpoints**	**Reference(s)**
A-screen	AR	MCF-7 cells transfected with androgen receptor (MCF7-AR1)	Estrogen-induced cell proliferation is inhibited by androgens	[60]
AR-CALUX	AR	U2-OS human osteosarcoma transfected with luciferase reporter	Androgen receptor-mediated luciferase reporter gene-expression	[61]
Aromatase induction		Human adrenocortical carcinoma (H295R) Human placental choriocarcinoma (JEG-3) Human breast cancer (MCF-7)	Aromatase activity as measured by conversion of androstenedione and induction of aromatase gene expression	[62]
E-screen	ER	Human breast cancer cell line MCF-7	Cell proliferation	[63-68]
E2SULT		Cell-free	Inhibition of estrogen sulfotransferase	[69]
ER-CALUX	ER	T47D.Luc- human breast cancer cells transfected with luciferase reporter	Estrogen receptor-mediated luciferase reporter gene-expression	[70]
EstrArray	ER	Human breast cancer cell line MCF-7	Gene expression of estrogen-dependent genes	[71]
PR – transactivation /transcription assay	PR	HEK 293T transfected with luciferase reporter	PR-mediated luciferase reporter protein expression (luminescence)	[72]
PR-CALUX	PR	U2-OS human osteosarcoma	progesterone receptor-mediated	[73]

		transfected with luciferase reporter	luciferase reporter gene-expression	
Steroidogenesis		Human adenocarcinoma cell line (H295R)	Interference with steroidogenesis-production of P4, T, and E2	[74]
YES, YAS, YPS, etc.	ERα, ERβ, AR, PR, GR, MR, AhR.	Yeast - *Saccharomyces cerevisiae*	Hormone-mediated β-galactosidase reporter gene-expression	[75, 76]
Hypothalamic-Pituitary-Thyroid Axis				
Assay	**Receptor**	**Cell Type**	**Endpoints**	**Reference(s)**
Dendrite arborization	TR	Primary Purkinje cells	TH-dependent dendrite arborization of cerebellar Purkinje cells	[77-79]
Iodide Uptake	NIS	NIS-transfected CHO or FRTL-5 cells	Inhibition of iodide uptake	[80]; [81]
Neurite extension	TR	Rat granule cells primary culture	Granule cell neurite extension	[82]
T-screen aka GH3 Cell Assay	TR	Rat pituitary tumor cell line GH3	Cell proliferation	[83], [84]
TH-reporter assay	TR	GH3 pituitary cells transfected with TRE-luciferase	Thyroid hormone receptor-mediated luciferase reporter-gene expression	[85]
TPO Inhibition	Thyroid Peroxidase	Cell-free	Inhibition of thyroperoxidase	[86], [87]
Retinoid/Peroxisome Proliferator-Activated Receptor Signaling Pathway				
Assay	**Receptor**	**Cell Type**	**Endpoints**	**Reference(s)**
Adipocyte differentiation assay	RXR/PPARg	Mouse fibroblasts (preadipocyte cell lines 3T3-L1 or C3H10T1/2)	Differentiation into adipocytes, accumulation of lipid droplets	[88-91]
AhR activation	AhR	Human HepG2 hepatoma Human MCF7 Mouse H1L1.1c2 hepatoma Mouse MLEL1.1c1 hepatoma	Arylhydrocarbon receptor-mediated luciferase reporter gene-expression	[92]
DR-CALUX	AhR	Rat hepatoma cell line (H4IIE) transfected with luciferase reporter	Arylhydrocarbon receptor-mediated luciferase reporter gene-expression	[93]
PPAR Transactivation Reporter Assay	PPAR	Several cell lines are used for this commercially available assay	PPAR-mediated luciferase reporter gene expression	[94]
Pregnane X Receptor Transactivation	PXR	Human hepatoma cell line HepG2	PXR-mediated induction of CYP3A4- luciferase	[95]

Reporter Assay			reporter gene	
RAR Transactivation Reporter Assay	RAR	COS-7 cells	RAR-mediated luciferase reporter activity (luminescence)	[96]
RXR Transactivation Reporter Assay	RXR	HEK 293T transfected with luciferase reporter	RXR-mediated luciferase reporter gene expression	[97, 98]
Non-genomic Actions of Steroid Mimetics				
Assay	**Receptor**	**Cell Type**	**Endpoints**	**Reference(s)**
ERK activation (or other MAPKs)	mER	Pituitary cell line (GH3/B6/F10)	Phosphorylation of ERK (or JNK or p38 kinases) – 96-well plate immunoassay	[99-101]
ERK activation (or other MAPKs)	mER	Breast cancer (MCF-7)	Phosphorylation of ERK (or JNK or p38 kinases) – 96-well plate immunoassay	[102]
ERK activation (or other MAPKs)	mPR	Human breast cancer cells MDA-MB-231	Phosphorylation of ERK- detected by Western Blot	[103]
Gαi activation	mER	Pituitary cell line (GH3/B6/F10)	GTP-bound (activated) Gαi protein– 96-well plate immunoassay	Watson, submitted
G protein activation	mPR	Human breast cancer cells MDA-MB-231	GTP-bound (activated) protein, cAMP levels	[104, 105]

Table S5: Whole fish and amphibian assays

Assay	Fish species	Endpoints	Reference(s)
Corticosteroid secretion	*Oncorhynchus mykiss*	Corticosteroid secretion in response to ACTH	[106]
Rapid developmental toxicity HTS (in Tier 2)	Zebrafish	Morphological endpoints (edema, bent body axes, pigmentation anomalies, and organ malformations)	[40, 107-111]
Fish sex development test	Fathead minnow Medaka Zebrafish	Designed to detect (anti-) estrogenic and (anti-) androgenic effects. Animals are exposed to test chemical before the onset of sexual differentiation. Vitellogenin induction in males/inhibition in females. Gonadal histopathology Hormone levels Sex ratio Development of intersex	[112] [113] [114]
Fish Two Generation Assay	Fathead minnow Medaka Zebrafish	Whole body, serum, tissue T4 levels	[115]
Locomotion medium throughput assay (in Tier 2)	Zebrafish	Can identify subtle developmental abnormalities between the nervous and musculoskeletal systems	[116]
Sex specific behavior	Zebrafish	Sex specific behaviors (aggressive: nipping, chasing, circling, avoiding, and reproductive: female association, spawning, chasing, and nipping)	[117]
Short-term reproduction assay/ 21-day fish assay	Fathead minnow Medaka	Designed to detect (anti-) estrogenic and (anti-) androgenic effects. Mature male and female fish will be monitored during a 21-day chemical exposure; survival, reproductive behavior, and secondary sexual characteristics will be	[115], [118]; [119], [120]

		observed while fecundity and fertilization success will be monitored daily. At termination of the assay, measurements will be made of a number of endpoints reflective of the status of the reproductive endocrine system, including the GSI, gonadal histology, and plasma concentrations of vitellogenin.	
Transgenic reporter lines	Zebrafish	Current lines can detect estrogenic activity and aromatase induction. More transgenic lines are being developed.	[41, 121, 122]
Assay	**Amphibian species**	**Endpoints**	**Reference(s)**
Corticosteroid secretion	*X. laevis* *Rana catesbeiana*	Corticosteroid secretion in response to ACTH	[123]
SEXDAMAX	*X. laevis* *X. tropicalis*	Sexual differentiation Metamorphosis	[124] [125]

Table S6: Factors for considerationin fish EDC studies

Species	Family/ Distribution	Adult Size	Generation Time	Sexually Dimorphic	Blood Collection	Clutch size	Hatch time
Fathead minnow	Cyprinidae/ North America	50 – 75mm 2 – 5 g	4 mos	Yes	Yes	50 – 200 every 3 days	4 – 5 days
Japanese medaka	Adrianichthyidae/ Southeast Asia	25 – 50mm 0.7 – 0.8 g	2 – 3 mos	Yes	No	10 – 30 daily	8 – 10 days
Zebrafish	Cyprinidae/ India and Myanmar	40 – 50mm 1.5 g	2 – 3 mos	Very little	A few microliters	>150 every 5 – 10 days	2 – 3 days

Table S7: Selecting species for amphibian assays

Species	Advantages	Disadvantages
Xenopus laevis	Well-established laboratory model, with available molecular and endocrinology tools. Individual females can breed once per month, year round, and husbandry techniques are well-established. It responds to thyroid hormone, estrogen, and androgens. Females have large clutch sizes (2000 eggs and higher in large adults) so fully replicated experiments can be conducted easily. Aquatic throughout its life cycle so embryos, larvae and adults can be treated by immersion.	Some aspects of *X. laevis* biology may not be reflective of the majority of amphibians. For example, its putative sex-determining gene (DMW) is apparently unique even in the genus. Larvae are not sex-reversed by androgens as in other species. Corticoids do not enhance larval development *in vivo* as in other species. Few amphibians are completely aquatic as adults. Generation time is about two years under ideal conditions, a long period for studies aimed at the full life cycle.
Hyperolius argus	Breeds repeatedly in the laboratory. Clear external markers for androgen, estrogen, and thyroid hormone effects. A single female may produce eggs once every few weeks. Breeding is spontaneous (unlike *X. laevis*) and does not require hormonal manipulation of adults.	Small clutch size (about 200). More complicated husbandry.
Lithobates pipiens	*L. pipiens* is a well-studied species in the lab and the field. Widespread distribution in the northern U.S. allows for study in the field, along with closely related species in the southern US, some of which have ranges into Central America. In the laboratory, the sex ratio is	Although newly collected females will breed in the laboratory, it is difficult to get them to cycle and produce regularly. There are no clear androgen or estrogen-dependent external markers at metamorphosis.

	affected by androgens and estrogens.	

Table S8: Examples of current assays, biological endpoints, and references, available for Tier 5 screening

Assay	Cell Type / Animal Model	Endpoints	Reference(s)
Asthma	Mouse	Pups (17 days old) are tested for functional markers of asthma: ELISA for IgE antibodies, eosinophilic inflammation (by lavage) and airway hyper-responsiveness by whole-body barometric plethysmography. Pregnant females are exposed to xenoestrogens in their drinking water. Pups (17 days old) are tested for functional markers for asthma: ELIZA for IgE antibodies, eosinophilic inflammation (by lavage) and airway hyperresponsiveness by whole-body barometric plethysmography.	[126]
Bone development assay	Mouse	Fetuses are examined at embryonic day 17 and calcification of the bones is determined by alcian blue/alizarin red incorporation	[127]
Brain sexual dimorphism	Mouse / Rat	Several regions of the brain are known to have sex-differences in the number and/or localization of specific populations of neurons (i.e. GABAergic cells, Tyrosine Hydroxylase-positive cells, etc.) Immunohistochemistry, in situ hybridization and/or RT-PCR analysis is used to measure these differences in specific brain nuclei.	[128-130]
Forced Breeding Assay	Mouse	Females are paired with control males (proven breeders) and 1) the time to mating is determined; 2) the number of pups delivered is determined.	[131, 132]
Kidney function assay	Rat	Blood urea nitrogen concentrations are measured using standard diagnostic kits. Levels of Malondialdehyde (a measure of lipid peroxidation) and Glutathione (an antioxidant) are measured in kidney extracts.	[133, 134]
Mammary gland carcinogenesis	Rat	Thin sections of mammary tissues are examined for neoplastic lesions (hyperplasias and DCIS) in animals with and without exposures to sub-effective doses of chemical carcinogens.	[135-138]
Mammary gland	Mouse – puberty & adulthood	Morphological characteristics of	[64-66]

development		whole mount mammary glands. In pubertal animals, the number and density of TEBs (proliferative structures) and size of the tree are easily assessed. In adult animals, the density of epithelial structures (alveolar buds & terminal ends) are calculated using a grid superimposed on whole mounts.	
Maternal behavior assay	Mouse	Between birth and weaning, dams are assessed at several discrete periods to determine time spent with/away from, nursing, and licking/grooming the pups. Additional tests can include the time it takes dams to retrieve pups that are moved by an experimenter out of the nest.	[139]
Obesity/ metabolic syndrome assays	Mouse / Rat	1) Body weight is monitored over several months. 2) Fat deposition is determined with CT-scan (live) and fat pad dissection (at time of death) 3) Fasting glucose/insulin levels are measured. Glucose and insulin tolerance tests are also performed. 4) Food consumption and activity tests. 5) RT-PCR analysis of brown and white fat.	[140, 141]
Prostate carcinogenesis	Rat	Adult animals are treated with a cocktail of estrogen & testosterone and the incidence of PIN lesions are determined from thin sections. This should be coupled with immunohistochemical analysis to quantify changes in specific cell types.	[142, 143]
Senesence (aging) assay	Mouse / Rat	1) Mice/rats are kept until later adulthood (9-12 months) and then mated to determine whether their reproductive axis is still capable of responding. This can be done in males and females. 2) Examination of methylation patterns in tissues where epigenetic changes are associated with aging (i.e. brain) 3) Estrous cyclicity is observed throughout adulthood for changing patterns from normal cycles	[54-56]
Sexually dimorphic	Mouse / Rat	A number of behaviors are different between males and females	[144-147]

behavior assays		including play behaviors, anxiety, exploratory behaviors, and other social interactions. These assays determine whether the normal sex-specific behaviors are retained. These tests can also be performed in castrated males, ovariectomized females, and adrenalectomized males & females to determine whether replacement with controlled levels of hormone can normalize abnormal behaviors.	
Tissue gene expression assay	Mouse / Rat	Hormone-sensitive genes have been identified for several tissues in rodents as well as other species. Simple RT-PCR analysis allows expression of these genes to be compared between exposed/unexposed individuals. Micro-array technology is also available for more widespread screening of a multitude of genes. Finally, epigenetic changes can be assessed for single genes of interest by examining methylation patterns.	[148-150]

Table S9: Use of TiPED to detect endocrine disrupting activity of known EDCs

	Assay	BPA	Atrazine	Perfluorinated compounds	Phthalates	Organotins	Perchlorate
Tier 1							
	Chemical reactivity						
	Physiochemical properties				[151]		
	Docking modeling	[152]			[153]	[154]	
	QSAR	[155]				[156]	
Tier 2							
	Tox21 qHTS	[157]	[157]		[157]		
Tier 3							
	MCF7 cell proliferation assay	[158]		[159]	[160]		
	Prostate cancer cell proliferation assay, PSA assay	[161]				[162]	
	3T3-L1 adipogenesis assay	[163]			[163]	[89]	
	GH3 T-screen assay	[164]			[165]		
Tier 4							
	Zebrafish rapid developmental toxicity HTS	[107, 108]	[109]	[110, 111]		[40]	
	Aquatic EDC reporter assays	[42, 166, 167] (ER) [43] (TH)					

	Medaka and fathead minnow reproductive assays	[168]	[169]	[170]	[171]	[172]	
	Xenopus metamorphosis assay	[173]			[174]		[175]
	Xenopus sexual dimorphism assays	[176]	[177]		[178]		[179]
	Frog metamorphosis assay	[173]			[174]		[175]
	H. argus color change assay						
	Xenopus corticoid assay		[51]				
Tier 5							
	Asthma assay	[180]					
	Brain sexual dimorphism assay	[129]			[181]	[182]	
	Mammary carcinogenesis assay	[138]	[183]				
	Mammary gland morphology assay	[64]	[184]	[185, 186]	[187]		
	Maternal behavior assay	[139]				[188]	
	Obesity / Metabolic syndrome assays	[189, 190]	[191]		[192]	[89]	
	Prostate carcinogenesis assay	[193]					

	Sexual dimorphism behavior assays	[129]					
	Tissue gene expression assay	[194]	[195]	[196]	[197]	[198]	[199]

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